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STAINS OF SAPWOOD AND SAPWOOD PRODUCTS AND THEIR CONTROL
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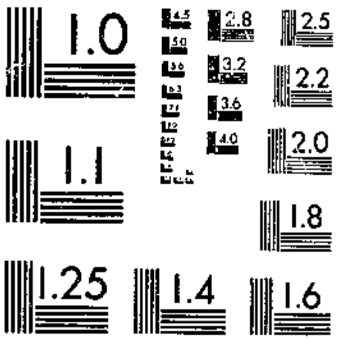




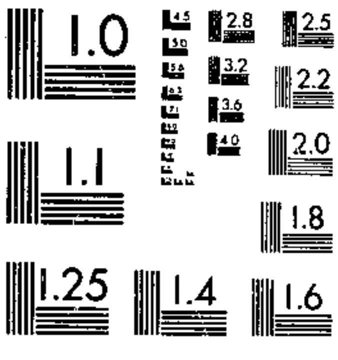


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# STAINS OF SAPWOOD AND SAPWOOD PRODUCTS AND THEIR CONTROL[1]

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## INTRODUCTION

The sapwood of most, and possibly all, of our domestic woods is subject to various discolorations of fungus origin, commonly known as sap stain. These blemishes occur in spots, streaks, or patches, which vary in intensity and shade of color and may penetrate all or part of the sapwood. They may appear in the log, lumber, or manufactured product, depending upon the conditions of handling or of use.

Most important of the sapwood stains, because of its prevalence and highly objectionable appearance, is the dark type widely referred to as blue stain. Predominant shades of blue stain are bluish black and steel gray, although brown hues are common. The particular color depends largely on the fungus involved and the species and moisture condition of the wood. In the Southern States, where climatic conditions particularly favor their development, sap stains are a source of much concern to the lumber and wood-using industries. This has led to extensive cooperative activity in that region by lumber and chemical industries and the Government directed at control measures.

This bulletin summarizes the work done in the United States within recent years on the control of sapwood stains. Consideration is given also to the nature of the factors underlying the occurrence of sapwood stains. Because sap stain is, and probably will continue to be, of greatest importance in the Southern States, the problems of this region receive special attention. The data presented are in the main derived from surveys and field experiments conducted in the Gulf States, and from supplementary laboratory investigations.

## ECONOMIC ASPECTS

Discolorations produced in wood by stain and mold fungi are of importance as depreciating rather than cull-producing factors. Losses result principally from reductions in grade, value, and marketability of the discolored material. Losses occur also in the form of charges against the necessary use of control practices and the additional handling frequently necessitated in disposing of stained stock. From a utilization standpoint, the objectionable features of sap-stained lumber lie largely in its appearance, its suitability for uses where appearance is not a factor being for the most part unimpaired. Since either actual or virtual degrade results, some of the overcutting of timber in an effort to replace the stained material and satisfy the demand for high-grade stock must be attributed to stain. To the mill, such overproduction means an excessive accumulation of low-quality material, which is not always marketed readily.

It would be difficult to make a quantitative estimate of present-day losses attributable to sap stains. Increasing insistence on bright lumber has been accompanied by increasing monetary losses on stained stock. On the other hand, recently developed stain-control methods have been so successfully and widely adopted by lumber manufacturers that the total annual losses incurred have unquestionably declined greatly. An early estimate (*78*)[2] placed the average loss due

[2] Italic numbers in parentheses refer to Literature Cited, p. 112.

to sap stain at $0.50 to $2 per 1,000 board feet, with an annual loss for the whole country at about $8,225,000. A later estimate (*34*) set the annual loss for the lumbering and sash and door industries at about $10,000,000. Individual losses from $10 to $40 per 1,000 board feet were reported for high-grade stock. Losses for other wood industries and those sustained by exporters were not included in the estimate. Even where stain is not a specific degrading factor in grading rules, operators often have no difficulty in obtaining premiums of several dollars a thousand for lumber that they can guarantee to be bright.

The point has now been reached in some cases where not only are losses incurred on sap-stained material but difficulty is also found in marketing discolored stock. Foreign markets are more exacting in demanding freedom from sap stain than are domestic markets. At the present time Gulf States exporters report great difficulty in disposing of stained lumber. This extreme situation is also being approached in domestic trade.

Many sap-stain losses have been unavoidable or the prevention of them would have required control practices that were economically impractical. Often, however, they could have been prevented if improved methods entailing little additional expense and only slight modifications in current handling practices had been used. The proper use of forest resources demands that such preventable waste and loss be eliminated through the development and adoption of feasible methods of control. With the depletion of virgin stands of timber and the consequent necessity of utilizing second-growth timber containing a large proportion of susceptible sapwood, the problem of stain and mold control assumes increasing economic significance. Adequate control of sap stain in forest products is, along with control of decay, probably one of the most important steps that can be taken to maintain wood in its present favorable position as a fabrication material.

## STAINS RESULTING FROM CHEMICAL CHANGES IN THE WOOD

Practically all sapwood stains originate either as a result of certain changes in the chemical composition of the wood, commonly arising from natural processes occasioned by seasoning, or as a result of infection of the wood by certain fungi. The stains of fungus origin are by far the more important and, with the exception of this brief discussion, are the ones principally considered in this bulletin.

Certain types of the chemically produced stains are apt to be confused with those produced by fungi. Obviously it is necessary to distinguish between the two kinds of stain in order to adopt suitable control measures. Many chemical stains occur in such a way as to indicate that they may be induced by oxidation of certain of the wood constituents upon exposure to the air. The familiar browning of a freshly cut apple would be an analogous process. Depending on the species and seasoning conditions, some of these stains will develop at ordinary air temperatures, whereas others apparently require higher temperatures.

## BROWN OXIDATION STAINS IN WESTERN AND EASTERN PINES

A light- to dark-brown stain frequently develops in northern white pine (*Pinus strobus* L.)[3] ponderosa pine (*P. ponderosa* Lawson), and sugar pine (*P. lambertiana* Dougl.) during air seasoning. A very similar and troublesome stain commonly develops in ponderosa pine, sugar pine, and occasionally in western white pine (*P. monticola* Dougl.) in the course of kiln drying. These stains frequently are characterized by narrow margins of bright wood at the board surfaces and near the juncture of sapwood and heartwood. Such margins typically are backed by extra-dark streaks of the stain. Although most common in the sapwood, the discolorations occur to some extent in the heartwood. The wood is not harmed except for purposes where a natural finish is desired.

The factors underlying the development of these brown stains have not been adequately ascertained. As a consequence no entirely satisfactory control measure has been discovered. The discoloration apparently results from a darkening of certain water-soluble materials in the wood, which have concentrated near the boundaries of the sapwood as a result of diffusion and deposition in the seasoning process. A fairly detailed account of these stains is given by Hubert (*34*). Control measures also are discussed by Thelen (*74*).

## OXIDATION STAINS IN HARDWOODS

As a group, hardwood species are more subject to discolorations of the presumably oxidation type than are the softwoods. In fact, the green sapwood of almost all hardwoods tends to assume various darker shades when exposed to the air. Many of these discolorations are of little economic importance; for example, the reddish-brown cast, which often develops on freshly cut sapwood surfaces of red gum (*Liquidambar styraciflua* L.), and the red color, which appears on green stock of red alder (*Alnus rubra* Bong.) often within an hour or so after sawing (*7*).

On the other hand, such oxidation discolorations in hardwood species may assume considerable importance, particularly if the sapwood is naturally white or very light colored. A deep greenish-brown to greenish-black color commonly develops with considerable rapidity in green persimmon (*Diospyros virginiana* L.) during air seasoning. The discoloration is extremely dense and penetrates the wood so completely that it renders the stock unfit for certain specialty articles for which persimmon is particularly adapted. This type of stain can be prevented by excluding air from the wood or by destroying the oxidizing enzymes in the wood which contribute to its formation (*64*). The latter can be accomplished with comparatively mild heat treatments, such as would be practicable commercially.

Another case in point is the interior discoloration that frequently occurs in tupelo gum (*Nyssa aquatica* L.), evergreen magnolia (*Magnolia grandiflora* L.), and sweetbay (*M. virginiana* L.). It closely resembles light interior blue stain but may develop in the course of kiln-drying as well as in air seasoning. Microscopical examinations indicate that starch in the parenchyma cells is converted to gumlike deposits, which in turn presumably are oxidized

[3] Names of trees are mainly according to Sudworth (72).

to a brownish color. A high moisture content in the wood seems to be necessary for these changes to take place, suggesting the need for more rapid drying. No satisfactory method of control has been devised for thicker stock, but end stacking followed by kiln-drying has been reported by one lumber mill to be fairly effective with 1-inch and 1¼-inch items.

Other interior stains of bluish or dull brownish shades, which may resemble certain types of blue stain, occasionally appear in air-seasoned lumber of oak, birch, maple, basswood, and other hardwood species. It is probable that these are oxidation stains, somewhat on the order of those just described. Frequently they appear only under the cross sticks, in such cases presumably being favored by the normally slower drying in these portions of the boards.

Still another example of what is believed to be oxidation stain is the reddish-yellow to rust color which develops in birch logs stored during warm weather. It works in rapidly from the ends of the logs and is so serious that manufacturers of birch veneer have largely abandoned cutting in summer months. Although it is said to be preventable by storing the freshly cut material under water, this method would be difficult of extensive commercial adoption. The discoloration has been prevented experimentally by treating pieces of green birch wood with boiling water prior to seasoning (2), suggesting that a combination of prompt utilization of the logs and the customary steam treatment of the veneer bolts should preclude its occurrence.

### KILN BURN AND MACHINE BURN

Kiln burn and its cause are familiar to anyone who has been associated with dry-kiln operations. It represents an actual scorching of the wood as a result of excessively high kiln temperatures. The remedy lies in closer control of kiln conditions. In the same category is the brown surface burning of finished stock caused by excessive friction developed when progress of the piece through the planer is impeded.

### MINERAL STAIN IN HARD MAPLE

In some localities of the Lake States and the Northeast a serious discoloration occurs in hard maple trees and to some extent in other hardwoods. So far as is known, this discoloration originates only in the tree. It appears on lumber as greenish-brown to greenish-black lenticular streaks of various magnitudes that parallel the grain, or as broad, longitudinally alined bands that may cover comparatively large areas of the board. The discoloration has been popularly termed "mineral stain" or "mineral streak," because of reports that the stained wood dulls saws and planer knives more rapidly than does the bright wood, and the belief of some mill men that mineral deposits are responsible.

Discolorations of this sort do not represent any specific type of defect but may result from a number of causes. Recent work of a preliminary nature indicates that they may originate at injuries and that micro-organisms, although commonly associated, are not necessarily always present. Although mineral stain is found in both heartwood and sapwood, there is some question as to whether it ever originates in the heartwood.

A limited number of chemical analyses disclosed that the ash content (consisting in large measure of carbonates) of the streaked portions may be several times as great as that of adjacent bright wood. This fact may partly explain why the stained wood also tends to be appreciably harder, as denoted by mechanical tests, than bright wood in the same boards, thus lending experimental support to the possibility that the former has a greater dulling effect on cutting equipment.

Yellow poplar or tuliptree (*Liriodendron tulipifera* L.) heartwood commonly is disfigured by purplish and greenish streaks which, with the exception of color, are not unlike the broadest and most extensive streaks in hard maple, just described (p. 5). Although largely heartwood discolorations, they are mentioned because of their similarity to some of the brighter colored sap stains. The cause of this staining is as yet unknown, but there has been no evidence to indicate that it is of fungus origin. Also like mineral streak, these stains develop in the tree.

### IRON TANNATE STAIN OF OAK AND OTHER HARDWOODS

A common stain ordinarily of minor importance is often produced on green hardwood material at the points where the sapwood has been in close contact with the saw, green chain, or any other iron equipment. The discoloration has a bluish to blue-black cast, essentially like that of an ink stain, and is very shallow, rarely penetrating deeply enough to persist after the lumber is surfaced. It may occur on a number of species but is particularly noticeable on oak and chestnut stock, which contain relatively larger amounts of tannin materials than other commercial woods. The stain is frequently objectionable in veneer products that are constructed with iron nails, staples, or wire. Not uncommonly dark streaks several inches long running with the grain on both sides of the point of contact of the iron fastener and wood are observed.

Iron tannate stain results from a chemical reaction between small amounts of iron and the tannins in the wood. The same reaction is used commercially in the manufacture of certain kinds of ink. Since an acid condition, which is present in most woods, is necessary the stain can be prevented by applying an alkaline solution to the surface of the wood before it comes in contact with the iron. Commercial soda (sodium carbonate or sodium bicarbonate or mixtures of these, hereafter generally referred to as soda), at a strength of 1 to 1½ pounds to 50 gallons of water, is ordinarily satisfactory for this purpose.

Care should be taken in dipping oak for blue stain control that iron tannate discoloration does not occur. Solutions may become so dark as to seriously discolor the entire surface not only of the oak boards but also of other species that are passed through the dipping vat. The conditions necessary to the discoloration are aggravated when iron is used in the construction of the vat, but the continual passing of the green chain through the solution is sufficient to bring about serious staining within a fairly short time. Antistain chemicals now in commercial use are in no way responsible for trouble of this type; the same thing would occur if only water were in the vat. The addition of a small amount of soda, as just prescribed, to the regular dipping solution is a dependable corrective measure.

#### WEATHER STAIN

Dust, rain, air, and sunlight combine to produce a general grayish-brown discoloration of exposed lumber, which may be ascribed to a single cause, weathering. The off-color is shallow and, except in some cases where an excessive amount of water has penetrated the stock, surfaces off easily.

#### WOUND STAINS

A number of discolorations can be traced to wounds of various sorts, produced in the sapwood of living trees. In many cases these take the form of abnormal accumulations of resin or gum about the wound zone. If the bark is broken so that the sapwood is exposed for a substantial period, discolorations fundamentally like some of the darker oxidation stains may occur. If the wound does not callus over, the exposed wood commonly decays. Boyce (*6*) mentions fire, lightning, insects, birds, and man as being among the common causes of wounds in living trees.

## STAINS CAUSED BY FUNGI

The sapwood stains of greatest importance are caused by minute threadlike plants, technically classified as fungi, that penetrate the wood to various depths and derive their nourishment from portions of the wood. The discoloration results from the dark color of the fungi themselves or from diffusible colored materials which they produce, depending on the organism involved. Common types of fungus discolorations in or on lumber are blue stain and mold.

#### BLUE STAIN

Blue stain is the most prevalent and economically important fungus discoloration in sapwood. Consequently the terms "blue stain" and "sap stain" have become practically synonymous in general usage. Blue stain is distinguishable by its surface appearance and the fact that it is almost exclusively confined to the sapwood. Often dark moldlike growths of the causal fungi will appear on the surface. In many cases a closer examination will reveal clusters of tiny globoid to pear-shaped bodies with bristlelike necks, which are special fruit structures of one of the most common types of staining organisms.

It is the mass color of the hyphae (individual filaments of the fungi), as seen through the surface layers of the wood, which mainly is responsible for the dark discoloration.[4] Although bluish-gray to blue-black colors predominate among blue stains, the microscopic fungus filaments within the wood are almost invariably brown in color. The reason for this lack of color agreement has not been explained conclusively. Two general theories are that either the brown color of the fungus is not readily transmitted by the overlying wood cells, with the result that chiefly the blue to blue-black shades (the presence of which is assumed) are visible at the wood

[4] Some darkening of the cell walls of the wood has been reported in the case of certain blue-stain fungi (*40*).

surface (*28*) or that the bluish color is produced by certain refraction phenomena induced by the scattering of dark hyphae in the light-colored wood cells (*54*). The coloring matter of the fungus filaments is insoluble in alcohol, ether, chloroform, benzol, alkalis, and acids (*28*) but can be removed by a bleaching agent, such as a solution of calcium hypochlorite. Bleaches are impractical for most purposes, since they are expensive and also remove the natural color of the wood. They can be used to advantage, however, in some pulping processes where bleaching is customary.

Some cases of so-called blue stain may have very little if any blue color. For example, *Endoconidiophora moniliformis* (Hedgc.) Davidson stains fresh sapwood of pine and hardwoods a light to dark brown, and *Torula ligniperda* (Willk.) Sacc., a common wood saprophyte, sometimes produces a brownish-black to neutral-gray discoloration in both sapwood and heartwood of logs and occasionally in exposed lumber, particularly in hardwoods (*70*). For this reason the term "blue stain" is perhaps an unfortunate one. However, it has become firmly entrenched through long usage, having been employed by early German foresters. Any other single name, if used to designate the entire group of sap stains of this general type, would probably be open to the same objection.

Practically all the important known staining fungi belong, in the natural scheme of classification, to either the Ascomycetes or the Fungi Imperfecti. Reports of rather extensive surveys of sap-stain organisms made in both the United States (*18*, *28*, *60*) and Europe (*40*, *53*, *54*, *57*) describe the respective species in considerable detail.

Among the principal blue-staining fungi that have been reported to occur on lumber and logs in the United States the family Ceratostomataceae, which includes such genera as *Ceratostomella* and *Endoconidiophora*, has the greatest representation.[5] Of the Fungi Imperfecti, *Diplodia*, *Cladosporium*, *Hormodendron*, and *Graphium* have been most frequently isolated from stained wood.

A number of important United States blue stain fungi appear to have definite predilections for either hardwood or softwood species. Davidson (*18*) and later unpublished data of the Division of Forest Pathology indicate that in the Southern States *Endoconidiophora coerulescens* Münch, *E. moniliformis*, *Ceratostomella pluriannulata* Hedgc., and *Graphium rigidum* (Pers.) Sacc. preponderate in hardwood lumber, whereas *C. ips* Rumbold, *C. pilifera* (Fr.) Winter, and *Diplodia* sp. preponderate in pine lumber. *Diplodia natalensis* P. Evans is the only species as yet found in comparatively large numbers in both hardwoods and pine.

### MINOR SAPWOOD STAINS

Many of the minor sapwood stains of fungus origin are bright colored and are usually found along with blue stain. Such hues as pink, purple, and yellow, and intermediate variations of these, are typical. The areas affected are usually limited to spots or small streaks. Field observations indicate that there is a tendency for many of these bright stains to occur in wood that is somewhat wetter than that in which only blue stain develops.

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[5] European investigators have recently revised the nomenclature of some of the sap-staining fungi; however, there seems to be some doubt as to the legitimacy or desirability of many of the changes and for this reason the older names are retained here.

The causal fungi characteristically penetrate into the wood much in the manner of the blue-stain fungi; therefore the stains usually persist after surfacing. Most of the discolorations are caused by soluble pigments, which are given off by the fungi and taken up by the wood cells, but in some instances a pigmentation of the fungus filaments themselves may contribute to the coloration. Although there seems to be some limitation to the natural territorial and host range of many of the causal fungi, the typical color apparently can be induced in practically any wood in which the fungi will grow.

Species of *Fusarium* and *Penicillium* are the most common causes of bright-colored stains. *Fusarium moniliforme* Sheld. has been isolated most frequently by the authors (*65*) from purple- and pink-stained lumber and logs of southern pine and red gum sapwood. *F. solani* (Mart.) App. and Wr. was mainly associated with purple stains in stored red gum logs. A third species, provisionally identified as *F. viride* (Lechm.) Wr., caused a light purple stain in southern pine lumber. Hedgcock (*28*) found *F. roseum* Link to be a cause of pink, red, and violet blotches on freshly cut pine lumber in northern Wisconsin. In the foregoing cases the wood was stained both by the secretion of a soluble pigment and by the colored hyphae. A carmine color commonly encountered in the heartwood and occasionally the sapwood of boxelder (*Acer negundo* L.) trees has been reported (*34*) to be the result of attack by *F. negundi* Sherb.

Whereas the *Fusarium* stains seem to be more commonly purple or red bordering on the purple, the *Penicillium* stains are more likely to be crimson red, orange red, or some intermediate color. Hedgcock (*28*) found *P. aureum* Corda to be one of the most common species producing orange-red stains in the sapwood of a number of trees. Frequently mingled with *P. aureum* was *P. roseum* Link, which produced a crimson pigment. A pale-yellow stain in oak and other hardwood stock [6] has been identified with *P. divaricatum* Thom (*Paecilomyces varioti* Bainier) or a related fungus species.

Bright-yellow and orange stains are occasionally produced in southern pine lumber in the early stages of drying (*65*). The former, which also occurs to a slight extent in red gum, is due to a *Gymnoascus*-like fungus which is itself of a strong yellow color. The fungus responsible for the orange stain could not be identified because of its failure to fruit. The hyphae of both fungi are colored much like the stain and secrete a small amount of pigment, which acts to deepen the color.

A pink stain in southern pines,[7] southern cypress (*Taxodium distichum* (L.) Rich.), and oak lumber, apparently not so common as those just discussed, has recently been investigated.[8] The stain occurs both in heartwood and sapwood. Taxonomic characteristics establish the causal fungus as an apparently new species of *Geotrichum*. Blocks of pine sapwood inoculated with pure cultures of the fungus became thoroughly stained within a few days. Only traces of the soluble pigment that is responsible for the coloration

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[6] COLLEY, R. H., WILSON, T. R. C., and LUXFORD, R. F. THE YELLOW-STAIN FUNGUS AND ITS EFFECT ON THE STRENGTH OF WHITE OAK. U. S. Forest Serv., Forest Prod. Lab. Rept., 30 pp., illus. 1924. [Typewritten.]

[7] Principal species being longleaf (*Pinus palustris* Mill.), shortleaf (*P. echinata* Mill.), loblolly (*P. taeda* L.), and slash (*P. caribaea* Morel.).

[8] CHIDESTER, M. S. A PINK-STAINING FUNGUS. U. S. Bur. Plant Indus., Div. Forest Path. Prog. Rept., 4 pp., illus. 1936. [Unpublished manuscript.]

of the wood are secreted by the fungus while growing on malt agar, an interesting physiological difference between this and the preceding wood-coloring fungi.

## MOLDS

Visible molding of wood takes place mainly at or near the surface and therefore does not typically result in deep discolorations, such as characterize blue stain and most of the minor stains just described.[9] The objectionable discoloration in most cases is due to the color of the spores, which are produced in abundance. Fortunately mold fungi as a rule do not sporulate readily in the deeper portions of the wood; hence any interior discoloration is mainly confined to the larger wood openings, such as resin ducts or vessels (*65*), and is usually shallow enough to come off with planing.

Molds most frequently encountered on lumber are ash green to deep green in color, although black is common. Species of *Penicillium*, *Trichoderma*, and *Gliocladium* are responsible for most of the green colors and species of *Aspergillus* for the black discolorations. A salmon-orange mold, which commonly occurs on the sapwood of steamed red gum lumber during air seasoning, is caused by *Monilia sitophila* (Mont.) Sacc. Mold discolorations that persist after surfacing or brushing often have an appearance similar to that produced by weathering. A number of mold fungi that have been found in or on wood are listed by Howard (*32*). Molds encountered while making a study of wood pulp deterioration at the Forest Products Laboratory have been described (*39*) in some detail. Many of these mold fungi also are found on lumber.

In many instances of light molding the objectionable fungus growths are eventually blown by the wind from the surface of the wood or are brushed off in the course of handling the stock. Cases of heavier molding in certain materials sometimes justify special brushing, as is sometimes done with round stock preliminary to pressure treating with creosote. A mechanical brush treatment has been successfully used on molded staves (*4*). Unfortunately, brushing is not particularly effective in cases where the wood itself is discolored, and it is expensive. Moreover, whenever molding occurs blue stain is also likely to be present. Since the comparatively inexpensive methods available for controlling sap-stain fungi are also effective against most mold fungi, it is usually desirable to take steps to control both at the same time.

In table 1 are grouped, according to common external characteristics, some of the various sapwood discolorations that have been discussed. For an exact determination of a particular stain, microscopical and cultural examinations are usually necessary; the acidity, moisture content, and species of the wood determine the color to some extent, and hence preclude the use of color shades as exact criteria. The list is intended only to give representative types of common discolorations and is in no wise complete.

In subsequent sections of this bulletin the term "sap stain" will refer exclusively to blue stain.

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[9] The term "mold" is a more or less arbitrary one applied to those discolorations that are in the main caused by the presence of the fungus on the surface of the wood and that largely disappear with brushing or planing. The term "stain," on the other hand, is used usually in designating those discolorations that go deeper into the wood and that are not necessarily accompanied by visible fungus growth. The distinction is not a technical one, however.

TABLE 1.—*Common sapwood discolorations and their causes*

| Color of stain | Designation and miscellaneous characteristics | Sapwood in which it commonly occurs | Common cause |
|---|---|---|---|
| Bluish black to steel gray principally; brown shades common. | Blue stain.—Occurs in spots, streaks, or patches which cover all or part of the sapwood. Moldlike growths of causal fungi often present on surface of stained areas. May penetrate deeply. | Lumber and logs of practically all commercial wood species. | Dark hyphae of species of *Ceratostomella*, *Endoconidiophora*, *Diplodia*, *Cladosporium*, *Hormodendron*, and *Graphium*, principally. |
| Inky blue | Iron tannate stain.—Inklike streaks or blotches where nails or iron equipment have contacted freshly cut stock. Without precautions may develop as general discoloration when dipping oak lumber with iron equipment. Usually shallow penetration. | Various products of oak, chestnut, red gum, and other species with necessary tannin content. | Chemical reaction between iron and tannins in the wood. |
| Pale blue and brown | Chemical stain of hardwoods.—Most common as a general interior stain and may not be observed until lumber is surfaced. Frequently resembles light blue stain. Sometimes appears only under seasoning stickers. May penetrate deeply. | Oak, birch, maple, basswood, tupelo gum, magnolia, and other hardwood lumber. | Oxidation of certain wood substances during air seasoning or kiln drying. |
| Greenish brown to greenish black | Mineral stain.—Occurs in lenticular streaks of all sizes or as a general discoloration. | Living hardwood trees—hard maples principally.[1] | Unknown. Possibly initiated by injuries. |
| | Chemical stain of persimmon.—Occurs as a general discoloration. May penetrate deeply. | Persimmon | Oxidation of certain wood substances upon contact with air during seasoning. |
| Dull brown to gray | Weather stain.—Occurs as general surface discoloration on exposed portions of wood. Usually shallow penetration. | Lumber of all commercial wood species.[1] | Action of air, dust, rain, sunlight ("weathering"). |
| | Mold stain.—Discoloration persisting in surface layers of molded wood after surfacing or brushing. Usually shallow penetration. | do | Sporulation of mold fungi in vessels and resin ducts near the surface of the wood. |
| Various, green predominating, black common. | Molds.—Colored fungus growths present on surface of wood. Generally surfaces off readily or can be considerably removed by brushing. | Various products of all commercial wood species. | Presence of *Trichoderma*, *Penicillium*, *Gliocladium*, *Aspergillus*, *Monilia*, and other fungi sporulating on the surface of the wood. |
| Various, brown or reddish shades principally. | Seasoning coloration.—Frequently appears simply as a deepening of color. Essentially a chemical stain but generally not objectionable. May penetrate deeply. | Lumber of hardwoods principally | Oxidation of certain wood substances during seasoning. |
| Yellow brown to dark brown | Brown seasoning stain of western and eastern pines.—Narrow margins of bright wood common at board surfaces and at juncture of heartwood and sapwood. May penetrate deeply. | White pine, ponderosa pine, and sugar pine lumber. | Oxidation of certain wood substances during air seasoning or kiln drying. |
| | Kiln burn and machine burn.—Surface of wood has a scorched appearance. Usually shallow penetration. | All lumber.[1] | Light burning of wood due to excessive kiln temperature or to heat developed by planer knives. |
| Red | Bright-colored chemical stain of hardwoods.—Appears more or less as a general discoloration. May penetrate deeply. | Western alder lumber and other hardwoods. | Oxidation of certain wood substances upon exposure to air. |
| Reddish yellow to rusty | | Birch logs | Oxidation of certain wood substances upon exposure to air. Promoted by warm weather. |

[1] Also occurs in heartwood.

TABLE 1.—*Common sapwood discolorations and their causes*—Continued

| Color of stain | Designation and miscellaneous characteristics | Sapwood in which it commonly occurs | Common cause |
|---|---|---|---|
| Purple to pink | Bright-colored fungus stain.—Occurs usually as blotches or small streaks. May penetrate deeply. | Southern pine and red gum lumber and logs. | Soluble pigment and colored hyphae of *Fusarium moniliforme*, *F. solani*, *F. viride*, and *F. roseum*. |
| Crimson to orange | do | Southern pine, gum, oak, and other hardwood lumber and logs. | Soluble pigment of *Penicillium roseum* and *P. aureum*. |
| | | Southern pine, southern cypress, and oak lumber.[1] | Soluble pigment of *Geotrichum* sp. |
| Pale yellow<br>Deep yellow | do | Lumber and logs of oak, birch, hickory, and maple.[1] | Soluble pigment of *Penicillium divaricatum*. |
| | | Southern pine and red gum lumber and logs. | Colored hyphae and to some extent soluble pigment of a *Gymnoascus*-like fungus. |

[1] Also occurs in heartwood.

## DIFFERENCE BETWEEN SAP STAIN AND DECAY

Sap stain is not a stage of decay. Decay is caused by fungi that extend their attack to the important structural elements of the wood, the fibers and the tracheids, and in time cause the familiar characteristics of rotten wood, such as softness or brittleness and marked reductions in strength and weight. Sap-stain fungi depend largely for their nourishment on soluble and semisoluble materials within the wood cells, and on the wood rays and the soluble and semisoluble material contained in them, which are of secondary importance in contributing to strength. They attack the fibers and tracheids slightly at most. The result is that their effect is mainly one of discoloration.

Failure to recognize these differences between decay and sap stain has led to some of the discrimination against stained products. The confusion is no doubt largely due to the fact that essentially the same conditions favor the development of both sap stain and decay. If favorable conditions are prolonged, as is sometimes occasioned by damp weather, decay may eventually be conspicuous along with the stain. With ordinary seasoning conditions, however, moderate amounts of stain are usually accompanied by little or no decay. Very early stages of certain kinds of heartwood decay may have the appearance of stain rather than decay. The pink to red-brown discoloration (commonly known as red heart) occurring in the heartwood of pines containing incipient infection by *Fomes pini* (Thore) Karst. is an example. But the fact that these discolorations occur exclusively in the heartwood clearly distinguishes them from the ordinary run of sap stains. Brownish discolorations caused by incipient decay in pine sapwood are sometimes difficult to distinguish from the browner types of sap stain. More advanced decay can ordinarily be identified by a definite softening or brittleness of the wood, ascertained by probing the discolored area with a knife. The sapwood of hardwoods frequently is bleached by incipient decays.

## SEASONAL AND REGIONAL DISTRIBUTION OF SAP STAIN

No lumbering section of the United States is entirely free from sap-stain problems during some portion of the year. The prevalence of sap stain in a particular region depends largely upon climatic conditions, especially temperature, rainfall, and relative humidity, because of their bearing on the development of the staining organisms. The inherent susceptibility of the predominant wood species, age of timber insofar as it relates to the proportion of sapwood in the tree, and lumbering practices insofar as they determine the length of exposure of green sapwood, also play an important part. These conditions naturally vary decidedly in a country embracing as much territory as the United States and hence warrant consideration by regions and areas.

### SOUTHERN REGION

The portion of the southern region in which sap stain is particularly important commercially covers the Atlantic and Gulf Coastal Plains from eastern Maryland to eastern Texas, the Piedmont Plateau, and the southern halves of the States of Arkansas and Tennessee. In the Gulf States and lower Mississippi Valley, high temperatures and an abundance of rainfall throughout the greater portion of the year provide ideal conditions for rapid development of stain organisms; consequently, it is here that sap stain affects the lumber industry most seriously.

Although stain in the more southerly parts varies considerably in severity or intensity at different periods of the year, there is no distinct season during which it is unable to develop sufficiently to require attempts at control. As the distance from the Gulf becomes greater, seasonal variations become more prominent, being rather pronounced in the northern portions of the Gulf States and the sections adjacent to them. In general, the period of greatest intensity occurs between the latter part of May and early September. Occasionally a second period of severe staining is encountered between the middle of November and the latter part of February.

Of the southern woods, the pines and red gum are affected most severely. Yellow poplar, beech, magnolia, oak, tupelo, and black gum, and other hardwoods are discolored to a lesser extent but nevertheless seriously at times. Cottonwood and willow will stain with comparative severity, but because of their limited commercial distribution such deterioration in these species is largely of local importance.

In addition to the outstanding natural susceptibility of the sapwood of southern wood species to staining and the marked suitability of climatic conditions, there are other circumstances that indirectly contribute to make sap stain more serious in this region than in all others combined. As yet, kiln drying green from the saw is practiced for only a very small portion of the large output of hardwood lumber. Kiln drying of pine stock is limited largely to the better grades and to the larger mills, which at present cut less than one-half of the total regional output of pine. Furthermore, the increasing dependence of the lumber industry on second-growth stands has resulted in the production of material containing a high proportion of sapwood. There is also a tendency on the part of southern hardwood operators to store their logs for various periods before sawing, thus providing an opportunity for development of considerable amounts of sap stain before the wood reaches the board stage. Wood-boring insects, which are abundant throughout much of the year, aggravate this condition by carrying the stain infection into the logs. Log stain in pine is also common but to a considerably smaller extent.

### CALIFORNIA PINE REGION

The California pine region, which is predominantly mountainous, occupies in large part the California Sierras and the eastern slopes of the coastal ranges of California and southern Oregon. Sap stain within this region is probably next in importance to that of the South, the difference being due largely to lower year-round temperatures and rainfall, distinct seasonal variation in stain occurrence, and a smaller proportion of sapwood in the timber being cut.

Because of the wide variation in temperature and humidity induced by topography and the relation of the latter to the prevailing winds off the Pacific Ocean, location plays a prominent part in stain development. Commercial pine production is confined almost entirely to the Sierras, on the eastern slopes of which the occurrence of stain is comparatively slight and is governed by the frequency and duration of rainy spells in the warmer months. On the western side of the Sierras, where sugar pine reaches its greatest commercial importance, blue stain has been reported to be a major problem in seasoning (*24*). The amounts of stain depend considerably on the degree of exposure of the seasoning yard. River valley locations, as might be expected, provide greater stain hazard than is encountered on the higher sites. Seasonal variation in the occurrence of sap stain on the western slopes of the Sierras is rather pronounced. The summer months are usually too dry and the winters too cold to permit more than slight discoloration. Most of the stain develops during spring, late summer, and fall, when both temperature and moisture conditions are generally favorable for fungus growth; those of the fall being generally the most favorable.

Of the four principal species of timber cut in the California pine region, sugar and ponderosa pines are most severely attacked. These two species are probably about equally susceptible, although most lumbermen are inclined to regard the latter as having the greater tendency to discolor. No doubt this impression is due partly to the facts that the proportion of sapwood in ponderosa pine averages higher than that in sugar pine and the cut of ponderosa pine greatly exceeds that of the other species. Stain in Douglas fir (*Pseudotsuga taxifolia* (LaM.) Brit.), in white fir (*Abies concolor* Lindl. and Gord.), and in lowland white fir (*A. grandis* Lindl.) is of less consequence, although as time brings second-growth stands into commercial production the resultant increase in manufacture of sapwood lumber may alter the situation somewhat.

### PACIFIC NORTHWEST REGION

The Pacific Northwest region, which contains the heavy timber stands of Oregon and Washington, presents relatively unimportant sap-stain problems, although there are rainy periods in the late spring and early fall when conditions would ordinarily be regarded as favorable for the development of stain. An important reason for this general freedom from stain is the comparatively small amount of sapwood in the timber being cut. Also, practically all the manufacturing plants, with the exception of a few cargo and portable mills, are equipped with dry kilns, so that the amount of air seasoning is limited. In 1928 about 35 percent of the total lumber cut was kiln-dried and only about 15 percent air-seasoned (*24*). The remainder was shipped green. These proportions have undoubtedly changed somewhat but probably represent roughly the general situation at the present time.

At the present time most of the sap-stain difficulties of the Pacific Northwest are associated with bulk shipments of green lumber. Although staining and molding in shipments of this sort have long been a source of some concern, it is apparently only within recent years that there have been any serious attempts to improve the situation (*1, 10, 77*).

Of the Pacific Northwest species, Boyce (*7*) regarded Sitka spruce (*Picea sitchensis* (Bong.) Carr.) as being most subject to sap stain, and the true firs (*Abies* spp.), western red cedar (*Thuja plicata* D. Don), Douglas fir, and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) as being less affected.

### NORTH IDAHO AND SURROUNDING AREA [10]

According to Fullaway, Johnson, and Hill (*24*), sap stain is of major importance as a cause of stock depreciation in this area, which is characterized by greater temperature and rainfall extremes than the other regions and areas discussed; therefore, by comparison, stain occurrence tends to be even more seasonal in character. The spring and fall months appear to be the ones in which stain development is particularly objectionable, although occasional periods of prolonged rain in the summer may cause some trouble. Low winter temperatures hold stain during this season to a negligible quantity.

Local drainage conditions and great variation in natural seasoning conditions, resulting from differences in elevation of the yards (1,800 to 4,000 feet), have a decided influence on the sap-stain problem.

The greatest trouble is encountered with ponderosa pine, although stain in western white pine is of practical importance. Degrade losses are likely to be particularly high with the white pine and for this reason chemical treatments have come into wide use on such products as match plank. Western larch (*Larix occidentalis* Nutt.) and Douglas fir are not seriously affected. The shop and select grades suffer more damage than do the common grades because of greater sapwood content.

### OTHER FOREST REGIONS

In other forested regions of the United States sap stain may or may not be an important problem, depending upon the several factors influencing its development. In addition to less favorable climatic conditions, the migration of lumbering centers from such regions as the Northeastern and Lake States no doubt is a factor in the total lesser stain than in the regions discussed in detail. However, losses are sufficient to require some use of control measures; for instance, chemical control is being practiced in Arizona, New Mexico, the Lake and Central States, and occasionally elsewhere. Even in such a northerly region as Ontario, Canada, sap stain has been estimated (*21*) to cause, in ordinary seasons, annual losses to manufacturers of white pine lumber ranging between $200,000 and $300,000.

## FACTORS INFLUENCING DEVELOPMENT OF SAP STAIN

The natural factors that determine the infection of wood by stain-producing fungi and the subsequent rate of development of the stain in the wood are (1) temperature, (2) oxygen, (3) moisture content, and (4) the kind of wood. The relations of these to the growth of the fungi constitute the basis for all control measures. If any one of the factors is unsuited to the growth of fungi, staining cannot occur. Wood-staining fungi may react somewhat differently

[10] Embracing northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the northeastern tip of Oregon. It is intended that this discussion also apply to contiguous timbered areas.

to conditions of the environment, but their general requirements are sufficiently alike to keep the control problem on a comparatively uniform basis.

### TEMPERATURE

On the whole, sap-staining fungi parallel rather closely higher plant life in respect to their temperature requirements for maximum rate of development, finding optimum conditions in moderate summer temperatures. But the range of temperatures in which growth may occur is substantially broader than that of most green plants, particularly on the cold side of the temperature optimum. Between upper and lower temperatures, which inhibit growth, great variation in rates of development is encountered.

Research by European investigators indicates that 32° to 41° F. (0° to 5° C.) and approximately 95° F. (35° C.) are common limiting temperatures for growth of their native species of stain fungi on artificial media (*40, 54, 75, 76*). Most of the fungi studied grew most rapidly between 71° and 77° F. (22° and 25° C.). In similar studies by one of the authors, the growth of several strains of *Ceratostomella pilifera* and a strain of *C. pluriannulata* from the Gulf States was inhibited by 39° F. (4° C.) or slightly less, and by 93° to 95° F. (34° to 35° C.). Maximum growth occurred at 82° to 84° F. (28° to 29° C.). *C. ips*, a common cause of log stain resulting from attack by Ips beetles, which carry the fungus, was the highest temperature organism of the group observed; it failed to grow at 41° F. (5° C.), made fairly rapid growth at 95° F. (35° C.), and had cardinal points varying from 4° to 14° F. (2° to 8° C.) above those of any of the other fungi tested.

Behavior of cultures of *Ceratostomella pilifera* from California and Mexico indicated that there are geographical strains of stain fungi, which differ measurably at least in their reaction to temperature. These had optimum and maximum temperatures for growth 4° to 7° F. (2° to 4° C.) lower than the strains from the warm Gulf States.

No significant differences in growth rate at different temperatures were detected for *Ceratostomella pilifera* on malt agar and in wood, indicating that the temperature relations may be practically the same on both substrates. Penetration of hyphae and discoloration of the wood occurred most rapidly and were greatest at temperatures that also favored mycelial growth on agar. The average longitudinal spread in wood over a 4-day period was in general close to the average rate on malt agar.

The influence of extreme temperatures on the viability of staining fungi has not received much attention. It has been reported that *Ceratostomella pilifera* (*33*) is more resistant to heat treatments than are certain wood-decaying organisms. Fritz (*22*) found a blue stain fungus alive in white pine wood after exposures to temperatures of 120° F. (49° C.) for 12 hours and 150° F. (66° C.) for 1 hour. In spite of the abilities of the fungi to withstand short exposures at such high temperatures, it is probable that temperatures not far above the maximum for growth may be lethal if maintained for a number of days. This generalization has been justified by the nonsurvival of most of the cultures used in the present studies, after

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incubation periods of 2 to 14 days at 95° to 104° F. (35° to 40° C.). In the Gulf States some difficulty has also been experienced in maintaining cultures of stain fungi during the summer without refrigeration.

A direct relation was found between cardinal temperatures and the ability of the blue stain isolates to remain viable and to grow at unfavorably high temperatures. In all cases the isolates with the lowest optima were the first to be killed or the last to recover from incubation at 95° and 104° F. (35° to 40° C.). Injurious exposures that did not kill were only temporary in effect, rapid growth being resumed after a day or two of favorable temperatures.

Sap-stain fungi are able to withstand comparatively low temperatures much better than temperatures above their optimum for growth. This is demonstrated by their survival in northern localities where winter temperatures reach the freezing point and commonly drop below 0° F. (−18° C.) for many days at a time. The same experimental work reported above indicates that low temperatures have no noticeable carry-over effect on growth rates at subsequent favorable temperatures.

On the basis of the experimental evidence and field records, high temperatures are not considered an important limiting factor in the discoloration of lumber during air seasoning. Studies in southern lumberyards indicate that whereas air temperatures around lumber piles are often above the maximum for growth of the fungi, the temperatures within the piles of drying lumber are lower and usually favorable for rapid stain development, even on the hottest days. Unfavorably high temperatures occur undoubtedly in the top courses and outside boards of piles and also throughout piles of dried lumber; however, stain development is of little importance in such circumstances due to rapid loss of moisture from the wood. So long as moisture conditions favorable to stain development prevail, loss of water from wood continues and is accompanied by the cooling effect of evaporation. As a general statement, it might be said that regardless of temperature conditions, wood in a seasoning pile will not stain if evaporation of water has permanently ceased.

The practical importance of low temperatures would vary with the locality and season of the year. In the Gulf States region, low temperatures during the winter undoubtedly retard staining to some extent, but seldom are an inhibiting factor. In northern regions such as the Lake States, on the other hand, winter temperatures for long periods at a time greatly retard and often inhibit discolorations due to these fungi.

### OXYGEN

Although their oxygen requirements seem to be very small, no wood-inhabiting fungi are known to be able to develop or survive in the absence of oxygen [13] (*3*). Since this gas is a major component of air, the quantity of oxygen available to fungi growing within wood depends largely on the amount of air space in the wood cells and the rate at which oxygen can diffuse into the wood to replace that consumed by the fungi. These conditioning factors are in turn

[13] SCHEFFER, T. C. OXYGEN REQUIREMENTS FOR GROWTH AND SURVIVAL OF CERTAIN WOOD-INHABITING FUNGI. 1935. [Unpublished manuscript.]

governed to a considerable extent by the water content of the wood. Obviously the more water the wood contains the less space there is available for air and the more difficult it is for oxygen to diffuse inward through the wood cells. Such factors as the specific gravity and external dimensions of the wood also are involved but need not be specially considered here.

#### MOISTURE

Sap-stain fungi cannot grow in water-saturated wood because the oxygen content is too low. This explains the absence of stain development in sunken logs and in the submerged portions of floating logs and timbers. According to European investigators (*40*) not all sap-stain fungi can tolerate moisture contents as high as those prevailing in fresh sapwood. From the practical standpoint, however, it is significant that such wood is not immune to attack by some of the important stainers. In some southern species, at least, the moisture content of green sapwood lumber, although comparatively high, does not seem to be high enough to prevent the occurrence of stain. The rapidity with which stain will develop in solidly bulk-piled lumber, or in freshly cut logs, bears evidence to this fact. The moisture content of green sapwood of southern pine species commonly amounts to 140 percent of the dry weight of the wood and in some of the southern hardwoods, such as red gum, it amounts to as much as 150 and 160 percent. These latter values probably border on the maximum permitting important stain development.

Ordinarily, as the wood dries the rate of stain development and intensity of the discoloration tend to increase, the optimal moisture condition depending on the particular fungus or fungi involved. Lagerberg, Lundberg, and Melin (*40*) report a rather broad moisture optimum (approximately 40 to 120 percent of the dry weight of the wood) when the internal aeration of the wood was not greatly restricted. With a limited supply of oxygen, which they produced by partially coating the surface of the experimental material with paraffin, the range of optimal moisture contents was greatly narrowed. Applying this information to commercial conditions it might be expected that in comparatively thin stock, such as lumber, the moisture content could vary considerably and still permit a maximum or near maximum of stain development, whereas with large stock, such as heavy timbers, poles, and logs, in which access of oxygen to the interior parts would be more difficult, stain penetration in the early stages of drying would be retarded.

A point in seasoning is reached eventually where the water itself, rather than oxygen, becomes the limiting factor in stain development. From the information available it seems probable that sap-staining fungi require free water in the wood cells in order to cause important staining. In other words, more water must be present than is simply sufficient to saturate the cell walls. For normal wood of most commercial species in this country the fiber-saturation point lies at a moisture content ranging from about 24 to 30 percent of the dry weight of the wood.

European investigators report the minimum moisture contents for growth of a number of stain fungi to be in the region of 27 and 28 percent (*40*, *54*). In the United States, Colley and Rumbold (*15*) found the lower limit for staining by *Ceratostomella pilifera* in loblolly pine to be about 24 percent. They set a figure of 20 percent as allowing a satisfactory margin of safety. Experiments by one of the authors indicated that there may be some penetration by staining fungi at moisture content slightly below the fiber-saturation point, but no important staining was observed in such cases.

To summarize, unless stored in water, wood seldom has a moisture content high enough to prevent stain development. In some species of trees the moisture content of the fresh sapwood is no doubt close to or at the inhibiting point for growth of stain fungi, but, shortly after sawing, it decreases to a favorable amount. Important stain development apparently does not occur with moisture contents below about 24 percent, but for a safe and practicable working basis 20 percent is suggested as the moisture content to be reached in the sapwood for control purposes. It may be concluded that fully seasoned wood that is stored or placed in service under conditions that do not permit water to come in contact with it will not stain.

## TYPE OF WOOD

### HEARTWOOD AND SAPWOOD

Ordinary blue stain occurs almost exclusively in the sapwood.[12] This no doubt is due mainly to the greater supply in the sapwood of nutrient materials upon which the stain organisms subsist. With some wood species, such as southern cypress, redwood (*Sequoia* spp.), and western red cedar, toxic materials, which occur naturally in the heartwood, might be expected to exclude many stain fungi from this portion of the wood, but these may be regarded as special cases. Occasionally a small amount of ordinary blue stain is observed in the heartwood of southern pine species where the heartwood has been in close contact with green sapwood, as is regularly the case where stock stickers are used in the seasoning pile. However, such stain is usually shallow and occurs only where soluble nutrient materials may have leached from the sapwood into the heartwood. Insufficient moisture in the heartwood is not considered an important limiting factor.

### SPECIES OF WOOD

Wood species may differ considerably in their susceptibility to sap stain, although it is not easy to ascertain whether the variability in this respect is due to the wood itself or is abetted by other factors, such as climatic conditions, relative amounts of sapwood, and possible specific causal relationships between the wood and fungus species. To answer properly the question of inherent susceptibility would entail systematic comparisons of different wood species placed under uniform conditions with respect to stain hazard and kind of infection. Most of the important species differences insofar as sap stain is concerned are known only from general observation, and then only within a particular forest region. In general, those woods with the greatest amount of sapwood are most susceptible to serious damage.

[12] The comparatively unimportant blue stain caused by *Torula ligniperda* occurs in the heartwood as well as sapwood; also certain uncommon blue stains have been encountered developing only in the heartwood of living trees.

### DENSITY OF WOOD

It is a common belief that wood of low density is more subject to staining than dense wood of the same species and, what often amounts to the same thing but not necessarily so, that wood with wide rings stains more readily than that with narrow rings. Although such relations may often be in evidence they can be by no means regarded as constant. Differences in relative amounts of sapwood rather than in specific gravity may be the differentiating factor. European investigators have concluded (*40*) that density has no great influence on the rate of penetration of blue stain fungi, at least for the species studied. It is their opinion that this might be expected since the hyphae grow chiefly in the wood rays, which do not vary significantly with density.

### FLAT-GRAINED AND EDGE-GRAINED LUMBER

Flat-grained lumber appears to be slightly more subject to staining than does edge-grained, but quantitative data are not available. What difference there may be could, no doubt, be accounted for by the greater number of exposed wood rays, serving as foci of infection, on the tangential surfaces than on the radial surfaces and the fact that flat-grained boards usually contain a greater proportion of sapwood than edge-grained boards.

In early stages of staining the discoloration on flat-grained surfaces is often in the form of numerous small spots, centering around the exposed ends of the wood rays, whereas on the edge-grained surfaces the initial discolorations are more apt to appear as scattered medium-sized blotches because of the greater individual but less frequent exposure of ray parenchyma. The first-formed areas of discoloration may ultimately coalesce so that the appearance of moderate to heavy stain is about the same on the tangential and radial faces.

### GREEN AND SEASONED WOOD

Wood that has been seasoned, either in the dry kiln or in the seasoning yard will, upon wetting, again be subject to infection by stain-producing fungi and therefore must be maintained in a reasonably dry condition (20-percent moisture content or less) if discoloration by sap-stain fungi is to be avoided. However, there is some indication in general observations, and experimental results (*40*), that previously seasoned wood does not stain so readily as green wood. Just what changes take place in wood upon seasoning that render it somewhat more resistant to staining are not perfectly understood. It is likely that they are both physical and chemical. However, any such protection afforded by drying can easily be reduced considerably by weather conditions and should in no wise be relied upon.

### WINTER-CUT AND SUMMER-CUT WOOD

Contrary to a common belief, spring- and summer-cut wood is probably not inherently more subject to sap stain than is wood cut in the colder months. In the Gulf States, where conditions frequently permit staining even during the winter, the impression that winter-cut wood stains less readily is probably created by the somewhat greater prevalence of stain in the spring and summer than in the winter. In reality, the difference is more logically attributable to the more favorable temperatures for sap-stain occurrence in the former seasons. In colder regions the same belief is prevalent, but a somewhat different explanation is required. No doubt differences can be accounted for largely by the fact that stain fungi do not attack wood out of doors in the cold weather of northerly climates, and by the time warm weather arrives winter-felled wood has partly seasoned and therefore is not so subject to attack as wood cut at that time.

Seasonal variation in the chemical composition of green sapwood does not appear to be a factor. It is known that in the winter months the starch and fat content of the sapwood is comparatively high, these materials serving as food reserves to be rapidly used when the tree becomes active in the spring. But, according to researches in Sweden (*40*), starches and fats are not particularly favored by sap-stain fungi, as might be supposed, but rather the protoplasm and soluble materials of the parenchyma cells serve as the main source of food for such organisms.

## MANNER OF SPREAD OF SAP-STAIN FUNGI

### DISSEMINATION OF STAIN FUNGI

#### MODES OF DISSEMINATION

Widespread and abundant occurrence of sap stain depends upon an extensive and plentiful distribution of the causal fungi. Such distribution apparently may take place in a number of ways. Bits of the fungi or their spores (fig. 1) may be blown from surface growths already established on stained wood in or outside the lumberyard and carried about by air currents to new wood, or they may be inadvertently picked up and distributed by such insects as wood-attacking beetles, and also by their near relatives, the mites, which frequent lumberyards and surrounding woods. There is some indication that stain infection also may be transmitted by the head saw when stained logs are being cut. Local spread of stain from board to board, of course, can take place by direct growth of the fungi, without the intervention of disseminating agencies. New infections, originating in any of these ways, are potential sources of zones of stain, their subsequent development depending upon moisture conditions on the surface of and within the wood, temperature conditions, and other factors governing growth of the fungi.

The relative importance of air and insects as agencies of sap-stain dissemination has not been established definitely. It is known that with propitious conditions lumber in any portion of the yard may bear considerable amounts of stain within a comparatively few days after sawing, indicating that, whatever the predominating mode of dissemination, primary infections of one sort or another generally are plentiful and occur with little delay.

As direct evidence of air-borne infection, short exposures of Petri-dish plates and green sterilized sapwood blocks gave cultures of a number of important blue stain fungi. Among these were species of *Ceratostomella* but, since the ascospores of this genus are extruded in sticky, water-resistant masses, it is believed that only the secondary spores are carried to any extent in the air. A further suggestion of consequential air-borne infection lies in the fact that important sap-staining is encountered during colder months in some portions of the South, when insects are not plentiful.

Evidence of insect dissemination also is good. In southern lumberyards the incidence of stain caused by *Ceratostomella ips* has been

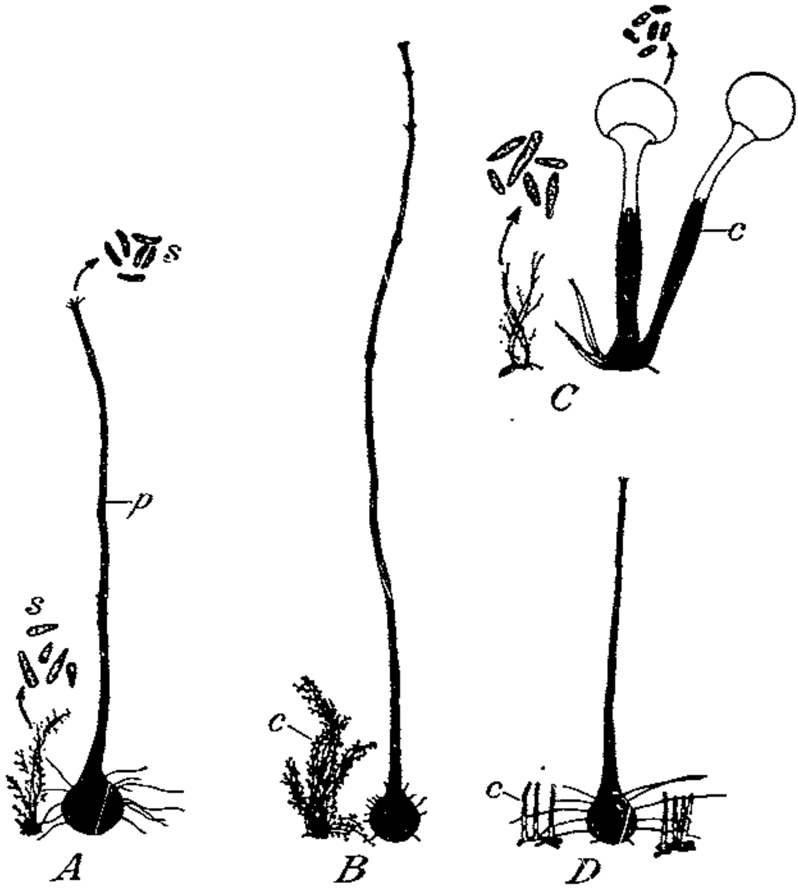



FIGURE 1.—Drawings of spores, *s* (× 556), spore-producing structures, conidiophores, *c*, and perithecia, *p* (× 105), of some common blue-stain fungi: *A*, *Ceratostomella pilifera*; *B*, *C. pluriannulata*; *C*, *Graphium rigidum*; *D*, *Endoconidiophora coerulescens*. (Adapted from drawings by C. T. Rumbold.)

found to parallel rather closely flights of *Ips* beetles, these beetles having long been known to be important carriers of the aforementioned fungus. It is therefore suggested that seasoning yard stain caused by *C. ips* is due almost entirely to visitations of *Ips* beetles to freshly sawn lumber and not indirectly to *C. ips* infections in the log, as formerly supposed. An even more important phase of animal dispersal is suggested by the frequently large populations of mites and small beetles on seasoning lumber. These, coming in contact with surface growths of the stain fungi, undoubtedly could be responsible for distributing substantial quantities of spores or other infectious material. Mites, because of their comparatively restricted wanderings, would presumably be a factor in spreading infection mainly within individual or adjacent piles; this presupposes, of course, a certain amount of primary infection to begin with. Beetles and certain other insects no doubt may distribute spores between widely separated piles and also bring about primary infections by transporting inoculum from stained debris and logs at substantial distances from the seasoning yard.

That important lumber infection may sometimes be caused by sawing stained logs is indicated by preliminary experimental observations. Stain fungi were cultured from dust collected on rollers in hardwood mills. Similar evidence of stain fungi was not found in brushings obtained at pine mills. A connection might reasonably be suspected between these results and the common abundance of sporulating fungi at the ends of stained hardwood logs and the much less frequent occurrence of external fungus development on exposed surfaces of pine logs. However, that there is also a possibility of immediate infection from stained pine logs is evident from experiments in which portions of bright sap pine boards taken from the trimmer and immediately sealed in a spore- and insect-proof box developed consequential stain only when taken at a time when numerous stained logs were being sawed. Further data along similar lines are needed for a better understanding of the dissemination of the important staining fungi.

### SPREAD OF LOG-STAINING FUNGI IN THE SEASONING YARD

Important questions from a control standpoint are whether log stain may continue to spread after the wood has been sawed into lumber and placed to season and whether the causal fungi may develop sufficiently on the surface of boards to serve as important secondary sources of yard infection. Numerous cultures from stains of southern pine and red gum reveal that the same fungi that are predominant in causing yard stains are also predominant in causing log stains.

Measurements of log-stained areas in lumber at the beginning and termination of seasoning have shown very little surface spreading particularly in the case of pine lumber. However, there was ample evidence of considerable interior spread. In boards of red gum sapwood, interior spread with the grain amounting to from 6 to 10 inches in 90 days was observed. Interior spread of *Ceratostomella ips* stain in pine lumber appeared to be of similar magnitudes. In one set of observations on pine about 1 to 6 inches of cross-grain spread from insect-initiated edge stains was noted. This information leaves little doubt but that interior spread of log stain in both pine and hardwood stock may be important, depending on the initial amount and position of the stain in the piece and the rate of seasoning. Surface spread of log stain on untreated lumber is presumably retarded by the more rapid exterior seasoning.

Unseasoned, bright boards of both pine and sap red gum placed in contact with fresh log-stained material of the same species and sealed against outside infection became stained by the fungi causing the log stain. Direct growth from one board to another was obvious, a result that would be expected from the observed ability of log-stain fungi to continue their development in lumber. From a practical standpoint, direct progress of infection from one board to another would probably be of particular importance only in connection with the drying of pine, where stock stickers are used commonly in the seasoning pile. Little opportunity for similar infection is provided in the case of hardwoods, since special dry seasoning sticks are ordinarily employed.

Surface development and fruiting of log-stain fungi on both pine and hardwood lumber apparently are common enough to contribute, at least slightly, to secondary yard infections. Much depends on the extent to which the surface of the lumber dries before a substantial amount of secondary inoculum develops. In any case, however, primary infections seem to be so plentiful that the amount of inoculum ordinarily arising from log stain undoubtedly adds but a small fraction to the total stain occurrence.

### PENETRATION OF STAIN FUNGI IN WOOD

The hyphae of sap stain fungi, arising from the germination of spores or from the growth of older hyphae, enter the wood largely by way of the exposed wood rays and other wood elements that are open to the exterior. Within the wood they occupy the fibers and tracheids to some extent and depend on these elements for their comparatively rapid progress in the direction of the grain, but they become most abundant and notably conspicuous in the ray cells (pl. 1, *A*), which presumably contain the nutritive substances best suited to their needs. The fungi apparently are able to destroy and pass through the rays rapidly, by dissolving and consuming the cross walls. Rays so affected commonly are reduced to large open channels with hardly more than a vestige of their former cellular structure (pl. 1, *B*). In the pines the parenchymatous tissues of the vertical resin ducts, being of similar composition, also are favored. Because of this uneven distribution of the stain fungi in the wood the stained areas actually may not be as uniformly discolored as they appear to be. Very often, if the wood is not too heavily stained, it is possible to detect an uneven distribution of color with the unaided eye. On freshly surfaced, edge-grain lumber the darkened wood rays may stand out as tiny blue-black ribbons of varying lengths, and the resin ducts as long, fine streaks of similar shade, paralleling the grain.

The strong tendency of sap stain fungi to follow the rays leads to a very characteristic distribution of stain in wood, which is particularly noticeable in materials of comparatively large size. If logs, poles, or large timbers that have undergone staining are cut across the grain, it will be observed that the discolored areas on the ends of the pieces are almost invariably wedge-shaped with the apex of the wedge pointing toward the pith (pl. 2, *A*).

Since the rays are not continuous, stain fungi complete their penetration by growing to some extent into and through the fibers or tracheids, as the case may be. This is accomplished by passage of the hyphae through the pits (pl. 1, *B*) in the cell walls or, less frequently, by direct penetration of the walls. Direct cell-wall penetration is apparently possible for all of the important stain fungi but does not seem to be so common with some fungi as with others (*11*). Just how such penetration is accomplished is disputed. In most cases the part of the hyphae that traverses the wall is considerably smaller than the remaining portion in the cell cavity. Hubert (*34*) has suggested that the undersized portion of the fungus within the wall represents the original diameter of very young hyphae, which are responsible for the penetration, enzymes at the hyphal tips dissolving the wall at the point of contact. Lagerberg, Lundberg, and Melin (*40*), however, feel that the evidence points toward direct penetration by mature hyphae, which are simply constricted in passing through the wall. Their discussion of this subject also suggests the possibility that penetration may be accomplished mechanically through the aid of appressoria. In any event, there is little evidence of extensive enzymatic action, such as is reflected in the large bore holes made by some of the wood-rotting fungi.

Measurements of rates of movement of *Ceratostomella pilifera* into green southern pine sapwood, held at temperatures between 77° and 82° F. (25° and 28° C.), disclosed approximate daily rates of penetration of 0.02, 0.04, and 0.2 inch (0.5, 1, and 5 mm.) in the tangential, radial, and longitudinal directions, respectively. These data, supplemented by a number of measurements of visible discoloration in pine wood, indicate that for *C. pilifera* the ratios 1:2:7 to 1:4:15 for tangential, radial, and longitudinal spread, respectively, might be expected to apply generally. There was no practical difference between the radial penetration from a summerwood face and that from a springwood face.

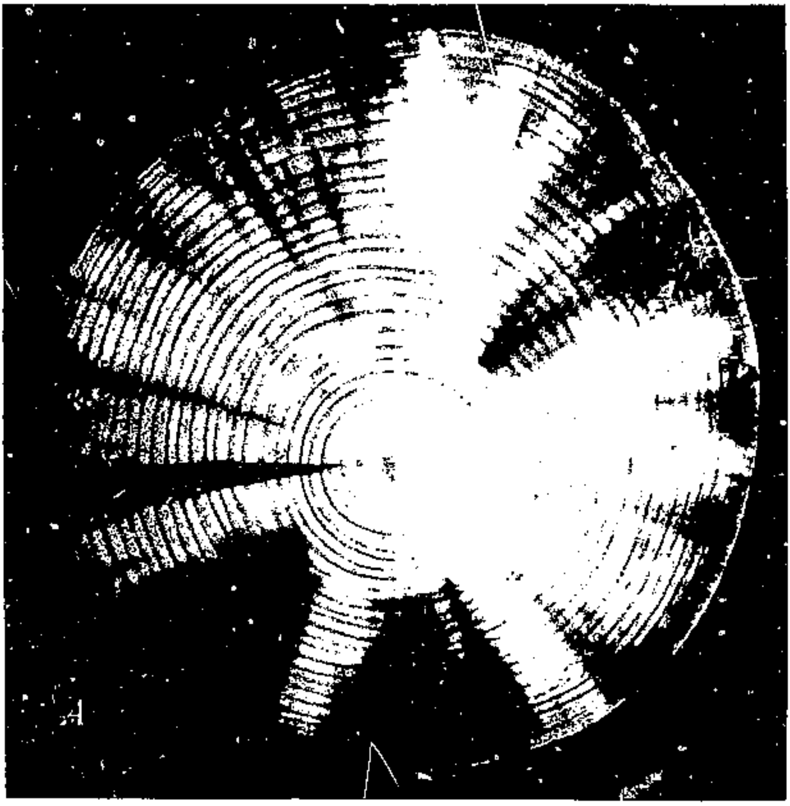
The rates of penetration observed for *Ceratostomella pilifera* are, of course, not to be regarded as representative of all the important blue stain fungi. Relative rates of growth on nutrient agar indicate that whereas some fungi may progress in the wood at about the same rate as or slower than *C. pilifera*, others may progress more rapidly. However, less variation among the fungi might be expected for the ratios of spread in the different structural directions, since the character of the wood rather than the respective rates of development would be the controlling factor.

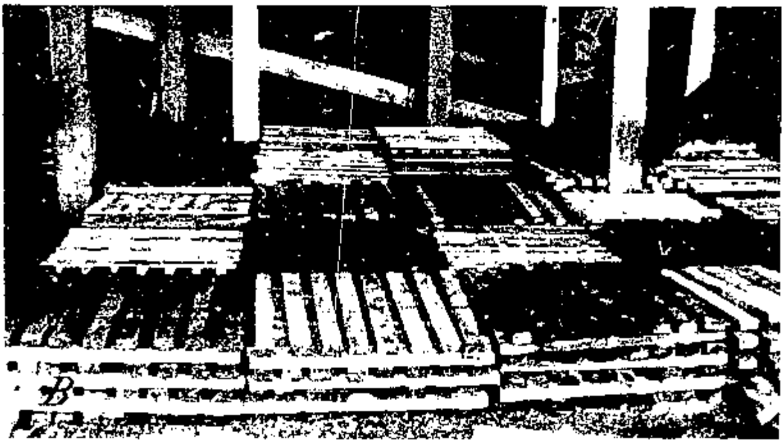
The prediction might be made that the greatest rate of spread is in the longitudinal direction from the fact that the length of wood tracheids and fibers commonly exceeds the diameter by 100 times or more. This means that far fewer obstructions in the form of cell walls would be encountered by a fungus growing longitudinally in the wood than when growing in other directions. Radial growth would, of course, be expected to surpass tangential growth because of the radial alignment of the rays which, as has been pointed out, offer comparatively little resistance to stain fungi and provide most of the food materials.

## INTERIOR SAP STAIN

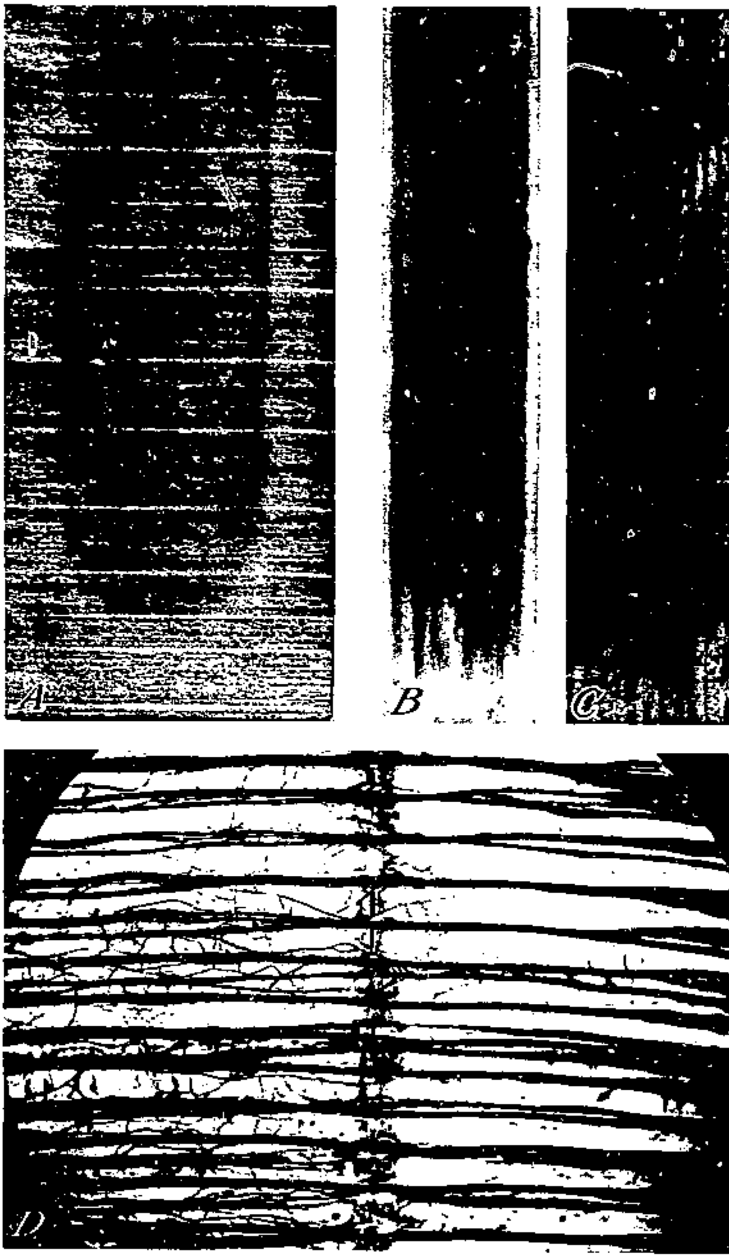
A condition is commonly encountered in lumber and dimension stock wherein the surface layers of the seasoned wood appear bright but the interior is badly stained. This type of discoloration is gen-

Sections of loblolly pine containing hyphae of *Ceratostomella pilifera:* *A*, Radial section showing typical concentration of the threadlike hyphae in one of the wood rays; *B*, tangential section showing decomposed condition of wood rays and penetration of hyphae through pits in the radial walls of the tracheids. × 370.




A, Cross section of pine post showing typical distribution of stain following surface infection; B, a small-scale test of chemicals for use on lumber. Side and cover boards have been removed. Note differences in stain occurrence.




Interior stain. *A*, Cross section of sap red gum board in which, following infection, drying had been rapid enough to prevent development of stain near the surface but not in the interior. *B*, Radial section of pine board which, 72 hours following infection, had been dipped. Stain developed in all parts except those near the surface where the chemical had penetrated. *C*, Companion board to *B*, which was not dipped. *D*, Radial section (× app. 110) taken near the end of a pine board, at the transition zone between bright and interior stained wood. Note fragmentary development of colorless hyphae of the stain fungus in bright zones in contrast to abundant development of mature brown hyphae in discolored zone.

erally known as interior stain. In a way it is more objectionable than ordinary sap stain, because it may not be discovered until the stock is surfaced or remanufactured, resulting in manufacturing or marketing costs that might have been avoided had this degrading factor been known earlier. Interior stain should not be confused with interior dote of hardwoods, which often occurs with it; dote is a stage of decay.

Interior stain differs from ordinary sap stain only in producing little or no discoloration of surface layers; the causal fungi are the same. It results largely because the fungi in the surface layers of the wood are prevented in some way from reaching the stage of maturity at which they change from a colorless condition to brown, while the fungi that have been able to penetrate deeper into the wood find conditions suitable for continued development. Practically all staining fungi are colorless at first and in this stage impart no color to the wood. Restriction of stain to the interior portions of the wood is in most cases due to unequal rates of seasoning on the inside and outside of the piece, so that the moisture content near the surface is from the first, or soon after the fungi have entered, too low for stain development, whereas the wood farther in remains moist for a period long enough to permit staining (pl. 3, *A*). Once the stain fungi get inside they are able to grow freely as long as there is an adequate supply of moisture, regardless of how dry the surface is.

Fungi responsible for interior sap stain may initially penetrate the wood in a number of ways. They may get in before rapid seasoning commences, while the moisture content of the surface layers is still high enough to support their growth. Commonly most of the surface may be critically dry very soon after the start of seasoning except for portions beneath the stickers, which may remain damp for a long enough time to serve as points of entrance for the fungi. In such cases stain will usually show on the surface where the stickers and stock boards lap. Still another point of entrance is through seasoning checks. Infection in this way is common in large round stock, such as poles, where the checks penetrate into moist wood. Log infection may also act as a starting point for interior stain.

Interior stain is sometimes associated with excessive delay in treating with antiseptic solutions for stain control. In this case it is the chemical on the surface rather than surface drying which is responsible for the absence of stain on the outside. If the stock is not treated promptly after it is sawed from the log, stain fungi may have time to establish themselves so deeply that the treating solution does not reach them. If at this time the surface infection is still colorless it is apt to remain so because the presence of the toxic chemical inhibits further development. But beneath the shell of wood occupied by the chemical the stain fungi may continue unrestricted and cause discoloration (pl. 3, *B* and *D*). Control of interior stain in lumber that is free from infection at the time of sawing lies either in more rapid drying during the seasoning period or in prompt surface application of a suitable chemical treatment. A detailed discussion of the control of interior stain by chemical treatment is given on pages 70 and 71.

## WOOD PROPERTIES AFFECTED BY SAP STAIN

The question commonly arises as to what properties of the wood other than color are affected by the presence of sap stain fungi. Strength, resistance to decay, resistance to impregnation with preservatives, and paper-making qualities seem to be of chief interest. Information along some of these lines is preliminary in nature and necessarily derived in large part from laboratory work.

### STRENGTH OF STAINED WOOD

Since blue stain fungi can attack wood fibers and tracheids to some extent it might be expected that various reductions in strength would result, depending upon the particular fungi concerned and the extent of their development in the wood. As has been pointed out, however, the major attack is on the parenchymatous elements, which are relatively of minor importance in contributing to strength. This would lead to the further expectation that any losses in strength would be considerably less than those occasioned by decay fungi. Studies of the strength of stained sapwood tend to confirm these predictions (table 2).

TABLE 2.—*Studies by various investigators relative to the effect of sap stain on strength of wood*

| Investigator and period | Test material | Results | Comments |
|---|---|---|---|
| Rudeloff (*58*), 1897 | Seasoned pine blocks from blued and bright portions of logs. | Stained wood slightly higher in endwise compression strength. | Variation in moisture content of test specimens not taken into account; hence results questionable. |
| Von Schrenk (*68*), 1903 | Blocks from blued and bright kiln-dried ponderosa pine lumber. | Stained wood slightly stronger in endwise compression and transverse bending. | Author concluded that the difference was probably due to fact that blued test blocks were somewhat drier than the controls. |
| Münch (*54*), 1907–1908 | Artificially inoculated (apparently unsterilized) pine sapwood cylinders, tested green and air dry. | Stained wood slightly weaker in endwise compression than corresponding wet and dry bright wood. Specific gravity of stained wood also slightly lower than that of bright wood. | Laboratory control of tests no doubt an aid to accuracy of results. Author concludes differences not significant. |
| Weiss and Barnum (*78*), 1911 | Roughly matched blued and bright blocks from shortleaf pine and longleaf pine lumber. | Stained shortleaf pine slightly softer and less tough than bright wood. No difference in longleaf pine. | Selection of matched test material and attention to moisture contents suggest greater significance of results. Authors conclude that stained wood, although it may be weaker, is not enough so to be of practical importance. |
| Vanin (*76*), 1932 | Partly matched, stained and bright wood from trees; also artificially inoculated (apparently unsterilized) material. Wood seasoned before testing. | Hardness and strength in endwise compression slightly less for stained than for bright wood. Static bending strength slightly increased. | Author's statistical analysis of results indicates differences not significant. |
| Chapman (*11*), 1933 | Carefully matched, green, stained and bright loblolly pine sticks. Stained material artificially inoculated. Both steamed and unsterilized specimens tested. | Toughness of green stained wood lowered substantially, particularly in steamed specimens. Specific gravity and strength in bending only slightly if at all affected. | Results significant for the conditions of the test. Toughness reduction of heavily stained wood of practical importance. |
| Findlay and Pettifor (*20*), 1937 | Carefully matched, green, stained, and bright Scotch pine sticks. Stained material artificially inoculated. Both steamed and unsterilized specimens tested. A second series of tests involved partly matched naturally infected samples. | Staining had but slight effect on strength in endwise compression and in bending. It caused various but significant reductions in toughness and slight reductions in hardness and specific gravity. Toughness was reduced more in steamed wood. | Most complete and exhaustive report of blue-stain effects on mechanical properties to date. Author concludes that only where exceptional toughness is required should blue-stained wood be regarded as deleterious. |

At first glance, the results summarized in table 2 appear to be somewhat conflicting. However, closer analysis shows that in all tests in which the experimental conditions were at least partly controlled the stained material was little, or not at all, weakened except in toughness. It seems reasonable to conclude that ordinarily only material that is badly stained is likely to be weakened significantly, and then, if no decay is present, mainly with respect to toughness.[13]

Since the conditions that favor the development of sap stain also favor decay, it is wise to examine heavily stained material for the presence of decay. Decay, even in its incipient stages, may greatly reduce some strength properties, and when strength is an important consideration the safe procedure is to discard material in which there is a suspicion of its presence.

Because molding commonly occurs with heavy staining its effect on strength is of some interest. Although most wood-inhabiting molds cause little or no interior discoloration, *Trichoderma lignorum* (Tode) Harz (*71*) and certain other species (*25*) appear to be capable of penetrating wood rather extensively. Tests of the strength of pine sapwood infected with *T. lignorum*[14] and of white oak infected with *Penicillium divaricatum*[15] indicate that these fungi affect the various strength properties similarly to blue stain fungi, but that the reduction in toughness may not be relatively so great. As with blue-stained material, heavily molded wood is objectionable because of the possible additional presence of decay rather than because of an effect of the mold fungi themselves.

### DECAY RESISTANCE OF STAINED WOOD

Whether stained wood inherently has greater or lesser resistance to decay than similar bright wood has been disputed. Von Schrenk (*68*) suggested that the resistance would be lowered because the stain fungi increased somewhat the number of openings in the wood through which air and water may pass. However, according to Münch (*54*), the decay resistance of stained wood is likely to be increased, because the stain organisms remove much of the food material in the parenchyma cells that logically might be expected to aid initially in the establishment of the decay fungi.

Chapman (*11*) subjected matched stained and bright loblolly pine blocks to decay by *Poria incrassata* Burt. and *Lentinus lepideus* Fries under controlled laboratory conditions. In general, the stained material decayed somewhat more rapidly (as denoted by loss in weight) than the unstained, although the results were not altogether consistent and varied considerably for the different stain fungi involved. Similar results were obtained in laboratory tests by one of the authors. Vanin (*76*), from a similar study but using *Coniophora cerebella* (Pers.) Schroet. (common cause of decay in buildings in Europe) as his decay organism, concluded that there is probably no difference in durability between stained and bright wood. The evidence indicates that whatever differences there may

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[13] Toughness is reflected in the ability of the wood to withstand quickly applied loads (shock).

[14] CHIDESTER, M. S. THE EFFECT OF A MOLD, TRICHODERMA LIGNORUM, ON LOBLOLLY PINE SAPWOOD. 1938. [Unpublished manuscript.]

[15] See footnote 6, p. 9.

be are not of practical importance. This might be expected since no sapwood is very resistant to fungus attack and would in any circumstance fail if placed under conditions suitable for decay.

## IMPREGNATION OF STAINED WOOD WITH PRESERVATIVES

There is some suspicion among many producers and users of pressure-treated wood that stained material does not take up the preservative so well as bright wood, and therefore is in comparatively more danger of being inadequately protected. Although this possibility has not been a source of much concern in the United States, it apparently has led to some discrimination against treated stained wood in Germany, and has even received attention in certain wood-preservation handbooks of that country. Vanin (*76*) stated that this unfavorable opinion of stained timber is to a considerable extent based on early water-absorption experiments by Rudeloff (*58*), which indicated that bright wood offers less impediment to entrance of liquids. Vanin concluded that a prejudicial attitude on this basis alone is not warranted because Rudeloff's experimental material was taken from different trees, and therefore was not suitable for comparisons of this sort.

Vanin (*76*) could find no significant difference between bright and stained wood, either in respect to rate of water absorption or penetration of either zinc chloride or creosote applied according to usual methods of pressure treatment. In the United States, Daniels (*17*) ascertained the amounts of creosote taken up by stained and unstained portions of a few selected ties and found no indication that the stained zones had received less treatment than the adjacent bright-wood zones. Şaling (*61*), using the hot-and-cold-bath treatment and small blocks selected from identical boards of ponderosa pine and southern pine, found both absorption and penetration of zinc chloride and creosote to be substantially greater in the stained material.

In view of the great variation in the evidence at hand the authors initiated similar absorption tests, using bright and stained sapwood blocks cut from the same boards of southern pine. The test specimens were steam sterilized, inoculated, and incubated in the laboratory. Starting from an air-dry condition, blocks stained by *Endoconidiophora moniliformis* (Hedgc.) Davidson, *Graphium rigidum* (Pers.) Sacc., and *Hormonema* sp. all absorbed substantially more water in a given time than did the corresponding bright blocks. The difference in absorption by stained and unstained material was most pronounced in the first one-half hour of soaking; thereafter, for 55 hours, the rates of absorption were roughly the same. Both stained and bright blocks presumably would have nearly the same saturation moisture content.

Additional tests were conducted on bright and stained, longitudinally matched, round pine bolts 6 to 10 inches in diameter and 3 feet long, using in one case a hot-and-cold-bath creosote treatment and in another case pressure treatment with creosote. In the pressure test end penetration was prevented by capping the ends with graphite and rubber gaskets. All bolts were fully air-dried before commencing the tests. With the hot-and-cold-bath treatment, the stained specimens absorbed from 100 to 150 percent more creosote than the matched unstained ones. Penetration of the sapwood was complete in all stained pieces but only slightly more than 50 percent in the unstained. Similar results were obtained when the creosote was applied with pressure.

From the general results obtained by several investigators there seems little reason to discriminate against seasoned sap-stained material from the standpoint of its penetrability by liquid preservatives. In fact there appears to be a greater possibility that staining actually may, in various degrees, facilitate penetration. Cases of poor penetration in stained material are more probably not due directly to the presence of stain but rather to an impeditive moisture content in the wood. The presence of the stain may be a consequence of comparatively high moisture contents. There is also the possibility, as some of the absorption experiments indicated, that a higher moisture content may be under certain conditions an indirect result of staining. The moisture factor can, of course, usually be taken care of by proper attention to the seasoning.

It should be pointed out that since these studies, and most of the previous ones, have employed dry wood infected with only a few fungi, the conclusions cannot be unreservedly applied to all cases of preservative treatment. It has been found that in the case of living pine trees zones of blue-stained wood associated with beetle attack tend to have a lower moisture content than corresponding zones of bright wood; furthermore, it was found that dyes would not pass through stained zones in pine saplings (*55*). It was suggested by way of explanation that the action of the fungus causes a permanent aspiration of the tracheid tori and thus interferes with the conduction of water. Conceivably with green or comparatively wet wood the effect of aspirated tori may outweigh an opposing effect of blue stain in determining water-absorption tendencies. With adequately seasoned wood, however, the situation is probably different; drying alone is generally believed to cause aspiration of the tori, hence would leave only blue stain as the important differentiating factor.

### DRYING CHARACTERISTICS OF STAINED WOOD

It is important to know whether the capacity of stained wood to take up and hold moisture from the air differs from that of bright wood, since this factor relates directly to seasoning characteristics of wood in the final stages of drying. In controlled laboratory experiments the writers could detect no significant difference between equilibrium moisture contents of stained and matched bright blocks. Similar results were reported by Vanin (*76*). As a check on the laboratory results, a number of moisture determinations were made on fully seasoned, stained and bright southern pine, red gum, and oak lumber. The moisture samples were taken from the lumber at comparable positions in the seasoning pile, and the initial weighings were made immediately. Only slight differences in moisture content were found, and these could not be correlated with the presence of stain.

A further laboratory study was conducted on matched sections of green boards, half of them blue stained and half of them maintained bright by chemical treatment, to determine whether staining may influence the rate of drying. The stained wood was found to lose moisture somewhat more rapidly than the bright. It is apparent that stained wood tends to season fully as rapidly as bright wood under the same conditions, and if there are any differences in the equilibrium moisture contents they are so small as to be of no practical importance.

### QUALITY OF PAPER PRODUCED FROM STAINED WOOD

Because of the discoloration, which characterizes sap-stained material, it might be expected that paper made from stained pulpwood would be somewhat off-color, or at least would require more drastic bleaching treatment. This would depend, of course, on the intensity and amount of stain entering into the pulp. Sap stain as a paper-degrading factor has received some attention in the Southern States, where large amounts of southern pine pulpwood are produced, and where climatic conditions are favorable to comparatively rapid development of blue stain in such material (*30*).

In experiments conducted at the Forest Products Laboratory (*14*) unbleached sulfite pulps made from blue-stained southern pine chips were substantially darker and had a higher dirt content than pulps from corresponding bright-wood chips. To attain the same degree of whiteness in bleached pulps, as much as 9 percent more bleaching powder was required by pulps from the stained wood. A similar but less pronounced effect of blue stain was found in connection with sulfate pulps. In neither case were there significant differences in yield or strength.

Other experiments at the same laboratory (*16*) showed that a moderate amount of stained wood does not necessarily harm southern pine ground-wood pulp, but may actually improve the color by masking the characteristic yellow tint. Further work (unpublished) indicated that about 10 percent of stain is needed to effect noticeable discoloration. Herty (*31*) reported producing comparatively light colored southern pine ground-wood pulp from wood estimated to be 25 percent blue stained.

### GLUING PROPERTIES AND PAINTABILITY OF STAINED WOOD

Although no specific tests have been made to ascertain the effect of sap stain on the gluing and painting properties of wood, general observations have shown stained material to be essentially comparable to bright wood in these respects. Sap stain offers no obstacle to a pleasing and durable paint finish if the wood is kept dry. If, however, painted wood becomes wet for any reason and stain fungi gain entrance or those already present resume growth, the fungi often develop sufficiently to show up as dark discolorations beneath the paint. This type of stain is frequently encountered in painted window sash and framing on which there has been considerable condensation of moisture. Occasionally stain organisms exert enough pressure from beneath to cause the paint film to blister, but since this is commonly the ultimate result of excessive moisture alone, the fungi can properly be regarded only as factors aggravating the condition.

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## COMMERCIAL ASPECTS OF STAIN CONTROL IN THE SOUTH

The various problems of sap-stain control, although much alike basically, require no small amount of individual attention. The species of wood being cut, location of the mill, character of the seasoning yard, logging and manufacturing facilities, and manner of handling the wood from the log to the fully seasoned product differ a great deal and hence preclude complete standardization of methods. Sap stain and mold may develop during any of the various stages of handling providing moisture and temperature conditions are favorable. They may occur in the log, in lumber seasoning on the yard, and occasionally in sawed products subsequently shipped from the mill. It is therefore necessary to know the critical points for stain occurrence for each mill operation in order to adopt the most efficient control measures.

### STAIN IN THE SEASONING YARD

Unquestionably the major losses from sap stain and molding occur in the seasoning yard. The amount of stain with which a particular mill will have to contend is dependent on several factors. The location of the mill and topographic variations may appreciably influence stain development. Mills located close to the Gulf of Mexico, along rivers and bayous, or those having creeks running through their seasoning yard, may have abnormally severe stain problems. Consequently, local conditions may produce pronounced differences within small geographic areas. The susceptibility of the timber being cut and the extent to which seasonal variations express themselves must also be considered.

Wet, warm periods are conducive to rapid stain development, and, if the lumber is not promptly moved from the saw to seasoning pile, severe sapwood discolorations may result. The rapidity with which stain may occur when conditions are favorable is impressive. Visible discoloration has been observed on freshly cut stock bulk piled for periods as short as 65 hours. After 5 days staining may be quite general although not usually intense. A second critical period is the first few weeks after the lumber is stacked on the yard. If conditions are such that drying progresses fairly rapidly during this time the stock will probably season bright; on the other hand, if the drying rate is slow the lumber may be seriously discolored.

In air seasoning a good seasoning yard site, alinement and spacing of piles on the yard, adequate roofs, foundations, and the like normally are of great importance in determining stain occurrence. These will be briefly considered later (pp. 76–81) in their relation to chemical control of sap stain. In general, good air-seasoning practices are substantial aids to stain control. Air-seasoning methods and problems in general and for various regions are treated in a number of readily available publications[16] (*24*, *52*). In certain cases

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[16] DEFLON, L. L. SURVEY OF AIR SEASONING PRACTICES IN THE NORTHERN HEMLOCK AND HARDWOOD REGION. U. S. Forest Serv., Forest Prod. Lab. Rpt. 21. 16 pp., illus. 1926. [Mimeographed.]

——— AIR SEASONING OF OAK AND SAP GUM IN THE SOUTHERN HARDWOOD REGION. U. S. Forest Serv. Forest Prod. Lab. Rpt. 26. 47 pp., illus. 1926. [Mimeographed.]

MATHEWSON, J. S. SMALL SAWMILL IMPROVEMENT, PRACTICAL POINTERS TO FIELD AGENCIES; AIR SEASONING AT SMALL MILLS. U. S. Forest Serv., Forest Prod. Lab. Rpt. 899–S. 5 pp., illus. 1932. [Mimeographed.]

considerable attention is also given to problems of stain and decay (*23*, *36*, *73*).

A large number of mills, by means of special air-seasoning methods, attempt to bring the wood to a dry condition more rapidly than can be accomplished by ordinary seasoning in flat piles. The primary object of these special methods is to dry lumber quickly without any resulting injury to the stock.

### END RACKING

End racking consists in standing the green lumber on end on both sides of a rack with the boards crossing above the center or near the top (pl. 4, *A*). After the surface is fairly dry the material, except pine, usually is flat piled for the remainder of the seasoning. This method is most extensively used in the handling of No. 1 Common and better grades of red gum sapwood, although yellow poplar, tupelo, magnolia, and occasionally pine are sometimes treated in this way, the last species at small mills largely. The time lumber remains end-racked is usually between 3 to 8 days, but in periods of wet weather it may be considerably longer.

End racking materially reduces the stain hazard if properly done and hastens the drying of the stock to the extent that the shipping weight is reached 10 to 30 days earlier than by flat piling alone. Operators of small pine mills where local trade is important sometimes find the method convenient because buyers can select boards without the necessity of the lumber being segregated into grades. A further advantage of end-racking, particularly in summer months, is that the accelerated drying also tends to discourage ambrosia beetle attacks on hardwoods.

The major disadvantages of end racking are that it requires a large amount of yard space, greatly increases the cost of handling (estimated cost ranges from $0.60 to $1.25 per thousand feet), necessitates careful supervision of the stock in the rack in order to avoid excessive drying and resultant seasoning defects, and subjects the stock to blow down in high winds. Furthermore it does not preclude the occurrence of serious amounts of sap stain in periods of adverse weather conditions. End racking of hardwoods has been discontinued at many mills in favor of chemical treatment.

### END PILING

End piling is occasionally observed at both pine and hardwood mills. The stacks resemble regular flat piles turned on end (pl. 4, *B*). A rack holds the stock in place. The lumber is left standing on end either until dry enough for shipping or for shorter periods of 10 to 30 days after which it is flat piled. End-piled stock does not dry so rapidly as end-racked lumber and for this reason does not require the careful supervision that the latter does, nor is it likely to be as severely degraded as a result of seasoning defects. Nevertheless, some warping and twisting may occur if the lumber is left on the racks until air-dry.

The method is not so effective as end racking against staining organisms although it is generally believed to have some advantage over flat piling in this respect. Whether the latter is always true is questionable, however, since it is customary to place no roofs over end piles and the stock consequently is not so well protected from the weather as in flat piles.

### CRIB PILING

Many small pine mills, particularly in Georgia, pile green stock in the form of hollow triangular, square, or hexagonal cribs (pl. 4, *C*). This method retains most of the advantages of end racking, hence greatly retards the development of sap stain. It has the further advantages of requiring no special rack to hold the lumber in place and does not occupy as much yard space. The stock is not adequately supported, however, and may cup and warp considerably before it is dry.

### STEAMING

As an alternative to end racking, some southern hardwood operators have in the past employed a steam treatment as a preliminary procedure to the air seasoning of sap red gum. Following steaming, the lumber is cooled in the open and then flat-piled on the yard. This treatment, when properly executed throughout, hastens surface drying of the lumber and thereby reduces development of stain and mold (*73*). Additional advantages are that it imparts a desired reddish color to the stock, and avoids largely such distortions as often result from the end-racking method of seasoning. The cost of steaming may be a little higher than that of end-racking.

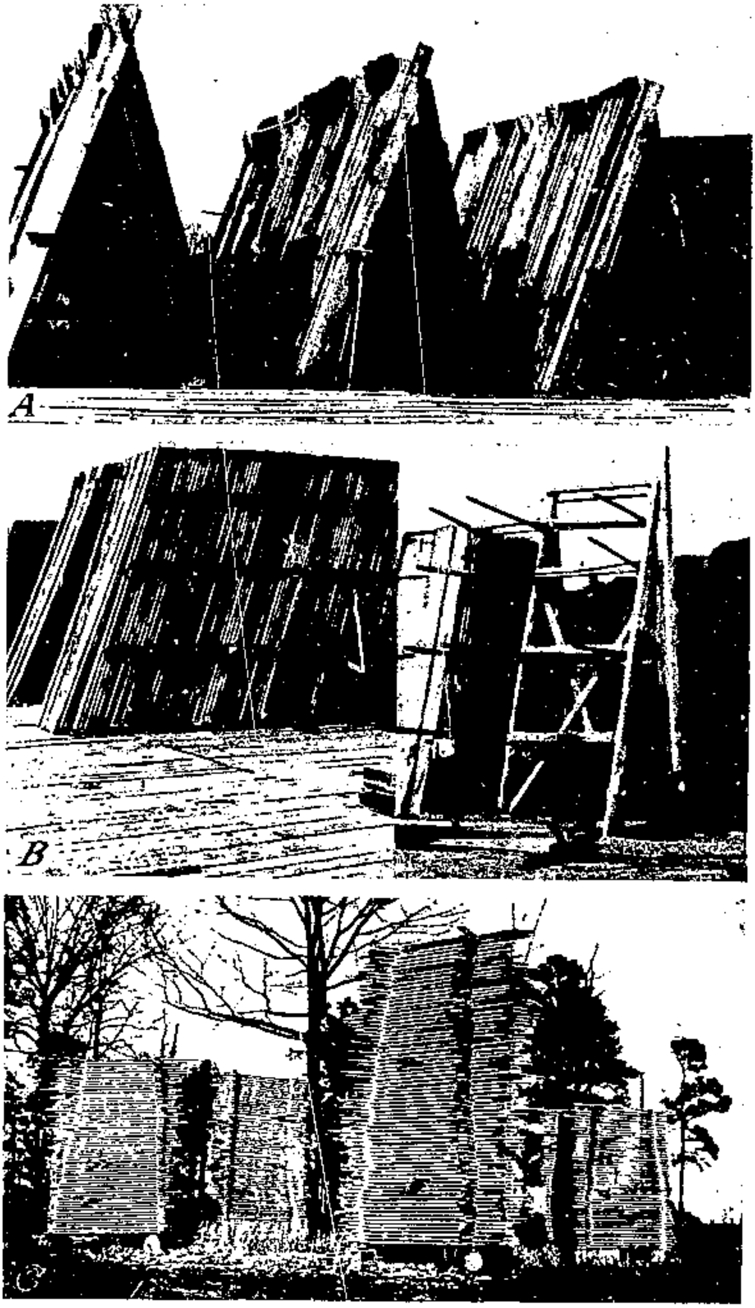
Unless strict attention is paid to handling the stock following steaming, heavier stain may result than if the material had been flat piled from the start. The steaming process removes very little water but depends on an accelerated surface drying of the heated (150° to 190° F.) wood after it is removed from the steam box. Improper handling or damp weather may defeat this purpose. One advantage of end-racking over steaming is that the influence of adverse climatic conditions is not so great. During periods of wet weather lumber can be left in the racks until the surface has had a chance to redry, while steamed stock may have to be piled in the rain even though it has had little chance of surface drying.

There is some indication that steaming may reduce somewhat the decay resistance of green stock (*66*). When properly conducted and followed by good drying practices, however, the difference is inconsequential. The practice has now given way at most mills to chemical treatment.

### KILN DRYING

Kiln drying of the better grades of lumber is the favored practice with pine operators who can afford the necessary equipment. Boilerless kilns or so-called smoke kilns are sometimes used by portable or semiportable pine mills for treating special orders and better grades.

Pine operators are practically unanimous in their choice of kiln drying as the most effective method of preventing subsequent staining and molding. Its advantages are many in addition to stain prevention. It kills all fungi that may be already present in the stock (*22*, *33*), makes the stock immediately available for shipment at the proper moisture content, thereby reducing the carrying charges



Special air-seasoning methods commonly used to reduce blue-stain occurrence: *A*, End racking; *B*, end piling; *C*, triangular crib piling.

at the mill, and eliminates the necessity of a large seasoning yard. Principal disadvantages of steam kilns apply particularly to small mills, where the high initial cost, requirement of large boiler capacity, and lack of portability may be prohibitive.

It is practicable to kiln-dry hardwoods green from the saw if suitable equipment and correct schedules are employed, and this procedure is gaining favor. When this is not done it is usual to kiln-dry stock that has been partially air seasoned.

Stain in kiln-dried stock can usually be traced to discolorations that were present in the log, to faulty methods of handling at the time of treatment or subsequent to it, or to leaky dry-shed roofs.

### STAIN IN THE LOG

Benefits received from efforts to control sap stain subsequent to sawing may be greatly reduced if stain is already present in the log. Not only does the existing stain remain as a permanent discoloration in the lumber but the infection may continue to spread to an important extent during seasoning of the stock. Log infection is a more important factor in stain occurrence than is commonly understood by most millmen. In 1928, a survey of 57 representative pine and hardwood mills in the Gulf States region revealed (*42*) that commonly as many as 10 percent of the logs were infected by the time they were sawed. Steady progress in reducing log-stain damage has been evident in recent years.

Log infection seems to occur more frequently in red gum than in other hardwood or southern pine species. Differences in the frequency of occurrence of stain in gum and pine are largely attributable to differences in the methods of logging. In the case of pine, logging operations generally continue throughout the year, whereas with hardwoods they are of necessity rather seasonal. The latter situation prevails because many hardwood stands, due to their bottom-land location, are in various degrees flooded in the late winter and early spring. It is necessary, therefore, to accumulate gum logs on higher ground to insure a continuous supply for the mill's use.

The current trend toward sustained-yield management of timber holdings may introduce a more widespread need for storage of both pine and hardwood logs at certain times of year in the Southern States. Under sustained-yield management trees in the larger diameter classes commonly are removed from each block of timber several times in the course of a single rotation. In spite of the increased demand for log-hauling facilities thereby necessitated, economic considerations preclude the maintenance of more than a skeleton system of improved roadways or permanent track. A large part of the initial hauling has to be done with trucks over temporary roadways, many of which become impassable during rainy weather of the late fall and winter months. Consequently, as in the case of bottom-land logging, it may at times be necessary to bank logs in regularly accessible locations, if a continuous supply is to be maintained at the mill without disrupting projected cutting plans.

Logs stored in the woods, along railroad rights-of-way, or at the mill are susceptible to infection for long periods because of their sustained high moisture content. Under favorable conditions of temperature and moisture, stain fungi become established in the log shortly after it is cut and develop rapidly. The infections usually occur at the ends or through barked areas and insect borings along the side of the log. Visible discoloration may be present on the ends within a week or 10 days, and stain may penetrate to a depth of 12 inches within 3 weeks after cutting, and as far as 3 feet within 3 months. Keeping in mind that the discoloration progresses inward from both ends of the log, it is apparent why end infection may damage a high percentage of the available lumber material. If, in addition, side infection resulting from insect attack is substantial, virtually the entire sapwood may be seriously stained after a storage period of 3 months.

Although logs in the Gulf region may be damaged during the winter, the greatest injury occurs throughout the remainder of the year when temperatures are high and insect attacks are prevalent. Insect borings besides being among the most important points of entrance for wood-attacking fungi are in themselves serious degrading factors. Principal insects attacking stored logs in the Southern States are known as pinhole borers or ambrosia beetles. Their prevalence in the logs varies greatly, depending on the time and conditions under which the logs are stored. They are most common during warm, wet periods in the spring and summer, less numerous during October, and of little consequence usually from November through February except in the immediate vicinity of the Gulf, where mild days permit them to resume activity. Logs left in contact with the ground and exposed to humid conditions are subject to most severe damage, the initial attack being concentrated more or less on the lower sides.

In many cases sap-stain losses in logs can be prevented by adopting improved methods involving little additional expense and only slight modifications in handling and storage practices. Often, however, damage is unavoidable or would require control practices that are impractical from the standpoint of cost. Any steps that can be taken to hasten conversion of the logs into lumber are the surest safeguards against stain. When delay is unavoidable certain relatively inexpensive chemical treatments can be used to minimize the danger from direct infection; infection occurring through insect holes is unfortunately not amenable to present methods of chemical control.

### STAIN IN EXPORT SHIPMENTS

Shipments of green and semigreen material are common in the export trade. Because of this practice, which involves comparatively long periods before the stock can be placed in a position to season, additional problems in stain control are presented. In the Gulf States practically all the 1-inch and 2-inch export lumber is kiln-dried or air seasoned at the mill before shipping. Once dried, these items are not likely to stain unless subsequent handling conditions are exceedingly bad. Thicker stock may be air seasoned before a shipment is made or it may be allowed to air season only until a carload is ready. Occasionally there may be no attempt to air season the stock, simply allowing it to accumulate on the loading platform until a shipment can be made. Sawn timbers and large dimension stock are usually sent out in a green or partially seasoned condition.

On the Pacific coast shipments of green lumber are common from tidewater mills.

In the long period that elapses between the time of loading at the mill and the time of delivery at foreign ports ideal conditions for stain development predominate in green stock or stock that retains a considerable amount of moisture. Except for intermittent periods of handling, export material is solid-piled in the holds or on deck. About the only precaution taken to avoid stain in dry stock while en route to the port of destination is to protect it from rain. Since this is usually effective for the major portion of the hold cargo, it is desirable to fully season as many export items as feasible before loading them. Deck loads, particularly the uppermost and lowermost layers of the cargo, are sometimes subject to considerable wetting (*37*); this is difficult to avoid in rough seas or rainy weather.

Occasionally stain develops in dry lumber stored in the hold, the necessary moisture being provided by water, which has condensed on steel deck members and dripped down on the stock[17] (*37*). An unfavorable condition of this sort is apt to occur when green and dry lumber are placed in the same compartments. In such cases some condensation may take place directly on portions of the lumber, particularly if the hold undergoes changes in temperature conducive to this.

Not infrequently serious staining of originally dry stock results from improper handling in the export and import harbors. It has been reported (*37*) that lumber sometimes becomes wet in the lighters owing to leakage, high seas, or faulty covering during rainy weather. The stock is also commonly subject to wetting as a result of improper coverage while lying at the docks.

Most mills find it either impractical or impossible to season thoroughly the larger materials before shipment. Timbers to be resawed are often shipped green in order to avoid seasoning checks, which would degrade the lumber cut from them. It has often been the practice to hold sawed timbers and large dimension stock in fresh-water ponds at shipping ports. This prevents stain temporarily but only on that portion of the piece that is below or near the surface of the water. Chemical treatments have been found helpful in controlling stain in shipments of green lumber.

### CHEMICAL TREATMENTS FOR SAP-STAIN CONTROL

Even when natural conditions are favorable, staining will not take place if chemicals that, by virtue of their toxic properties, prohibit growth of stain fungi are introduced into the wood. To be effective chemicals must be at least slightly soluble in water; otherwise adequate contact cannot be made with the fungus protoplasm, which is itself largely comprised of water. Chemicals vary greatly in toxicity; therefore the minimum effective solution strengths necessarily differ considerably. Moreover, they are not equally effective against all fungi. Consequently an attempt is always made to find a treatment that will control all the fungi that are involved in the particular problem at hand. A few very viscous treatments, such

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[17] JENKINS, J. H. SUMMARY OF INFORMATION EXTRACTED FROM INSURANCE UNDERWRITERS' REPORTS ON CAUSES OF DAMAGE TO BRITISH COLUMBIA LUMBER WHEN EXPORTED TO THE UNITED KINGDOM. Canada Dept. Int. Forest Serv., Forest Prod. Lab. Canada, Vancouver Lab. 10 pp. 1936. [Mimeographed.]

as those sometimes used as end coatings on logs, act simply as physical barriers to stain fungi and depend little on toxic effects.

For many years the practice of dipping or spraying lumber in hot soda solutions ranging in strength from 3 to 7 percent has found favor with a number of the larger pine mills as an aid in the control of sap stain and mold during the period of air seasoning.

Timbers and larger dimension materials usually have been treated by spraying. Prior to the use of materials tested in the experiments described in this bulletin several chemicals other than soda had been tried commercially at various times but none proved so satisfactory. Although the soda treatment has been on the whole unquestionably beneficial, it is of little value on hardwoods and, as prevalently used, lacked the uniformity of effectiveness desired by the majority of pine mills. It is recognized that much of this lack of uniformity was often due to faulty practices and cannot be ascribed entirely to failure of soda itself.

In considering the problem of sap-stain prevention in the southern pine and hardwood region it appeared that of the two general methods in use for this purpose, namely, rapid seasoning practices such as kiln drying, end racking, and steaming, and the use of chemical treatment, the latter had greatest possibilities (*41*). Although limited to a comparatively small number of mills, the commercial use of soda treatments gave evidence of being practical on a large scale and the cost was well under that of the several special air-seasoning methods. The dipping and spraying processes were simple in operation, required no technical supervision, caused little inconvenience in the handling of the output of the mill, and seemed generally applicable to a wide variety of products. Chemical treatments also offered particular promise for success among the available methods for improving stain control in stored logs and green export materials.

The remainder of this bulletin is devoted to experimental work on stain and mold control by chemical treatments and to a consideration of commercial utilization of them.

## HISTORY OF CHEMICAL STAIN-CONTROL EXPERIMENTS IN THE UNITED STATES

According to Bryant (*9*) attempts to solve the sap-stain problem by chemical means date back to as early as 1888, when lime was tested, by sprinkling it on the lumber, by depositing it under the piles, and in some cases by sprinkling weak limewater on the surfaces of the boards. The same source of information relates that the first patent on a process to prevent sap stain was granted in 1903 and involved the use of a 5-percent solution of sodium bicarbonate. This patent was later declared invalid on the basis that it did not embody new patentable ideas. However, it was but a comparatively short time after this that sodium carbonate and sodium bicarbonate began to be used among lumber manufacturers as dipping treatments, and they were the only antistain materials adopted commercially in this country until recent years.

During the interval between 1905 and 1916 the Forest Service and others conducted a number of dipping experiments in which soda (sodium carbonate or sodium bicarbonate) on the whole appeared to be the most suitable of the chemicals tried for general use on pine stock[18] (*34, 59, 78*). Requisite concentrations for fullest effectiveness were indicated as ranging from 5 to 8 percent, depending on seasoning conditions. Low concentrations of mercuric chloride were also found to be effective, but the highly poisonous character of this material and its corrosive qualities render it unfit for all but special purposes. Later experiments with chemical control, prior to 1928[19] (*32*), brought out other promising treatments which were tried commercially at one time and another, but all except soda were ultimately discontinued.

Previous to the experiments herein reported, no treatment was disclosed as being particularly suitable for control of sap stain in hardwood lumber. Borax, which is now known to be one of the better treatments for hardwoods, was incorporated in tests conducted on red oak vehicle stock (*32*) and on hardwood veneers (*29*) with variable success, but its full potentialities as a sap-stain preventive were apparently not revealed. A few of the larger hardwood mills tried dipping with soda, but the unsatisfactory results obtained soon led to the abandonment of this practice.

By 1928 most of the large pine mills in the Southern States were treating their output of air-seasoned lumber with soda. Practically all the dipping equipment was mechanically operated. On the basis of tests conducted at the Forest Products Laboratory and theoretical considerations, a temperature of from 160° to 170° F. was recommended for the dipping solution. However, the limitations of the soda treatment were recognized, particularly with respect to extending its use to other types of operations and to other species in which stain and mold were a serious problem.

In view of the current widespread need for an improved chemical treatment for pine, and for one that could be successfully employed on hardwoods, two independent experimental programs directed to this end were instituted by the United States Department of Agriculture in 1928. In the California pine region, tests were conducted on sugar pine and ponderosa pine, while in the Gulf States tests were made on southern pines and hardwoods. The California tests (*8*), which were completed in 1929, were the most extensive carried out up to that time. In these soda proved to be relatively ineffective on both species of pine, but a new material, ethyl mercuric chloride, applied at 0.015-percent concentration,[20] gave good results. The latter compound was regarded with considerable interest since it was believed to be substantially less likely to injure workmen handling it than most of the inorganic mercurials. This favorable showing of ethyl mercuric chloride was subsequently substantiated in the Gulf States tests, which are taken up in detail in the present bulletin (pp. 45–57).

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[18] KNOWLTON, H. N. EFFICIENCY OF SODIUM FLUORIDE AS A PREVENTIVE FOR BLUE STAIN IN SOUTHERN YELLOW PINE LUMBER. U. S. Forest Serv., Forest Prod. Lab., Prog. Rept. 1, Proj. L-117, 10 pp., illus. 1915. [Mimeographed.]

[19] HUBERT, E. E. FOREST SERVICE EXPERIMENTS ON THE PREVENTION OF SAP STAIN IN LUMBER. U. S. Forest Serv., Forest Prod. Lab. Rept. 521, 5 pp. Revised, 1924. [Mimeographed.]

PETTIGREW, R. L. RESULTS OF EXPERIMENTS ON THE PREVENTION OF SAP STAIN IN SOUTHERN YELLOW (LONGLEAF, SHORTLEAF, AND LOBLOLLY) PINES. U. S. Forest Serv., Forest Prod. Lab. Prog. Rept. 3, Proj. L-117-G, 7 pp. 1917. [Mimeographed.]

[20] Here and elsewhere concentrations of organic mercury compounds are given for the active ingredients only, and do not include the essentially inert materials regularly incorporated with these chemicals when made up by the manufacturers for stain control.

A summary of field and laboratory sap-stain control tests in the United States preceding those covered in the present writing is given on pages 116 to 118.

With the exception of recent work herein reported, attempts to reduce by chemical means the occurrence of sap stain in stored logs over prolonged periods have been comparatively few. In 1907 Von Schrenk (*69*) found hot coal-tar creosote applied to the ends of red gum logs rather effective. Considerably later Knauss (*38*) and Teesdale (*73*) made field trials of certain chemicals that had appeared promising in tests previously conducted at the Forest Products Laboratory (*51*). Spray treatments with cresylic acid in kerosene or crude oil confined end penetration of stain in red gum logs, stored for 3 to 4 weeks in the summer, to wood that would ordinarily be trimmed off at the mill. For longer periods of storage repetitions of the treatment were recommended. Combining filled hardened gloss oil with cresylic acid provided a treatment for brush application, which reduced excessive end checking as well as stain.

The tests in the South, herein reported, had as one of their major objectives improvements in chemical measures that would furnish a somewhat cheaper and higher degree of stain control in stored logs and in addition permit somewhat longer storage periods.

## RECENT EXPERIMENTS ON CHEMICAL CONTROL OF SAP STAIN AND MOLD IN LUMBER [21]

### GENERAL PLAN OF EXPERIMENTS

The further search for chemical treatments that might be effective in controlling sap stain and mold on lumber was conducted principally by dipping green sapwood in solutions of a large number of selected chemicals and allowing it to season at the sawmill. The effectiveness of a particular treatment was measured in each case by the percentage of sapwood area discolored by stain at the end of the seasoning period. Except for a comparatively few cases the testing was confined to southern pines and red gum. These woods are especially subject to sap staining and in their response to stain control by chemical means appear to be representative of softwoods and hardwoods in general.

Since it was obviously impossible to make tests on a commercial scale of all the chemicals warranting trial, one or more preliminary small-scale tests of each were always made. Such small-scale tests, which are less costly and time consuming than commercial trials, permitted the testing of a large number of materials and the early elimination of all but the most effective ones. The technic employed permitted close control of environmental factors, thus assuring uniform conditions of exposure and making possible a comparison of a large number of treatments at one time. Such a condition is not attainable with more than a few chemicals at one time in commercial testing. The reliability of the method for the intended purposes is indicated by the consistency of the results and the corroborative evidence from subsequent commercial trials of the better treatments.

The usual procedure in small-scale testing was to immerse sawed

[21] Earlier reports of some of the experiments have appeared in lumber trade and professional journals (*12, 13, 53, 55, 56, 57, 59, 60, 62, 64*).

pieces of green sapwood, 1 by 2 by 24 inches in size, in a barrel containing solutions of the various chemicals on trial. In the earlier tests the solutions were applied both hot (about 160° F.; 71°C.) and at air temperatures; later tests were run with cold solutions only. Up to and including test 10, results of the small-scale tests are given for hot treatments only. The results for the cold treatments are not given throughout because the proportion of material treated with cold solutions in the early tests was comparatively small. The dipped pieces, together with untreated control material for comparison, were semibulk-piled somewhere about the sawmill in a moist location, as under a tramway, which tended to present uniformly severe moisture conditions for the different treatments (pl. 2, *B*). Both separate and composite arrangements of the different treatments in the piles were employed. In most cases the tests were loosely boxed in with boards to further retard drying, particularly in the outside piles. At the end of a testing period of 30 to 40 days, each of the 40 to 60 pieces in each test pile was examined and the amount of sapwood stained or molded recorded.

In commercial-scale testing usual mill practices were followed throughout. Freshly cut, regular run-of-mill stock [22] was either dipped by hand or passed through the regular mechanical dipping vat. A few early tests were conducted with hot solutions, but this procedure was early abandoned in favor of cold solutions after small-scale tests results indicated that the newer treatments were little or not at all improved in effectiveness by heating. The treated lumber and untreated stock for comparison were stacked immediately on the yard in conventional flat piles, the several piles being placed under as uniform drying conditions as possible. In a few final tests (Nos. 20, 21, 22, and 23) the several treatments were compositely grouped in a single seasoning pile, in such a manner that their relative order of effectiveness could be more accurately determined than when each treatment was placed in separate piles. In these tests the use of dry stickers decreased the chance for intertreatment influences. After an air-seasoning period of usually about 90 days, the piles were dismantled and the amount of sap stain and mold recorded for each board. The percentage of sapwood was recorded separately.

Chemicals tested included the more promising ones reported in previous sap-stain investigations, a number of materials known to be of value as fungicides in other connections, compounds that demonstrated superior qualities in laboratory toxicity tests (*26, 27, 56, 67*), and various commercial products, proprietary and otherwise, of potential value. Several materials derived from wood distillation were tested in the hope that one or more might prove effective and thereby introduce a new use for wood products.

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[22] Practically all the test lumber was from second-growth timber, the pine consisting largely of Nos. 2 and 3 Common grades with some No. 1, and the hardwoods of Nos. 1 and 2 Common grades. Excepting for one pine test, 1-inch lumber was used. Board lengths were usually 14 or 16 feet except for 8- to 12-foot stock stickers in a number of the pine tests (stock stickers were used in all pine tests specifically reported except Nos. 4, 9, 20, 21, 22, and 23). The pine boards were usually 8 inches wide, but 10-inch boards were used in some tests; hardwood boards were of all common widths. Approximately 99 percent of all boards tested had some sapwood. The average proportion of sapwood in the pine test piles, as estimated from 21 piles at 5 mills, was 63 percent (standard deviation 13) and the average proportion of sapwood in the red gum test piles, as estimated from 16 piles at 4 mills, was 72 percent (standard deviation 16).

In selecting the chemicals for trial and in evaluating them later for stain control, such factors as cost, solubility, ease of preparation and application, effect on equipment and color of lumber, and injuriousness to workmen were considered, as well as toxicity to stain and mold organisms.

With commercial requirements in mind, the strength of the chemical solutions usually was established on an approximately equal-cost basis rather than on an equal-concentration basis. For this reason the observed effectiveness of each treatment must be interpreted in the light of concentration as well as toxic quality. In most cases the cost ranged from 1 to 2 cents per gallon of solution, depending on the test.

Before considering the results of the experimental work it should be emphasized that the procedures followed were designed largely from practical considerations. The object was to survey the field of available chemicals as rapidly as possible consistent with reasonably adequate trials of each. Treatments that definitely were shown to be ineffective were eliminated from further testing and new ones were introduced. Because different groups of chemicals were therefore tested at different times and places, and consequently under different degrees of stain hazard, it is not possible to compare the entire series of chemicals quantitatively. However, it is possible to separate out the more promising materials with some idea of their relative values. Methods that would have permitted closer quantitative analysis were for a number of reasons impractical of application; it is believed that they would not have led to materially different conclusions with respect to effective treatments.

## SMALL-SCALE TESTS OF CHEMICAL TREATMENTS

### INEFFECTIVE TREATMENTS

In all, 157 different treatments were tested, exclusive of numerous tests of concentration. Of these, approximately one-third were promisingly effective against sap stain in either pine or red gum sapwood. Materials that, because of lack of suitably toxic qualities or because of low concentration necessitated by cost considerations, were practically ineffective in controlling sap stain on both pine and red gum are listed on pages 119 to 121.

Besides those that were ineffective against sap-stain fungi, a number of chemicals were placed in the discard group because they were highly corrosive to iron or discolored the stock to an objectionable degree. The most corrosive materials, as judged by their effect on iron mixing buckets, pieces of green chain, and nails, consisted of the inorganic metallic compounds, particularly the sulfates of cadmium, thallium, and copper, including bordeaux mixture. All chemicals with an alkaline reaction tended to turn gum sapwood reddish brown, the intensity of the discoloration depending on the degree of alkalinity. The more alkaline treatments, such as sodium metasilicate, also produced considerable yellow color in pine sapwood. Ammonium bicarbonate and Somol (table 24, footnote 3) solutions, being themselves strongly orange to yellow, imparted these colors to the wood. Copper sulfate and ferrous fluoride reacted with tannins in the gumwood and produced a deep blue-gray color, but they had no effect on pine.

Chemicals that are corrosive are suitable only for hand-dipping or hand-spraying operations involving a limited amount or no iron equipment. Chemicals producing objectionable discoloration are necessarily limited to treatment of stored logs.

TREATMENTS GENERALLY EFFECTIVE ON PINE

Treatments that were variously effective in controlling stain in small-scale pine tests are given in tables 3 to 7. To judge their comparative effectiveness it is necessary to consider the results obtained both in identical tests and in all tests as a whole. To simplify analysis of the data the tests are treated in four groups, according to similar types of treatments used.

Of the inorganic treatments (table 3) a 7.2-percent solution of commercial soda permitted least stain development. Next in order of apparent effectiveness was 1.08- to 1.5-percent ammonium fluoride; 4.1-percent sodium fluoride, 0.16-percent mercuric chloride,[23] 5.3-percent soda, and 7.2-percent ferrous sulfate were least effective.

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[23] Although its poisonous and corrosive qualities render it impractical for general use in the field of stain control, mercuric chloride was incorporated in the tests because it is more or less of a standard antiseptic and has been extensively tested in other connections.

TABLE 3.—*Inorganic treatments generally effective on pine in small-scale tests*[1]

| Chemical | Concentration | Amount of sapwood stained[2] in test No.— | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17 | 18 | 9 | 5 | 4 | 2 | 1 | 3 | 6 | 7 | 8 | 11 | 12 | 10 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Ammonium fluoride | 1.08 | | | | | | 2 | 6 | 7 | | | | | | |
| Do | 1.5 | 0.5 | 2 | | | | | | | | | | 12 | 16 | 2 |
| Ferrous sulfate | 7.2 | | | | | 6 | | | | | | | | | |
| Mercuric chloride | .16 | | | | | | 4 | 6 | 22 | | | | | | |
| Soda | 5.3 | | | | 2 | 2 | | | | 8 | | | 51 | 54 | 83 |
| Do | 7.2 | | | 0.8 | .6 | 2 | 2 | 2 | 6 | 4 | 7 | 37 | | | |
| Sodium fluoride | 4.1 | | | | | | 7 | 12 | 4 | | | | | | |
| Untreated | | 51 | 66 | 30 | 30 | 46 | 55 | 29 | 72 | 75 | 65 | 64 | 92 | 99 | 60 |

[1] Tests arranged roughly in order of increasing stain.
[2] Stain percentages above 1 given as nearest whole number.

TABLE 4.—*Organic mercurial treatments generally effective on pine in small-scale tests*

| Chemical[1] | Concentration | Amount of sapwood stained[2] in test No.[3] | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17 | 18 | 9 | 5 | 22 | 4 | 15 | 2 | 14 | 1 | 3 | 6 | 7 | 25 | 10 | 8 | 11 | 12 | 21 | 24 | 23 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Ethyl mercuric chloride | 0.009-0.012 | 0.2 | 0.1 | | 0 | 0.2 | 0.9 | 0.9 | | 3 | | | 7 | | 15 | 22 | 33 | 38 | 36 | 9 | 57 | 30 |
| Do | .014- .017 | | | | 0 | | 1 | | 2 | | 3 | 3 | .6 | 5 | | | | | | | | |
| Do | .020- .024 | | | 0.1 | | | | | | | | | | | | | 39 | | | | | |
| Do (emulsion) | .005- .010 | | .4 | | | | | | | | | | | | | 6 | | | | 36 | | |
| Ethyl mercuric fluoride | .010 | | | | | | | | | | | | | 5 | | | 28 | | | | | |
| Ethyl mercuric oleate | .012 | | 4 | | | | | | | | | | | | | .3 | 4 | | | 4 | | |
| Ethyl mercuric oxalate | .014 | | | | 0 | | .5 | | | | | | 0 | | | | | | | | | |
| Ethyl mercuric phosphate | .012- .014 | 0 | .2 | .1 | 0 | | .3 | | | | | | 1 | 2 | | 11 | 44 | | 31 | 9 | | |
| Ethyl mercuric sulfate | .024 | | | | 0 | | .5 | | | | | | .1 | | | | | | | | | |
| Ethyl mercuric tetraborate | .010 | | | | | | | | | | | | | 5 | | | 34 | | | | | |
| Phenyl mercuric acetate | .017 | | | | | | | | 4 | | 6 | 10 | | | | | | | | | | 29 |
| Do | .025 | | | | | | | | | | | | | | | | | | | | 48 | 24 |
| Phenyl mercuric nitrate | .006 | | | | | | 3 | | | | | | | | | | | | | | | |
| Do | .013 | | | .1 | | | | | | | | | | | | | | | | | | |
| Untreated | | 51 | 66 | 30 | 30 | 99 | 46 | 43 | 55 | 73 | 29 | 72 | 75 | 65 | 65 | 77 | 64 | 92 | 99 | 98 | 94 | 58 |

[1] See footnote 20, p. 41.
[2] Stain percentages above 1 given as nearest whole number.
[3] Tests arranged roughly in order of increasing stain.

TABLE 5.—*Phenolic treatments generally effective on pine in small-scale tests*

| Chemical | Concentration | Amount of sapwood stained[1] in test No.[2]— | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17 | 18 | 9 | 5 | 6 | 19 | 14 | 4 | 15 | 22 | 21 | 8 | 11 | 12 | 10 | 7 | 24 | 23 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Sodium o-phenylphenolate | 0.48 | 0 | 0 | 0.1 | | | | 5 | | 7 | | 8 | 34 | | | | | | |
| Do | .62 | | | | 0.2 | | | | 7 | | | | | | | | | | |
| Do | .96 | .2 | | | | 3 | | | | | | | | 10 | | | 26 | | |
| Sodium 2-chloro-o-phenylphenolate | .48 | .8 | .1 | | | | 0.6 | .6 | | .2 | | .8 | | | | | | | |
| Do | .72 | 0 | 0 | | | | .7 | | | | 0.3 | .6 | | | | | | 5 | 9 |
| Do | .96 | 0 | | | | | | | | | .3 | | | | | | | | |
| Sodium tetrachlorophenolate | .48 | | | 1 | | | | 2 | | 4 | | 46 | 39 | | | | 30 | | |
| Do | .72 | | | | | | 6 | | | | 11 | | | | | | | 53 | 63 |
| Do | .96 | | | | | | | | | | 4 | | | 47 | 62 | 31 | | | |
| Sodium dinitrophenolate | 1.2 | | | | | .8 | | | | | | | 5 | | | | 6 | | |
| Sodium dinitro-o-phenylphenolate | .48 | | | .8 | | | | 11 | | 3 | | | | | | | | | |
| Untreated | | 51 | 66 | 30 | 30 | 75 | 77 | 73 | 46 | 43 | 99 | 98 | 64 | 92 | 99 | 60 | 65 | 94 | 58 |

[1] Stain percentages above 1 given as nearest whole number.
[2] Tests arranged roughly in order of increasing stain.

TABLE 6.—*Mixed treatments generally effective on pine in small-scale tests*

| Chemical and concentration | | | | Amount of sapwood[1] in test No.[2] — | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 17 | 18 | 5 | 4 | 2 | 1 | 6 | 23 | 14 | 15 | 25 | 3 | 19 | 24 |
| | *Percent* | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Aezol[3] | 6.0 | | | 0.4 | | | | | | | | | | | | | |
| Ethyl mercuric chloride | .006 | +Sodium tetrachlorophenolate | 0.48 | | | | | | | | 6 | | | | | | 40 |
| Do | .007 | +Sodium 2-chloro-o-phenylphenolate. | .48 | | | | | | | | | | | 1 | | | |
| Do | .007 | {+Sodium tetrachlorophenolate+ sodium 2-chloro-o-phenylphenolate. | .24 .24 | | | | | | | | | | | 5 | | | |
| Do | .009 | +Soda | 5.3 | | | | | 2 | 2 | | | | | | 12 | | |
| Mercuric iodide | .15 | +Potassium iodide | .19 | | | 0 | 0.7 | | | 1 | | | | | | | |
| Soda | 3.5 | +Sodium fluoride | 1.9 | | | | | 6 | 2 | | | | | | 12 | | |
| Sodium o-phenylphenolate | .5 | +Ammonium fluoride | .5 | | | | | | | | | 7 | 6 | | | | |
| Do | .37 | +Boric acid | .72 | | 0.1 | | | | | | | | | | | 0.7 | |
| Do | .48 | +Sodium tetrachlorophenolate | .48 | | .4 | | | | | | | 1 | 1 | | | 2 | |
| Sodium 2-chloro-o-phenylphenolate. | .48 | +Sodium tetrachlorophenolate | .48 | | | | | | | | .8 | | | .1 | | | 4 |
| Sodium tetrachlorophenolate | .37 | +Ammonium fluoride | .37 | | 4 | | | | | | | | | | | 16 | |
| Untreated | | | | 51 | 66 | 30 | 46 | 55 | 29 | 75 | 58 | 73 | 43 | 65 | 72 | 77 | 94 |

[1] Stain percentages above 1 given as nearest whole number.
[2] Treatments arranged roughly in order of increasing stain.
[3] A proprietary mixture of copper and zinc salts with phenol; furnished by Zinsser & Co.

TABLE 7.—*Promising treatments from each group that were generally effective on pine in small-scale tests*

| Chemical | Concentration | Amount of sapwood stained[1] in test No.[2]— | | | | | | | | | | | | | | | | | | | | | Adjusted mean[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 17 | 18 | 22 | 1 | 2 | 3 | 5 | 4 | 6 | 7 | 14 | 15 | 21 | 19 | 23 | 24 | 25 | 8 | 11 | 12 | |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Ammonium fluoride | 1.08 | | | | | 6 | 2 | 7 | | | | | | | | | | | | | | | 5 |
| Do | 1.5 | | 0.5 | 2 | | | | | | | | | | | | | | | | | 12 | 16 | 10 |
| Soda | 5.3 | | | | | | | | 2 | 2 | 8 | | | | | | | | | | 51 | 54 | 20 |
| Do | 7.2 | 0.8 | | | | 2 | 2 | 6 | .6 | 2 | 4 | 7 | | | | | | | | 37 | | | 5 |
| Ethyl mercuric chloride | .012 | | .2 | .1 | 0.2 | | | | | | | | | | 9 | 22 | 30 | 57 | 15 | | | | 7 |
| Do | .014– .017 | | | | | 3 | 2 | 3 | 0 | 1 | .6 | 5 | | | | | | | | | | | 1 |
| Do | .020– .024 | .1 | | | | | | | | | | | | | | | | | | 39 | | | 2 |
| Ethyl mercuric oleate | .012 | | | 4 | | | | | | | | | | | 4 | .3 | | | | 4 | | | .8 |
| Ethyl mercuric phosphate | .012– .014 | .1 | 0 | .2 | | | | | 0 | .3 | 1 | 2 | | | 9 | 11 | | | | 44 | | 31 | 2 |
| Sodium o-phenylphenolate | .48 | .1 | 0 | 0 | | | | | | | | | 5 | 7 | 8 | | | | | 34 | | | 2 |
| Do | .62 | | | | | | | | .2 | 7 | | | | | | | | | | | | | 6 |
| Do | .96 | | .2 | | | | | | | | 3 | 26 | | | | | | | | | 10 | | 5 |
| Sodium 2-chloro-o-phenylphenolate | .48 | | .8 | .1 | | | | | | | | | .6 | .2 | .8 | .6 | | | | | | | .7 |
| Do | .72 | | 0 | 0 | .3 | | | | | | | | | | .6 | .7 | 9 | 5 | | | | | .8 |
| Do | .96 | | 0 | | .3 | | | | | | | | | | | | | | | | | | 1 |
| Sodium 2-chloro-o-phenylphenolate + sodium tetrachlorophenolate | .48 + .48 | | | | | | | | | | | | | | | | .8 | 4 | .1 | | | | 1 |
| Sodium o-phenylphenolate + sodium tetrachlorophenolate | .48 + .48 | | | .4 | | | | | | | | | 1 | 1 | | 2 | | | | | | | 4 |
| Sodium o-phenylphenolate + boric acid | .37 + .72 | | | .1 | | | | | | | | | | | | .7 | | | | | | | .9 |
| Untreated | | 30 | 51 | 66 | 99 | 29 | 55 | 72 | 30 | 40 | 75 | 65 | 73 | 43 | 98 | 77 | 58 | 94 | 65 | 64 | 92 | 99 | 72 |

[1] Stain percentages above 1 given to nearest whole number.

[2] Tests arranged roughly in order of increasing stain.

[3] The adjusted mean was obtained by adjusting each result in an effort to make it represent the expected one, had all experiments been subjected to equal amounts of infection. The percentages were first transformed into values which should decrease the unevenness of the variation throughout. The transformation employed was based on the normal frequency distribution and gives the same end result as the probit method described by Bliss (5). All the transformed values in a particular test were as a whole lower or higher than the mean for all tests of these treatments. The values thus adjusted were averaged and transformed back to percentages.

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Among the organic mercurials (table 4) the ethyl compounds seemed to give somewhat better control than the phenyl compounds. Other than this it is difficult to ascribe any practical differences to the treatments. Ethyl mercuric chloride was used most extensively in commercial-scale tests, because technical advantages in its preparation pointed to the greater likelihood of its commercial production.

The results obtained with a number of phenolic treatments are summarized in table 5. Direct comparisons in several tests and a high level of control throughout point rather definitely toward sodium 2-chloro-o-phenylphenolate as having been the most effective pine treatment in this group. The 1.2-percent sodium dinitrophenolate treatment appeared second in effectiveness with sodium o-phenylphenolate and sodium dinitro-o-phenylphenolate ranking about equally in third place. The two dinitrophenolates, although good stain preventives, discolored the wood so badly that they were not considered further. Sodium tetrachlorophenolate looked promising usually but ranked lower than sodium o-phenylphenolate in these tests because of its comparative showing in tests 11 and 21.

A number of treatment mixtures composed of two to three of the more promising materials were tested and found to be approximately as effective as any one used alone at the same total concentration. This indicated the possibility of successfully combining, for advantages of one sort or another, rather diverse types of compounds without necessarily increasing the cost of treatment. From the limited comparisons permitted by the tests (table 6) sodium 2-chloro-o-phenylphenolate plus sodium tetrachlorophenolate, sodium o-phenylphenolate plus sodium tetrachlorophenolate, and sodium o-phenylphenolate plus boric acid apparently were among the most effective of the mixtures. The chlorinated phenolates were not so effective combined with ethyl mercuric chloride as with one another. Aczol and the mixture of mercuric and potassium iodides, although promisingly effective, could not be regarded as suitable for general use on lumber because they corrode iron equipment severely.

From table 7 comparisons of the most effective treatments from each of the chemical groups just considered having commercial qualifications for use on pine may be made. It is significant that in the majority of cases staining was reduced to less than 10 percent of the amount that occurred in the untreated wood, and in many instances to less than 1 percent. There is some evidence that ethyl mercuric chloride at the lowest concentration (0.012 percent), 5.3-percent soda and sodium o-phenylphenolate at all tested concentrations, were somewhat less effective than the others. Beyond this the results do not safely permit ranking the treatments. Most of the more effective treatments were considered worthy of incorporation in the commercial-scale tests, thus providing further opportunity to compare them.

An attempt is made to arrive at some indication of mean results for the better treatments. (See adjusted mean, table 7, footnote 3.) Since the treatments were not replicated systematically, nor for the most part extensively, the means could not be derived directly but instead were approximated from the comparative performances of the treatments primarily with reference to treatments that overlap from one test to another. It may be noted that the adjusted means, although not altogether in line with the conclusions reached by direct comparison of results, which should probably in this case be regarded as the more nearly correct, nevertheless corroborate them fairly well. However, it is recognized that any method of estimating the comparative degree of effectiveness shown by these selected treatments is subject to considerable error because of the over-all small differences in amounts of stain and the difficulties of comparison arising from the manner in which the treatments are replicated in the tests.

A disturbing element in the preceding tests and those that follow is the somewhat weakly defined relation between the amount of stain associated with a particular treatment and the amount of stain developed in the corresponding untreated wood or in the test as a whole. A more definite relationship in either of these respects would have facilitated the comparison of treatments greatly. It appears that in spite of precautions taken there was still substantial, although rather obscure, variation in one or more of the several factors that directly or indirectly influence stain development. Had it been practicable to design the tests for greater uniformity of stain hazard among the treatments it is believed that more regular trends of stain occurrence would have been evidenced. The difficulty of field testing lies in controlling all conditions that influence staining.

### TREATMENTS GENERALLY EFFECTIVE ON RED GUM SAPWOOD

Treatments that were variously effective in controlling stain in small-scale red gum tests may be compared in tables 8 to 12. Particularly effective among the inorganic treatments was a 4-percent solution of borax. The other treatments in this group are represented too inadequately to permit generalization, but in the tests where they occurred together boric acid and sodium monoborate were about equal to borax in effectiveness, while a 0.05-percent solution of mercuric iodide was inferior to borax.

The results obtained on red gum with the organic mercurial treatments are given in table 9. The high degree of control obtained leaves little room for comparing the several materials. Considering differences in concentration, the phenyl mercuric compounds appear to have been quite as effective as the ethyl mercuric compounds. An emulsion in water of ethyl mercuric chloride in oil showed no advantages over the chemical in water solution.

TABLE 8.—*Inorganic treatments generally effective on red gum in small-scale tests*

| Chemical | Concentration | Amount of sapwood stained [1] in test No.[2] — | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 15 | 18 | 22 | 25 | 8 | 16 | 14 | 4 | 21 | 10 | 13 | 7 | 26 | 27 | 6 | 11 | 2 | 19 | 12 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Boric acid | 3.6 | | | | | | | 0.5 | | | | | | | | | | | 7 | | |
| Borax | 4 | 0 | 0 | 0 | 0 | 0.2 | 0.2 | .4 | 0.6 | 0.9 | 2 | 2 | 2 | 2 | 2 | 4 | 5 | 0.7 | 5 | 8 | 10 |
| Mercuric iodide | .05 | | | | | | | | | | | | | | | | | 8 | | | |
| Sodium monoborate | 5.4 | | | | | | | | | | | 2 | | | | | | | | | |
| Untreated | | 8 | 60 | 50 | 67 | 67 | 43 | 82 | 57 | 52 | 99 | 62 | 83 | 62 | 91 | 75 | 74 | 32 | 71 | 62 | 93 |

[1] Stain percentages above 1 given as nearest whole number.
[2] Tests arranged roughly in order of increasing stain.

TABLE 9.—*Organic mercury treatments generally effective on red gum in small-scale tests*

| Chemical [1] | Concentration | Amount of sapwood stained [2] in test No.[3] — | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 6 | 4 | 19 | 18 | 16 | 7 | 27 | 26 | 22 | 24 | 14 | 15 | 25 | 11 | 13 | 21 | 8 | 23 | 2 | 12 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Ethyl mercuric chloride | 0.009–0.012 | 0.1 | 0.5 | 3 | 0.1 | 0 | 0.1 | | | | 0.2 | 0.5 | 0.4 | 0.2 | 2 | 3 | 3 | 0 | 8 | 10 | | 6 |
| Do | .014– .017 | 0 | .5 | .9 | | | | 0.6 | 0.5 | 0.6 | | | | | | | | | | | 4 | |
| Do | .020– .024 | | | | | | | | | | | | | | | | | | 6 | | | |
| Do. (emulsion) | .010 | | | | .7 | .7 | .9 | | | | | | | | | | | 59 | | | | |
| Ethyl mercuric fluoride | .010 | | | | | | | .3 | | | | | | | | | | | 3 | | | |
| Ethyl mercuric oleate | .012– .030 | | | | 0 | 0 | | | .9 | .9 | | | | | | | | .1 | | | | |
| Ethyl mercuric oxalate | .014 | 0 | .1 | .7 | | | | | | | | | | | | | | | | | | |
| Ethyl mercuric phosphate | .012– .014 | 0 | 2 | .5 | .1 | .4 | .5 | .2 | | | | | | | | | 1 | .3 | 2 | | | 20 |
| Ethyl mercuric sulfate | .024 | 0 | .8 | .4 | | | | | | | | | | | | | | | | | | |
| Ethyl mercuric tetraborate | .010 | | | | | | | 1 | | | | | | | | | | | 10 | | | |
| Phenyl mercuric acetate | .017 | | | | | | | | | | | | | | | | | | | 8 | 8 | |
| Do | .025 | | | | | | | | | | | 1 | | | | | | | | 1 | | |
| Phenyl mercuric nitrate | .008 | | | 2 | | | | | | | | | | | | | | | | | | |
| Untreated | | 8 | 74 | 52 | 62 | 50 | 82 | 62 | 75 | 91 | 67 | 91 | 57 | 60 | 67 | 32 | 83 | 99 | 43 | 87 | 71 | 93 |

[1] See footnote 20, p. 41.
[2] Stain percentages above 1 percent given as nearest whole number.
[3] Tests arranged roughly in order of increasing stain.

TABLE 10.—*Phenolic treatments generally effective on red gum in small-scale tests*

| Chemical | Concentration | Amount of sapwood stained[1] in test No.[2]— | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 18 | 19 | 22 | 10 | 13 | 5 | 11 | 16 | 26 | 27 | 15 | 8 | 14 | 7 | 6 | 12 | 24 | 23 | 21 | 4 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Sodium o-phenylphenolate | 0.48 | | | | | | | | | | | 30 | 5 | 24 | | | | | | | |
| Do | .62 | | | | | | 0.7 | | | | | | | | | | | | | | 39 |
| Do | .96 | | | | | | | 1 | | | | | | | 5 | 14 | | | | | |
| Sodium 2-chloro-o-phenylphenolate | .48 | 0 | 0.4 | | | | | | 1 | | | 5 | | 9 | | | | | | 27 | |
| Do | .72 | 0 | .1 | 0 | | | | | | | | | | | | | | 38 | 52 | 36 | |
| Do | .96 | | | 0 | | | | | 0 | | | | | | | | | | | | |
| Sodium tetrachlorophenolate | .48 | 0 | | | | | | | .7 | | | .2 | 3 | .3 | 9 | | | | | 7 | |
| Do | .72 | | 0 | 0 | | | | | | | | | | | | | | 0 | 5 | | |
| Do | .96 | | | 0 | 0 | 0.3 | | 0 | .3 | 0.8 | 0.7 | | | | | | 18 | | | | |
| Untreated | | 50 | 62 | 67 | 62 | 83 | 8 | 32 | 82 | 91 | 75 | 60 | 43 | 57 | 62 | 74 | 93 | 91 | 87 | 99 | 52 |

[1] Stain percentages above 1 percent given as nearest whole number.
[2] Tests arranged roughly in order of increasing stain.

TABLE 11.—*Mixed treatments generally effective on red gum in small-scale tests*

| Chemical and concentration | | | | Amount of sapwood stained[1] in test No.[2]— | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 15 | 18 | 26 | 27 | 5 | 19 | 21 | 14 | 23 | 24 | 6 | 4 | 25 | 13 | 11 | 12 | 10 |
| | *Percent* | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Boric acid | 1.8 | Zinc sulfate | 1.8 | | | | | | | | | | | | | | 11 | 5 | 7 | 13 |
| Borax | 3.6 | Boric acid | 1.8 | | | | | | 1 | 1 | | 0.5 | 0.4 | | | | | | | |
| Do | 3.0 | Sodium fluoride | 1.0 | | | | | | | | | .2 | 1 | | | | | | | |
| Do | 5.4 | Sodium hydroxide | .3 | | | | | | | | | | | | | | 1 | 2 | 8 | 4 |
| Do | 4.2 | Sodium o-phenylphenolate | .3 | | | | | | | | | | | | | | | 1 | 6 | 4 |
| Do | 5.4 | Copper carbonate | .3 | | | | | | | | | | | | | | 1 | | 4 | 7 |
| Ethyl mercuric chloride | .012 | Ammonium borofluoride | .2 | | | | | | | | | 1 | | | | | | | | |
| Do | .006 | Borax | 2.0 | | | | | | | | | | | | | 2 | | | | |
| Do | .004 | Phenyl mercuric acetate | .004 | | | 0.3 | 0.3 | | | | | | | | | | | | | |
| Do | .006 | Sodium tetrachlorophenolate | .5 | | | 0 | 0 | | | | | .3 | 0 | | | | | | | |
| Do | .007 | Sodium tetrachlorophenolate+ sodium 2-chloro-o-phenylphenolate. | .24<br>.24 | | | 0 | 0 | | | | | | | | | 7 | | | | |
| Mercuric iodide | .15 | Potassium iodide | .19 | | | | | 0.9 | | | | | | 2 | 5 | | | | | |
| Sodium tetrachlorophenolate. | .37 | Ammonium fluoride | .37 | | 0 | | | | .3 | | | | | | | | | | | |
| Do | .48 | Sodium o-phenylphenolate | .48 | 0.3 | 0 | | | | 0 | | 1 | | | | | | .3 | | | |
| Do | .48 | Sodium 2-chloro-o-phenylphenolate | .48 | | | 1 | 1 | | | | | 4 | 2 | | | 5 | | | | |
| Do | .5 | Sodium fluoride | .5 | | | | | | | | | 4 | 10 | | | | | | | |
| Sodium tetrachlorophenolate. +sodium 2-chloro-o-phenylphenolate. | .24<br>.24 | Ethyl mercuric oleate | .015 | | | 0 | .1 | | | | | | | | | | | | | |
| Untreated | | | | 60 | 50 | 91 | 75 | 8 | 62 | 99 | 57 | 87 | 91 | 71 | 52 | 67 | 83 | 32 | 93 | 62 |

[1] Stain percentages above 1 percent given as nearest whole number.
[2] Tests arranged roughly in order of increasing stain.

TABLE 12.—*Promising treatments from each group which were generally effective on red gum in small-scale tests*

| Chemical | Concentration | Amount of sapwood stained [1] in test No. [2]— | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 18 | 22 | 5 | 15 | 16 | 14 | 24 | 25 | 19 | 4 | 11 | 10 | 26 | 27 | 21 | 6 | 7 | 8 | 13 | 2 | 23 | 12 | Adjusted mean [3] |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Borax | 4 | 0 | 0 | 0 | 0 | 0.4 | 0.6 | | 0.2 | 8 | 0.9 | 0.7 | 2 | 2 | 4 | 2 | 5 | 2 | 0.2 | 2 | 5 | | 10 | 0.9 |
| Ethyl mercuric chloride | 0.009–0.012 | 0 | .2 | .1 | .2 | .1 | .4 | 0.5 | 2 | .1 | 3 | 3 | | | | 0 | .5 | | 8 | 3 | | 10 | 6 | 1 |
| Do. | .014– .017 | | | 0 | | | | | | | .9 | | | .6 | .5 | | .5 | .6 | | | 4 | | | .6 |
| Ethyl mercuric oleate | .012– .030 | 0 | | | | | | | | 0 | | | | .9 | .9 | .1 | | | | | | | | .5 |
| Ethyl mercuric phosphate | .012– .014 | .4 | | 0 | | .5 | | | | .1 | .5 | | | | | .3 | 2 | .2 | 2 | 1 | | | 20 | .7 |
| Sodium tetrachlorophenolate | .48 | 0 | | | .2 | .7 | .3 | | | | | | | | | 7 | | 9 | 3 | | | | | 1 |
| Do. | .76 | | 0 | | | | | 0 | | 0 | | | | | | | | | | | | 5 | | .1 |
| Do. | .96 | | 0 | | | .3 | | | | | | 0 | 0 | .8 | .7 | | | | | .3 | | | 18 | 4 |
| Sodium tetrachlorophenolate +sodium 2-chloro-o-phenylphenolate | .48 / .48 | | | | | | | 2 | 5 | | | | | 1 | 1 | | | | | | | 4 | | 1 |
| Sodium tetrachlorophenolate +sodium o-phenylphenolate | .48 / .48 | 0 | | | .3 | | 1 | | | 0 | | | | | | | | | | .3 | | | | .7 |
| Untreated | | 50 | 67 | 8 | 60 | 82 | 57 | 91 | 67 | 62 | 52 | 32 | 62 | 91 | 75 | 99 | 74 | 62 | 43 | 83 | 71 | 87 | 93 | 69 |

[1] Stain percentages above 1 percent given as nearest whole number.
[2] Tests arranged roughly in order of increasing stain.
[3] See footnote 3, table 7.

Only three of the phenolic treatments (table 10) showed promise in controlling stain on sap gum. Of these, sodium o-phenylphenolate (0.48-percent) was less effective than the same concentration of the two chlorinated phenols. As to the latter materials, tests 14, 15, 21, 23, and 24 definitely indicate that sodium tetrachlorophenolate was superior to sodium 2-chloro-o-phenylphenolate on gum.

On gum as well as pine, mixtures of the better treatments were effective in controlling stain (table 11). Although most of the mixed treatments did not differ greatly in control value, boric acid (in low concentration) plus zinc sulfate, and sodium tetrachlorophenolate plus sodium fluoride seemed somewhat less effective than the others.

Treatments selected for further comparison (table 12) were chosen for their potential advantages for commercial use as well as for any superiority demonstrated within the chemical group to which they belong.

As nearly as can be judged from the limited number of direct comparisons permitted, there were no important differences in effectiveness between higher concentrations of the organic mercury treatments in this set and the phenolic treatments. Moreover, the control generally obtained with the selected phenolic mixtures was essentially like that obtained with any of the other treatments. Borax appeared definitely less effective than the organic compounds in tests 6, 19, and 27, but on the whole ranked about the same.

The entire range of approximated means (adjusted mean, see footnote 3, table 7), as explained in connection with the pine tests, does not exceed 1 percent, further emphasizing the small differences between treatments.

### TREATMENTS GENERALLY EFFECTIVE ON BOTH PINE AND GUM

Of 47 different materials, including combinations, that were promising on pine or on gum, 19 gave at least fair results on both. These consisted of the several organic mercurials, the phenolic compounds with the exception of the nitrophenols, mixtures of these phenols, sodium tetrachlorophenolate plus ammonium fluoride, sodium tetrachlorophenolate plus ethyl mercuric chloride, and mercuric iodide plus potassium iodide. Most effective on both pine and gum were the ethyl mercurials, sodium o-phenylphenolate plus sodium tetrachlorophenolate, and sodium 2-chloro-o-phenylphenolate plus sodium tetrachlorophenolate.

Other than the organic mercurials, there were no single treatments within the same range of effectiveness on both kinds of wood as the mixtures just given. Sodium tetrachlorophenolate, sodium 2-chloro-o-phenylphenolate, and sodium o-phenylphenolate, alone, were somewhat effective on both pine and gum, but the first gave erratic results on pine while the other two materials were erratic on gum.

Outstanding examples of treatments that seemed promising on pine but notably ineffective on gum were soda, ammonium fluoride, sodium dinitrophenolate, and sodium dinitro-o-phenylphenolate. Treatments good on gum but apparently poor on pine were borax, boric acid, and sodium monoborate. Many of the less effective treatments demonstrated the same tendencies. Of particular interest were indications of specific effects of hydroxyl and borate ions, compounds depending on an alkaline reaction for effectiveness generally being considerably superior to boric acid and its derivatives on pine whereas on gum the reverse was true.

In general, treated gum was characterized by lower average and maximal stain development than treated pine. These observations subsequently have been borne out by commercial results with chemical treatments, satisfactory stain control being more easily attained with hardwood stock than with pine. Why control of stain should, in general, be more easily accomplished on gum than on pine, or why one treatment should be more effective on pine and another on gum, is uncertain. It may be that the stain fungi occurring on such diverse wood types as pine and red gum are to a considerable extent comprised of different species, which react differently to toxic materials. Davidson's observations (*18*) and data subsequently gathered suggest strongly that the common stain flora of pine lumber may differ considerably from that of hardwood lumber. To answer the question on this basis, however, it would, of course, be additionally necessary to determine whether the fungi from pine and hardwood lumber differed in their tolerance to chemical treatments, and, if so, whether in the same way as suggested by the comparative effectiveness of the treatments on the two kinds of stock.

As another possibility, certain mild chemical or physical reactions may take place between the chemical and the wood, a situation that might so affect the original toxicity or effective concentrations of the treatments as to bring about the observed differences.

### EFFECT OF CHEMICAL CONCENTRATION AND SOLUTION TEMPERATURE

No special study was made of the relation between concentration and treatment effectiveness. However, while concentrations were for the most part established to give approximately equal solution costs, a few of the better treatments were tested for minimum effective solution strengths. Except in a few cases, different concentrations of the same chemical were not included in the same tests; instead, the comparative effectiveness of the different concentrations in relation to all other treatments in respective tests was for the most part depended on as a basis for judgment of concentration effect. The procedure was sufficiently satisfactory for the purpose, but does not permit quantitative evaluations.

In most cases, the highest concentrations shown in tables 7 and 12 appear to be adequate for general practical use. In all but the most severe tests considerable variation in concentration without material effect on the results is indicated. It seems questionable that concentrations higher than the highest of those tested would give sufficiently better stain control under most conditions, except possibly for thick stock and exceptionally severe seasoning conditions, to justify the additional cost.

Comparative merits of hot and cold treating solutions were not fully ascertained. Results obtained with some of the better chemicals in tests permitting direct comparisons are presented in table 13. Hot solutions of soda on pine definitely were more effective than cold solutions of the same concentrations. Also, on gum, hot solutions of borax and sodium o-phenylphenolate apparently were more effective. On the other hand, cold solutions of ethyl mercuric chloride were more effective on both pine and gum, and cold solutions of ethyl mercuric phosphate at least as good if not somewhat better than hot solutions. On pine, hot and cold solutions of sodium o-phenylphenolate were about equally effective. Although little generalization is warranted, there is some suggestion that chemicals required in very low concentrations, such as the organic mercurials, may commonly be more effective in cold solution whereas chemicals required in substantially higher concentrations, such as soda, borax, and sodium o-phenylphenolate, may be applied to advantage in hot solutions. It may be that the greater volatility of the organic mercurials was responsible for some of the decrease in effectiveness with hot solutions.

TABLE 13.—*Comparative effectiveness of hot and cold treatments in small-scale dipping tests*

| Treatment | Condition of solution[1] | Sapwood stained | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pine tests | | | | | | Red gum tests | | | | | |
| | | A | B | C | D | E | F | A | B | C | D | E | F |
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Soda | Hot | 2 | 2 | 8 | 7 | 37 | ... | ... | ... | ... | ... | ... | ... |
| | Cold | 17 | 4 | 23 | 31 | 67 | ... | ... | ... | ... | ... | ... | ... |
| Borax | Hot | ... | ... | ... | ... | ... | ... | 0.9 | 0 | 5 | 2 | ... | ... |
| | Cold | ... | ... | ... | ... | ... | ... | 4 | .6 | 4 | 5 | ... | ... |
| Ethyl mercuric chloride. | Hot | 1 | 0 | 7 | 5 | 8 | 39 | .9 | .1 | .5 | .6 | 33 | 6 |
| | Cold | .5 | 0 | 3 | 1 | 3 | 25 | .2 | 0 | 0 | .7 | 10 | .9 |
| Ethyl mecuric phosphate | Hot | 0 | 1 | 2 | 57 | 34 | ... | .5 | 0 | 2 | .2 | 5 | 0 |
| | Cold | 0 | 6 | 2 | 66 | 12 | | 0 | .1 | 0 | .3 | 1 | 1 |
| Sodium o-phenylphenolate. | Hot | .2 | 26 | ... | ... | ... | | 39 | .7 | 5 | ... | ... | ... |
| | Cold | 0 | 27 | ... | ... | ... | | 58 | 2 | 17 | ... | ... | ... |

[1] Concentrations of the respective chemicals were the same in corresponding hot and cold solutions.

Testing of hot solutions was discontinued after it seemed unlikely that a hot treatment would be found that would be enough better than the already proved cold ones to warrant the additional requirements for their preparation and maintenance. A hot treatment, no matter how effective, has the disadvantage of being unsuited to a large percentage of mills, such as small operations where hand dipping is required or where steam power is not used. However, some mills that can conveniently employ them may find hot solutions advantageous under certain conditions.

### COMMERCIAL-SCALE TESTS OF CHEMICAL TREATMENTS ON PINE

The results of three series of tests, involving full-sized conventional air-seasoning piles, each series representing a different year, are shown in figure 2. The tests in each case are given in the order of increasing stain in the untreated wood.[24]

From series A (fig. 2) it is evident that a 5-percent solution of soda was markedly inferior to sodium o-phenylphenolate, ethyl mercuric chloride, and ethyl mercuric phosphate. Judging from the results of test series D, which are presented later, the comparative showing of soda would have been better had all chemicals been used at higher concentrations. No essential difference in effectiveness is

[24] In all pine tests except Nos. 2, 3, 4, and 5 the chemicals were applied in cold solution.

indicated between the ethyl mercuric chloride and ethyl mercuric phosphate treatments, in spite of the fact that the latter material was used at a lower concentration than the former. Both mercurials appear to have been slightly better than sodium o-phenylphenolate in the two comparatively mild tests in which they occurred together. The reduction in sap stain by the mercurials in the five tests is striking; for example, an average of 51 percent of the sapwood in the untreated lumber was stained, while only 2 percent of the sapwood treated with ethyl mercuric phosphate was stained.

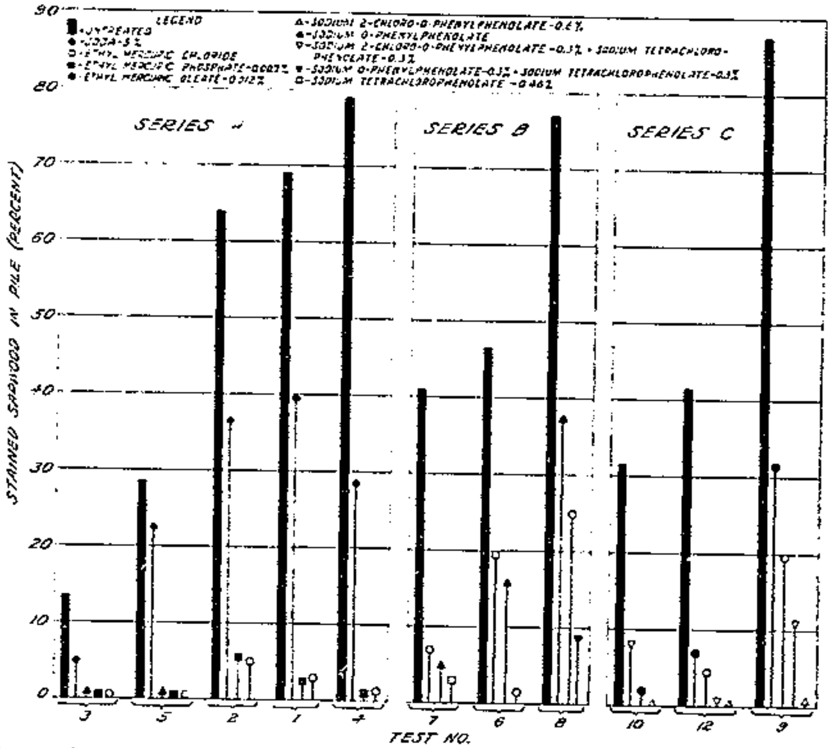


FIGURE 2.—Effectiveness of chemical treatments in commercial-scale tests on southern pine lumber. (0.01-percent ethyl mercuric chloride was used in series A; 0.012-percent in series B and C. 0.24-percent sodium o-phenylphenolate was used in series A; and 0.37-percent in series B.)

Test series B (fig. 2) largely removes any doubt as to the general superiority of 0.010- to 0.012-percent ethyl mercuric chloride over 0.24- to 0.37-percent sodium o-phenylphenolate. The series further indicates that the former treatment also surpasses 0.48-percent sodium tetrachlorophenolate in most cases. A 0.6-percent mixture of sodium o-phenylphenolate and sodium tetrachlorophenolate in equal proportions (test 8) appears to have been the most effective of all treatments in this series.

In series C (fig. 2), sodium 2-chloro-o-phenylphenolate, used for the first time, reduced stain in all tests of the series to 1 percent or less of the sapwood area. Although the most effective stain treatment in this series of tests on pine, it unfortunately permitted the development of objectionable amounts of a fungus growth, which at the time could not be definitely classed as either decay or mold. A mixture of 0.3-percent sodium 2-chloro-o-phenylphenolate and 0.3-percent sodium tetrachlorophenolate virtually eliminated this growth but permitted more stain than sodium 2-chloro-o-phenylphenolate alone. Nevertheless it was still more effective for the most part than the mercurial treatments. Of the latter, 0.012-percent ethyl mercuric chloride appeared to be superior to the same concentration of ethyl mercuric oleate.

Both of the phenolic treatments used in this series were subsequently tried on pine in separate noncompetitive tests in order to investigate further their commercial potentialities. The maximum stain recorded for the treated material in these instances was 1 percent of the sapwood, while the minimum of stain in the untreated material was 36 percent of the sapwood.

A final series of tests, D, on pine, using generally higher concentrations of the chemicals to correspond with those coming into general commercial usage toward the end of the testing program, is summarized in table 14. A previously untried chemical, sodium pentachlorophenolate, is incorporated. The results are similar to those of the preceding series. The phenolates were more consistent in the amount of control provided than ethyl mercuric chloride. However, the latter was very effective in two of the four tests. There appears to have been little practical difference in results obtained with the two phenolic mixtures and with sodium pentachlorophenolate. The protection afforded by soda despite the fact that the tests were with cold solutions is somewhat surprising in view of results obtained in previous tests. But it should be kept in mind that a higher concentration was used than formerly.

TABLE 14.—*Effectiveness of chemical treatments on southern pine lumber in commercial-scale test series D*

| Chemical | Concentration | Sapwood in pile stained [1] in test No.— | | | |
|---|---|---|---|---|---|
| | | 20 | 21 | 22 | 23 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Ethyl mercuric chloride [2] | 0.018 | 3 | 17 | 0.1 | 21 |
| Ethyl mercuric phosphate [2] | .018 | | | .4 | |
| Sodium pentachlorophenolate | .9 | | 3 | 1 | 9 |
| Do | 1.2 | .5 | | | |
| Sodium tetrachlorophenolate +sodium o-phenylphenolate | 0.75+.25 | .7 | 1 | | |
| | .9 +.3 | | | .3 | |
| Sodium tetrachlorophenolate+sodium 2-chloro-o-phenylphenolate | .5 +.5 | 2 | 2 | 2 | 5 |
| Soda | 8.34 | | | .1 | 6 |
| Untreated | | 31 | 42 | 53 | 66 |

[1] Stain percentages above 1 given as nearest whole number.
[2] See footnote 20, p. 41.

## COMMERCIAL-SCALE TESTS OF CHEMICAL TREATMENTS ON RED GUM AND OTHER HARDWOODS

Results of commercial-scale dipping tests on red gum lumber are presented in table 15. As with the pine tests, each series represents a different year.[25] The outstanding feature of these results is that

[25] In all gum tests except Nos. 2, 3, and 4 the chemicals were applied in cold solution.

the treatments used were either definitely good or definitely poor in controlling stain.

At concentrations tested, the most satisfactory materials were as follows: Ethyl mercuric chloride, ethyl mercuric phosphate, sodium tetrachlorophenolate, and borax. Slightly less effective were ethyl mercuric oleate and the mixtures of sodium tetrachlorophenolate and sodium 2-chloro-o-phenylphenolate. Soda, sodium o-phenylphenolate, a mixture of sodium o-phenylphenolate and sodium tetrachlorophenolate, and sodium 2-chloro-o-phenylphenolate permitted considerably more stain than the others mentioned.

TABLE 15.—*Effectiveness of chemical treatments on red gum lumber in commercial-scale tests*

| Test series and chemical [1] | Concentration | Sapwood in pile stained [2] in— | | | |
|---|---|---|---|---|---|
| | | Test 1 | Test 2 | Test 3 | Test 4 |
| Series A: | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Borax | 5 | ------ | 0 | 0.6 | 1 |
| Soda | 5 | 38 | ------ | | ------ |
| Ethyl mercuric chloride | .010 | 3 | .1 | ------ | 1 |
| Ethyl mercuric phosphate | .007 | 2 | .1 | .7 | .9 |
| Sodium o-phenylphenolate | .24 | ------ | ------ | 59 | ------ |
| Untreated | ------ | 23 | 12 | 92 | 59 |

| Test series and chemical [1] | Concentration | Sapwood in pile stained [2] in— | | |
|---|---|---|---|---|
| | | Test 6 | Test 7 | Test 8 |
| Series B: | *Percent* | *Percent* | *Percent* | *Percent* |
| Borax | 5 | 0.9 | 0.1 | 0.2 |
| Ethyl mercuric chloride | .012 | 0 | .1 | .2 |
| Sodium tetrachlorophenolate | .48 | .7 | .4 | .6 |
| Sodium o-phenylphenolate +sodium tetrachlorophenolate | .24 +.24 | ------ | ------ | 29 |
| Untreated | ------ | 46 | 36 | 96 |

| Test series and chemical [1] | Concentration | Sapwood in pile stained [2] in— | | |
|---|---|---|---|---|
| | | Test 9 | Test 11 | Test 15 |
| Series C: | *Percent* | *Percent* | *Percent* | *Percent* |
| Ethyl mercuric chloride | 0.012 | 0.2 | ------ | ------ |
| Ethyl mercuric oleate | .012 | 4 | ------ | ------ |
| Sodium 2-chloro-o-phenylphenolate | .6 | 39 | 13 | 1 |
| Sodium tetrachlorophenolate | .6 | .4 | .6 | .6 |
| Sodium tetrachlorophenolate +sodium 2-chloro-o-phenylphenolate | .3 .3 | 5 | 2 | ------ |
| Untreated | ------ | 82 | 27 | 85 |

| Test series and chemical [1] | Concentration | Sapwood in pile stained [2] in test 20 |
|---|---|---|
| Series D: | *Percent* | *Percent* |
| Borax | 4 | 0.7 |
| Ethyl mercuric chloride | .018 | .1 |
| Ethyl mercuric phosphate | .018 | .1 |
| Sodium pentachlorophenolate | .91 | .3 |
| Sodium tetrachlorophenolate | 1.03 | .3 |
| Sodium tetrachlorophenolate +sodium 2-chloro-o-phenylphenolate | .5 .5 | 4 |
| Untreated | --- | 75 |

[1] See footnote 20, p. 41.
[2] Stain percentages above 1 percent given as nearest whole number.

In some of the tests a number of other hardwoods were included along with red gum. These furnish more concrete evidence regarding the suitability of red gum as a test material for hardwoods in general. The results, which are summarized in table 16, indicate that, practically speaking, the treatments that were effective against sap stain in red gum are also about equally effective on yellow poplar, magnolia, oak, and beech. There is some indication that yellow poplar and beech may be slightly less benefited by the treatments used, but the evidence is not conclusive. The poor results in some instances with oak are believed to be due largely to log-stained material, which was unavoidably included at the time the tests were established.

The two treatments that were relatively ineffective on gum, namely, sodium o-phenylphenolate, and sodium o-phenylphenolate in mixture with sodium tetrachlorophenolate, were probably no more effective on the other hardwood species, at least at the concentration used. The first treatment also failed on yellow poplar and the second, while tested on oak, can hardly be said to have been successful in view of the negligible amount of stain in the untreated stock.

TABLE 16.—*Comparison of effectiveness of chemical treatments on different southern hardwoods*

| Chemical | Concentration | Test No. | Sapwood in pile stained[1] | | | | |
|---|---|---|---|---|---|---|---|
| | | | Gum | Poplar | Magnolia | Oak | Beech |
| | *Percent* | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Borax | 5.0 | 3 | 0.6 | 6 | | | |
| | | 4 | 1 | 2 | 1 | 8 | |
| | | 6 | .9 | .2 | | 1 | |
| | | 7 | 0 | | | .4 | |
| | | 8 | .2 | | | 0 | |
| Average untreated | | | 66 | 23 | 3 | 7 | |
| Ethyl mercuric chloride | 0.010 to 0.012 | 2 | .1 | 0 | .9 | | |
| | | 4 | 1 | 7 | 2 | 17 | |
| | | 6 | 0 | 0 | | 0 | |
| | | 7 | 0 | | | .1 | |
| | | 8 | .2 | | | 0 | |
| | | 9 | .2 | | | | |
| Average untreated | | | 55 | 6 | 3 | 7 | |
| Ethyl mercuric oleate | 0.012 | 9 | 4 | 9 | 1 | 2 | 11 |
| Average untreated | | | 82 | | 25 | 13 | 78 |
| Ethyl mercuric phosphate | 0.007 | 2 | .1 | 0 | 0 | | |
| | | 3 | .7 | 2 | | | |
| | | 4 | .9 | 1 | .9 | .3 | |
| Average untreated | | | 54 | 31 | 3 | 11 | |
| Sodium o-phenylphenolate | 0.24 | 3 | 59 | 13 | | | |
| Average untreated | | | 62 | 56 | | | |
| Sodium o-phenylphenolate+sodium tetrachlorophenolate. | 0.24+0.24 | 8 | 29 | | | 0 | |
| Average untreated | | | 96 | | | .1 | |
| Sodium tetrachlorophenolate | 0.48 to 0.6 | 6 | .7 | 0 | | .3 | |
| | | 7 | .4 | | | .2 | |
| | | 8 | .6 | | | 0 | |
| | | 9 | .4 | | | | .4 |
| Average untreated | | | 64 | 6 | | 6 | 78 |
| Sodium tetrachlorophenolate+sodium 2-chloro-o-phenylphenolate. | 0.3+0.3 | 9 | 5 | | .5 | 2 | |
| Average untreated | | | 82 | | 25 | 13 | 78 |

[1] Stain percentages above 1 percent given as nearest whole number.

Speaking strictly from the standpoint of amount of sap stain eliminated, the sap gum lumber seems to have benefited most from chemical treatment. Treated gum developed little or no more stain than the other treated hardwood species but, with the exception of beech, was much more severely attacked in the absence of treatment. It appears from this that a species that has a natural tendency to stain badly is not necessarily more difficult to treat successfully than an inherently less susceptible species. Complete elimination of sap stain seems to be about as difficult in either case.

### CONTROL OF MOLD

Development of mold on red gum or other hardwoods treated with any of the better antistain chemicals usually was so slight as to be unimportant. Molding was not so readily controlled on pine but, fortunately, was limited to a satisfactory degree by most of the treatments that were effective against stain.

From the accumulated evidence, sodium tetrachlorophenolate, sodium pentachlorophenolate, and mixtures of the former with sodium 2-chloro-o-phenylphenolate or sodium o-phenylphenolate, might be placed at the top of the list of tested materials as mold preventives. Somewhat less effective at times, but nevertheless for the most part giving a high degree of control, are sodium 2-chloro-o-phenylphenolate and soda. Sodium o-phenylphenolate and the organic mercurials are somewhat less effective against mold than those mentioned. *Penicillium capsulatum* Link or related species frequently grow on lumber treated with organic mercurials.

The fluorides were the only effective pine treatments that consistently permitted objectionable mold development. Ammonium fluoride and sodium fluoride were notably unsuccessful in this respect. There was some evidence that these treatments when used alone or in combination with other chemicals actually stimulated certain types of molds while controlling other types. Likewise, some of the poorer pine treatments appeared to stimulate certain molds; for example, borax, boric acid, sodium bisulfite, arsenic trioxide, arsenic pentoxide, sodium benzoate, and benzoic acid. In the case of borax and boric acid, the common varieties of molds apparently were controlled, but a smoky-gray species was so constantly associated as to serve to identify these treatments.

### CONTROL OF STAIN IN BULK-PILED STOCK

Many small pine mills in the Southern States allow certain items that accumulate slowly to lie, solid-piled, in front of the seasoning-pile foundations for a number of days at a time. Some small mills would like to bulk their kiln material for from 10 to 30 days until sufficient amounts accumulate for a full charge. In many cases, particularly in localities where hauling is difficult in rainy weather, there would be a definite advantage to bulk-piling stock a short time prior to bringing it to concentration yards. Furthermore, bulk-piled green stock of certain types is sometimes shipped by boat by both southern and west-coast mills. Therefore, the effectiveness of chemical treatments in controlling sap stain under the severe conditions imposed by bulk piling has definite practical aspects.

In studying the effectiveness of treatments under conditions of bulk piling, freshly cut shortleaf pine lumber was dipped by hand in solutions of a number of the antistain materials and immediately solid-piled. The results of the first of these tests are summarized in table 17. Satisfactory control of stain was accomplished by several treatments for as long as 7 weeks. Ethyl mercuric chloride proved effective in the test extending 14 weeks, but failed in the 7-weeks test. This discrepancy is probably explainable by the fact that the treated stock was uncovered in the 7-weeks test and covered in the 14-weeks test. Judging from the 7-weeks test, the other organic mercurials appear to have been even more effective than ethyl mercuric chloride. A 6.7-percent solution of soda was virtually unsurpassed in this same test. Only soda and the chlorinated phenolate mixture had any important effect on mold development. The molding permitted by the organic mercurials, although widespread in area, was not heavy. Twenty-one weeks apparently were too long for any of the treatments.

The results of the 7-weeks and the 14-weeks tests indicate that for shorter bulking periods, possibly not exceeding 4 weeks, good control of sap stain may be obtained with a number of the treatments employed. It seems advisable to cover the piles.

TABLE 17.—*Stain, mold, and decay occurrence in bulk-piled shortleaf pine lumber*

| Period bulk-piled (weeks) | Chemical in which lumber was previously dipped | Concentration | Sapwood stained | Sapwood molded | Sapwood decay | Remarks |
|---|---|---|---|---|---|---|
| | | *Percent* | *Percent* | *Percent* | | |
| 7 | Ethyl mercuric chloride | 0.015 | 25 | 20 | None visible with any treatment. | Piles uncovered. |
| | Ethyl mercuric chloride<br>+phenyl mercuric acetate | .009<br>.009 | .2 | 25 | | |
| | Phenyl mercuric oleate<br>+phenyl mercuric acetate | .015<br>.015 | 1.6 | 36 | | |
| | Sodium tetrachlorophenolate<br>+sodium 2-chloro-o-phenylphenolate | .48<br>.48 | 7 | 0 | | |
| | Soda | 6.7 | .4 | 2.4 | | |
| | Untreated | | 77 | 39 | Substantial amounts visible. | Do. |
| 14 | Ethyl mercuric chloride | .015 | 1 | 44 | None visible with either treatment. | Piles covered. |
| | Sodium tetrachlorophenolate<br>+sodium 2-chloro-o-phenylphenolate | .48<br>.48 | 20 | 2 | | |
| 21 | Ethyl mercuric chloride | .012 | 93 | (1) | Various amounts with all treatments. | Piles incompletely covered. |
| | Ethyl mercuric chloride<br>+sodium tetrachlorophenolate<br>+sodium 2-chloro-o-phenylphenolate | .006<br>.19<br>.19 | 68 | | | |
| | Sodium tetrachlorophenolate<br>+sodium 2-chloro-o-phenylphenolate | .38<br>.38 | 28 | | | |
| | Soda | 5 | 65 | | | |

[1] Not readily distinguished from stain and decay.

Successful control of stain during the bulking period does not indicate how lumber so treated and handled will turn out when subsequently placed in the seasoning pile to dry. Therefore these tests were followed by others in which lumber that had been preliminarily treated and bulked for periods of 2 and 4 weeks was randomly mixed in air-seasoning piles with freshly dipped lumber and the comparative amounts of stain on each observed at the completion of seasoning. The results corroborated previous conclusions, that properly treated fresh lumber may be bulked for as long as 4 weeks without the occurrence of objectionable stain. In the seasoning pile no more stain developed in the stock that had been bulk-piled than in the stock that had been piled immediately following dipping. Unfortunately, however, due to very favorable drying conditions the air-seasoning portion of the test was not severe enough to disclose whether previous bulking is apt to jeopardize stain control in the seasoning pile during poor drying weather.

## SOME CONSIDERATIONS IN GATHERING STAIN DATA

In order to determine whether surfacing would reveal a different order of effectiveness for the several treatments from that indicated by the rough lumber, all boards from a number of the commercial-scale test piles were surfaced and a second recording made of the amounts of stain. The differences between corresponding data in the two sets of observations are brought out in figure 3. It is evident that, although quantitative differences between treatments were not altogether alike on the rough and surfaced lumber, the order of effectiveness in all four tests was essentially the same except in the case of sodium o-phenylphenolate in test No. 3. With the exception of some of the soda-treated stock, the amount of stain in three of the four tests was variously greater on the surfaced lumber than on the rough. Although the differences were small in a number of cases, tendencies of the same sort may be common in view of the fact that both drying out of the wood and the presence of the chemical ordinarily place greater restrictions on the development of the stain fungi at the surface. On the other hand, if surface drying is comparatively slow the greater amount of stain may be close to the surface, where infection takes place; this may have been the situation in the case of test No. 1. The inconsistent trends (with reference to the other treatments) in the case of the soda-treated lumber in tests 2, 3, and 4 may have been due to the fact that in those tests penetration was increased by using hot dipping solutions, the effect of which, judging from tests already described, might be presumed to have particularly benefited the soda treatment.

The greatest differences between amounts of stain on the rough and surfaced lumber occurred with the untreated stock. These results point to the conclusion that with a series of several tests rough lumber can be relied upon to disclose the most effective treatments. However, where a very limited number of tests are involved, it might be advantageous to extend the observations to the surfaced material.

Parts of several test piles also were examined to determine whether significant and consistent differences in staining occurred on the upper and lower surfaces of the boards. From the summary of results (table 18) it is evident that in no case was the order of effectiveness of the treatments importantly affected by the side of the boards from which the stain notes were taken. Quantitative differences were greatest in the cases of the soda treatments and the untreated gum stock, although in the former they were not consistent. For all other cases the greatest difference in percentages of stain observed on the top and bottom surfaces was 3.

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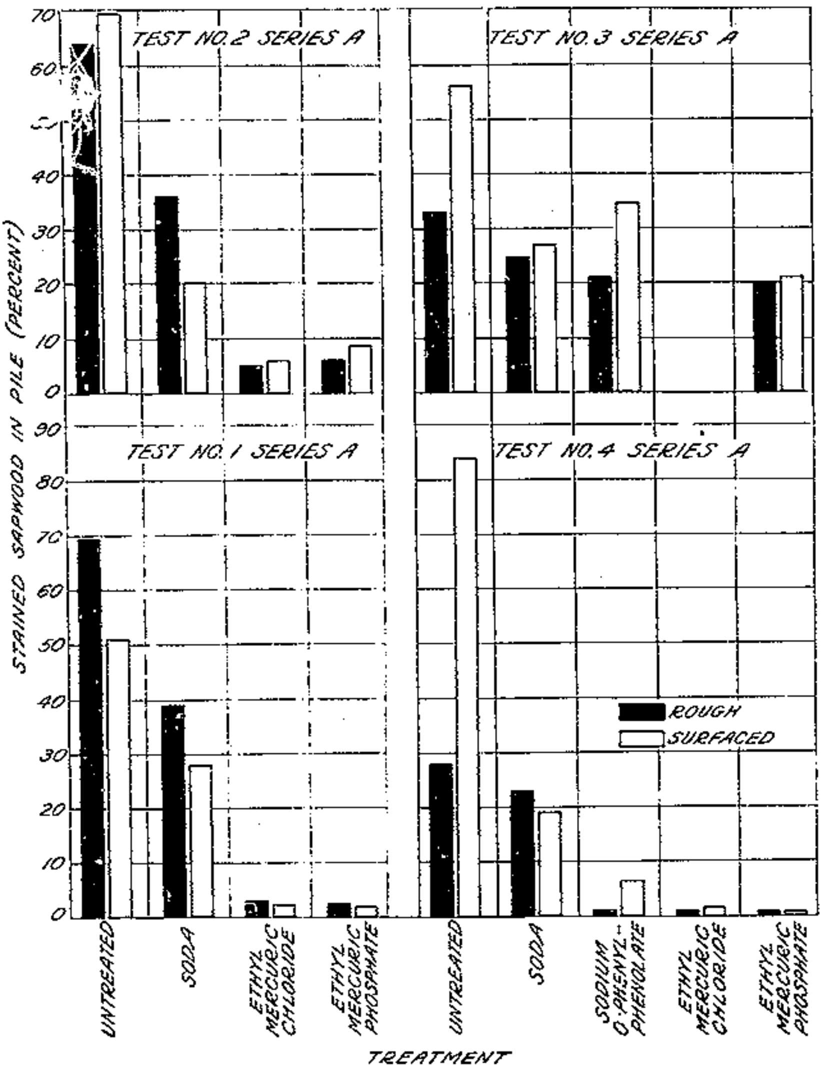



FIGURE 3.—Amounts of sap stain showing on southern pine lumber before and after surfacing.

TABLE 18.—*Stain occurrence on upper and lower surfaces of 1-inch boards in the same seasoning piles*

| Chemical | Sapwood stained[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Southern pine in test No.— | | | | | | Red gum in test No. 2 | |
| | 1 | | 2 | | 3 | | | |
| | Upper surface | Lower surface | Upper surface | Lower surface | Upper surface | Lower surface | Upper surface | Lower surface |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Borax | ----- | ----- | ----- | ----- | ----- | ----- | 0 | 0 |
| Soda | 39 | 50 | 36 | 9 | 5 | 2 | ----- | ----- |
| Ethyl mercuric chloride | ----- | ----- | 5 | 6 | ----- | ----- | .1 | .3 |
| Ethyl mercuric phosphate | ----- | ----- | 6 | 8 | ----- | ----- | .1 | .1 |
| Sodium o-phenylphenolate | ----- | ----- | ----- | ----- | 1 | .6 | ----- | ----- |
| Untreated | 69 | 72 | 64 | 64 | 13 | 14 | 12 | 21 |

[1] Upper-surface percentages are based on observations of all boards in each pile. Lower-surface percentages are based on a representative portion of the boards in each pile and are computed from the ratios of percentages of stain on upper and lower surfaces of the respective samples.

The reason for differences of this sort, which seem to be rather consistent throughout any test pile in which they occur, is not clear. They are no doubt related partly to differences in rate of drying at the upper and lower surfaces; in addition the chemical itself may be an influencing factor. However, such differences appear to be so small on the average as to be practically unimportant. On the whole, the data suggest that top-surface observations will usually be sufficient for tests in which moderately large differences in effectiveness of the treatments are likely, or for elimination tests in which it is desired simply to separate poor treatments from good ones, as was the case in most of the tests reported. On the other hand, when separation of treatments known to be comparatively high in effectiveness is aimed at, the advisability of observing both surfaces should be considered.

## CHOICE OF CHEMICAL TREATMENT

Three of the more recent treatments herein reported have been placed in extensive commercial use with outstanding success (pl. 5). Lignasan (ethyl mercuric chloride plus inerts)[26] and Dowicide P (mixture in equal proportions of sodium tetrachlorophenolate and sodium 2-chloro-o-phenylphenolate plus excess alkali) are used for treating both softwood and hardwood stock. The third treatment, Dowicide H (sodium tetrachlorophenolate plus excess alkali), is distributed for use on practically all species except southern pines in the immediate Gulf territory. Although a number of the organic mercury compounds appear to be suitable for commercial use, ethyl mercuric chloride has been favored by the manufacturers for technical reasons. At the present time, however, ethyl mercuric phosphate is being used to an increasing extent in place of the chloride

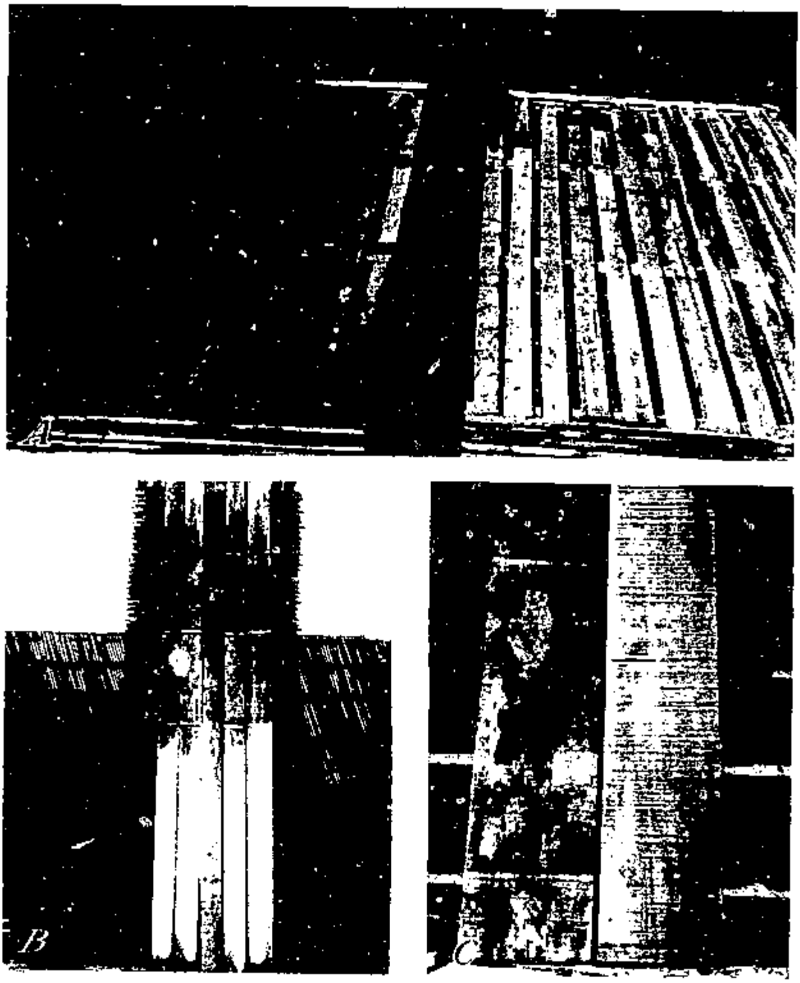
[26] Trade names are given to augment the utility of the discussion to readers actively engaged in stain control. However, it should be kept in mind here and elsewhere in the bulletin that the composition of materials designated by trade names may not always be the same as at present; therefore past experience with a proprietary product can be used as a basis for judging future effects or results only insofar as its chemical composition remains unchanged.

compound and may eventually replace it. Borax is also available in commercial quantities for treatment of hardwoods, but at present is not promoted for this purpose. Dowicide G and Santobrite (sodium pentachlorophenolate plus excess alkali), the newest of the better antistain materials tested, have come into commercial use more recently. These are employed on both hardwoods and softwoods and, to date, have given results comparable to those obtained with the treatments just mentioned. In addition to the newer treatments soda is being used on pine lumber.

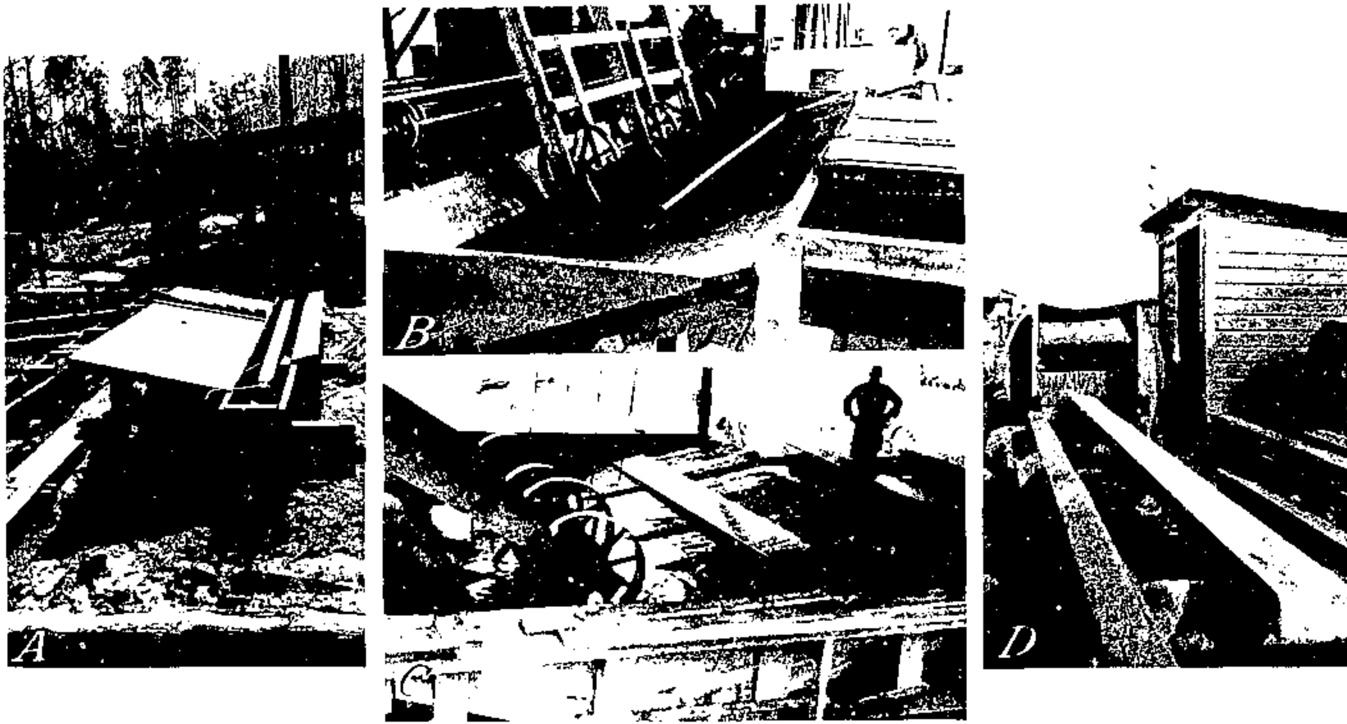
In spite of certain differences in effectiveness noted in the testing program, the question of the relative desirability of the several treatments cannot be answered on the basis of these alone. In the first place the tests were not extensive enough to bring out the full range of possibilities of the different treatments, nor were they altogether consistent. There is considerable evidence in the results of the tests, and of subsequent commercial usage, that the comparative effectiveness may in no small degree be governed by several factors, chief among these being the drying conditions attending the stock in the seasoning pile. In addition there are other considerations to be evaluated, such as the effect on workmen coming in contact with them and effectiveness against molds.

The limited experimental information at hand indicates that in connection with normal mill practices neither the organic mercurial nor the chlorinated phenolates are likely to be absorbed through the skin in sufficient amounts to cause internal injury. However, until further experimentation or service records show definitely that this is the case the possibility of its occurrence cannot be discounted. Actually there have been, so far as is known, no cases of such injury during the 7 years in which the former material has been in commercial use, or during the 5 years in which two of the phenols have been in use. Sodium pentachlorophenolate has not had adequate time to demonstrate its potentialities in this respect. Soda and borax would be expected to be free of hazard along this line. All of these chemicals, with the exception of soda and borax, may cause severe local burns if they come in contact with the skin in the concentrated powder or solution form, particularly if the skin is damp with perspiration and the pores are open. For this reason they must be handled with care, and weighed out in a well-ventilated place.

In solution, at recommended concentrations, ethyl mercuric chloride and borax can be handled with no observed difficulty; soda may have a caustic action, causing the skin on the hands to become tender and crack open on the palms, but this is apparently never more than painful. On the other hand, solutions of the chlorinated phenolates may cause rather severe blistering and swelling of the skin if the person contacting them happens to be susceptible to chemicals of this type. This may not cause difficulty at mills where mechanical dipping equipment is used, but it frequently is troublesome at hand-dipping operations where it is the practice of the vat operator to place his hands in the solution to remove the lumber. In such cases it may not be feasible to use the phenolates unless protective devices, such as rubber gloves or gauntlets and possibly a waterproof apron, are worn. Generally recommended practices in connection with the use of the phenolates are to select resistant individuals for work at



Examples of stain control obtained with the aid of some of the newer chemical treatments. *A*, Pine piles with dipped (right) and undipped (left) lumber at the end of 90 days' seasoning. The marked contrast in stain development indicates what can be accomplished by chemical treatment. *B*, Red gum sapwood boards, half portions of each of which were dipped and the remainders left untreated. This is a simple way of demonstrating treatment effectiveness. *C*, Treated and untreated red gum sapwood boards taken from comparable positions in adjacent test piles after seasoning for 120 days.



Treating equipment. *A*, Well-designed hand-dipping vat. Commendable features are the splashboard and ample drain apron. Cleats on the drain apron hold the boards partly on edge, thus hastening draining. *B* and *C*, Mechanical dipping vats, of simple design suited to both semiportable and large mills. Note that only a small amount of solution is needed to obtain complete coverage of the boards. *D*, Common type of mechanical timber spray.

the vat and for handling the wet lumber, to avoid splashing of solution in the face, and to use protective coverings. A more detailed discussion of precautions, particularly for hand dipping, is given on page 82.

The chlorinated phenolates are known to be more persistent than ethyl mercuric chloride and hence are effective in protecting lumber in the seasoning pile over somewhat longer periods. This characteristic seems to be of advantage largely in cases of pine seasoning requiring more than the usual time in drying. In the case of hardwoods, the mercurial and the phenolates appear to work equally well, even over extended seasoning periods. Borax, although not in commercial use, would be expected to rank close to these chemicals in effectiveness. Soda appears to give generally satisfactory results on pine stock at a concentration of at least 7 percent but not at lower concentrations such as have been prevalent in the past; application in hot solution seems necessary for best results.

Where molds on pine are an important problem the phenolates and soda may be more suitable. As has been pointed out, the organic mercurials show some weakness in combating certain of the mold fungi.

Although the cost per gallon of solution is not greatly different the amounts of chemical required in the preparation of effective solutions vary considerably. In general, 1 pound of Lignasan is needed per 50 gallons as compared with 3 to 4 pounds of the phenolates, approximately 15 pounds of borax, and about 30 pounds of soda. Quantity differences may in some cases be a consideration in the handling and storage of these materials.

This brief discussion of the characteristics of the present commercial sap-stain treatments will serve to show that choice of material may rest on a number of factors, all of which must be evaluated as a whole. If the decision rests solely on the comparative ability of the treatments to control sap stain it is suggested that the mill operator conduct his own tests to determine whether any important differences are likely to be encountered in this respect at his particular plant. To be of value such tests should be established at one time, so that seasonal climatic differences do not influence the results. Results obtained with a treatment in one month or year cannot be compared with the results obtained with a second treatment tried in another month or year. The test piles should be placed adjacent to one another, away from the border of the seasoning yard, and comparably closed in with other piles, in order to subject them to as nearly the same drying conditions as possible. If the seasoning factors surrounding the treated material can be made reasonably uniform and the tests properly established at a critical time of year for stain occurrence, few test piles may be needed to furnish the desired information.

Also tests can be established in which boards treated with different chemicals are mixed in the same seasoning pile. This method has definite advantages but requires special care to see that the treatments are so distributed as to subject all to the same drying conditions. Furthermore, dry stickers or stock stickers all treated with the same chemical, must be employed. If no more than three treatments are being compared a good procedure is to keep them in separate courses and regularly alternate the respective courses as the seasoning pile is erected.

No matter what plan is followed, it is desirable to hand-dip the test lumber in a small vat. Not only will less chemical be required but accurate preparation of the dipping solutions can be more easily assured. A few carefully established test piles are far better than a large number of questionably treated ones.

## PRACTICES AND PRECAUTIONS ESSENTIAL TO SUCCESSFUL USE OF CHEMICAL TREATMENTS

The first essential for fullest returns from the use of a chemical treatment on stock that is to be air-seasoned is to see that it is as free from stain as possible when it comes from the log. The second essential involves prompt and adequate treatment following sawing, with continued care to see that the treatment remains intact up to the time the lumber is placed in the seasoning pile. A third important requirement is to provide good drying conditions in the seasoning pile. With regard to the latter point, it cannot be emphasized too strongly that the chemical treatment must be regarded simply as an aid to good air seasoning in controlling stain and not as an antidote for poor seasoning practices. None of the present chemicals are sufficiently effective to compensate fully for very poor drying conditions; therefore, if successful stain control is to be expected at all times of the year, the mill operator must maintain reasonably high standards of air seasoning. Practices and precautions that should be observed in the treatment and handling of treated lumber are covered in the following paragraphs.

### STAIN-FREE LOGS

Logs must be essentially free from stain if best results are to be obtained with chemical treatment of lumber cut from them. As previously pointed out, stains that are already present in the lumber at the time of treating will remain as permanent discolorations and may continue to spread during the seasoning period. Control of log stain is discussed in the section beginning on page 86.

### PROMPT TREATMENT

It is extremely important that the lumber be treated as promptly as possible after it is sawed. Re-saw mills and mills that dip lumber at a concentration yard are most apt to find difficulty in avoiding critical delays in dipping. In certain cases where seasoning conditions are severe, visible discolorations may appear as early as 72 hours following sawing. In summer-cut, bulk-piled pine stock, "spot" staining may be expected after 5 days; and not infrequently the larger fruiting structures of the causal fungi can be seen at this time. These observations provide indirect evidence that little time elapses between the time the lumber is sawed and the time infection with stain organisms occurs.

Delays in dipping are especially apt to result in objectionable interior stain (p. 26), even though the surface discoloration, because of the presence of the chemical, may not develop to serious proportions. This is brought out by the results of a series of tests (table 19) in which dipping of some of the lumber was delayed for as long as a week. Similar tests in the laboratory, employing inoculated wood and longer periods very favorable to staining, resulted in bright wood when dipping was not delayed more than 24 hours, but a delay of 48 hours permitted from 5 to 25 percent surface stain and from 20 to 75 percent interior stain.

TABLE 19.—*Increase in amounts of stain in air-seasoned 1-inch shortleaf pine lumber as a result of delays in dipping*[1]

| Delay in dipping (days) | Some insects in logs at time of sawing, but very little sap stain | | Logs free from insects and stain | |
|---|---|---|---|---|
| | Sapwood stained in— | | Sapwood stained in— | |
| | Rough lumber | Same lumber after surfacing | Rough lumber | Same lumber after surfacing |
| | *Percent* | *Percent* | *Percent* | *Percent* |
| 0 | 0.7 | 0 | 0.1 | 1.2 |
| 1 | .4 | 40 | .5 | .3 |
| 2 | 1.3 | 61 | .1 | 1.3 |
| 3 | ------ | ------ | 1.5 | 34 |
| 4 | 3 | 82 | .2 | 26 |
| 5 | 5 | 75 | .4 | 21 |
| 6 | 6 | 69 | 3 | 33 |
| 7 | 8 | 60 | 5 | 50 |

[1] Percentages based on the results of 1 to 3 tests. All lumber in each test was placed in the same seasoning pile to reduce seasoning differences. Material bulked prior to dipping.

These results are readily explainable from laboratory observations of the rate of penetration of stain fungi and the depth to which the chemical penetrates the surface layers. As previously noted (p. 26), at optimum temperatures and moisture conditions, *Ceratostomella pilifera* was able to pentrate southern pine sapwood at an average rate of 0.02 inch (0.5 mm.), 0.04 inch (1 mm.), and 0.20 inch (5 mm.) daily in the tangential, radial, and longitudinal directions, respectively. The corresponding average penetrations of several chemicals in water solution were 0.08 inch (2 mm.), 0.08 inch (2 mm.), and 0.28 inch (7 mm.), about four, two, and one and one-half times the respective depths reached by the fungus in a day. While the average depth of hyphal penetration after 48 hours was usually less or no greater in the tangential and radial directions than that reached by the solution, maximum hyphal spread was often greater than the recorded maximum depth of the solution.

It is evident that 2 days approaches and sometimes exceeds the maximum period that dipping can be safely delayed; 1 day is more certain to give the desired results. In some localities there are no doubt times in colder weather when dipping might be successfully postponed more than 1 or 2 days, but to do so regularly would involve a risk if control under all conditions is to be expected. Nevertheless, when short delays occasionally cannot be avoided, it is advisable to dip, with a good chance that the treatment will prove worthwhile.

#### PROPER SOLUTION CONCENTRATION

The concentration of the dipping solution recommended by reputable manufacturers of the respective chemicals is designed to give the mill operator adequate protection to his stock with a minimum of cost. Too frequently an attempt is made to reduce the solution strength with the aim of reducing expenses. This practice may work in favorable drying weather, but the risk involved is entirely out of proportion to any benefits received. The comparatively long periods required to air-season lumber preclude the prediction of weather conditions, so that unless at least the minimum recommended solution concentration is employed at all times extensive development of sap stain may be incurred during an unforeseen period of wet weather.

A commendable practice adopted by many operators is to increase the minimum recommended strength of the solution by 25 to 50 percent during seasons in which sap stain would ordinarily be most severe. On lumber, at least, there seems to be little advantage in using any of the present treatments at concentrations greater than one and one-half times those recommended for ordinary seasoning conditions. Thicker stock dries more slowly than 1-inch lumber, and more frequently may require stronger solutions.

A most important adjunct to successful dipping is the use of a mixing tank for preparing the solution. This may be specially constructed or, for small vats, may consist of a 50-gallon barrel. Without a tank into which the requisite proportions of water and chemical can be accurately measured before the latter are placed in the vat, there can be no assurance that the dipping solution is of the proper strength or, conversely, that the chemical is not being wasted. A small error in mixing the newer chemicals may be quite serious since only a small amount of material is used in 100 gallons of water.

A mixing tank of known capacity not only insures that all the fresh solution going into the vat is at proper concentration but also that the concentration throughout the vat is reasonably uniform at all times. No simple method for testing the strength of either the organic mercury or the chlorinated phenolate solutions is available. The low concentrations employed preclude the use of the hydrometer test, which has been the standard means of measuring the strength of soda solutions. The only practicable way of insuring appropriate solutions of chemicals used in low concentrations is to see that every batch of solution introduced into the vat is accurately prepared. As a rule, when the chemical is mixed directly in the vat some time elapses before it becomes uniformly distributed, which would mean that after each charging of the vat a considerable amount of lumber may pass through inadequately treated. The increased use of mixing tanks has aided greatly in improving results from the use of dipping treatments in the Southern States.

As previously pointed out, any iron in the dipping equipment, such as the green chain, tends to react with tannins leached from oak wood, producing an inky discoloration of the dipping solution, which in turn may be imparted to the stock passing through. When treating oak this difficulty can usually be eliminated by adding 1 to 1½ pounds of commercial soda to each 50 gallons of solution in the vat.

## TREATING EQUIPMENT

### THE DIPPING VAT

Dipping of lumber, whether done mechanically or by hand, involves essentially the same type of apparatus, namely, a vat containing the dipping solution through which the material is passed on its way from the saw to the seasoning yard. It is not necessary to discuss dipping vats in detail here since the individual operator will have his own ideas on the construction and location of the vat to suit his particular needs.[27] Nevertheless, a few general notes based on observations of existing equipment may be helpful in avoiding certain mistakes which are frequently not recognized. Mechanically operated vats will be considered first, reserving discussion of hand-operated vats for the section dealing with small-mill operations (p. 83).

For mechanical dipping the vat commonly, but not necessarily, is built into some portion of the sorting table (pl. 6, *B* and *C*). The lumber is carried through the solution on the green chain. Power to the chains passing through the vat is applied in front, in order to bring the slack portion of the chains directly over the treating solution. Sufficient slack should be provided to permit the lumber to be transported deep in the vat, thus avoiding the necessity of carrying an excess of dipping solution. A hanging overhead weight presses the boards against the green chain and down into the solution. At most mills wheels or rolls are employed for this purpose, but occasionally only heavy chains or curved metal bars are used. The wheel or roller types of rider seem to be more satisfactory in most cases, because they are better adapted to insure complete immersion and uninterrupted passage of lumber beneath them. Sometimes small mills are encountered that use no riders at all but simply allow the lumber to drop into the vat with sufficient force to carry it under. This practice commonly results in undue waste of solution because of the splash created each time a board enters the vat. Moreover, if much heartwood is present the boards tend to float over the chains and pile up in the vat. An incline on the discharge side of the vat tilts the boards and catches the excess solution as it drains off, returning it to the vat. The steeper and, within limits, the longer the drain apron, the greater will be the saving of dipping solution. Space requirements of the drain apron should be considered in locating the vat with respect to the sorting table. Following dipping, the lumber is handled in the usual way.

The best dipping vats are no larger than is necessary to handle conveniently the output to be treated; they are constructed to insure at all times complete immersion of the stock in the solution; they permit little waste of solution resulting from splashing and inadequate drainage; and they can be readily charged and thoroughly drained.

The most suitable vat for use in connection with a green chain is probably the shallow V-shaped type or some modification of this. If constructed of heartwood of cypress, oak, or pine, a dipping vat will have sufficient durability and strength to give many years of service.

The desirable capacity for a mechanical dipping vat will depend on the mill output. Generally speaking, the vat should be comparatively small. A small vat permits more space to be devoted to the drain apron, is less expensive to construct, and, because of

[27] Designs for both mechanical and hand-operated vats are available from companies furnishing antistain chemicals.

the limited capacity, tends to keep the dipping solution fresh and up to full strength at all times. For operations cutting from 50,000 to 100,000 board feet daily, a capacity of 500 to 800 gallons of solution should be ample. In any case it should always be possible to dip effectively in as little as 200 to 250 gallons. Assuming that the solution is consumed at the rate of 15 gallons per 1,000 board feet of lumber dipped, a mill dipping 50,000 feet of lumber daily and employing about 600 gallons of solution in the vat as a maximum working volume would have to replenish the solution in the vat only about twice during the day. A vat having less capacity would require more frequent charging, which is not undesirable so long as extra care is taken to see that the solution never becomes so low that lumber passes through incompletely dipped.

The dipping vat should be cleaned frequently if the lumber passing through is to remain free from deposits of sawdust and the fullest advantage is to be taken of its capacity. Also, where oak is dipped, it is believed that prevention of sawdust accumulations will reduce the tendency toward an acid condition of the solution, which is one of the factors involved in iron-tannate discoloration.

Frequent cleaning of vats in which heavy accumulations of sawdust occur is good practice. Small mechanical vats clean themselves to some extent by the sweeping action of the lumber, nevertheless sawdust will accumulate at the ends. In such cases the sawdust can often be scooped out without removing the solution. Larger vats should be drained. This can be accomplished without waste by maintaining a small reservoir tank in which the solution can be temporarily stored.

The proper location for the vat will depend a great deal on the output of the mill, proportion of dipped and undipped items, and available space on the sorting table; hence it is largely a matter of individual requirements. Where possible, mechanical vats fitted into the sorting table should not be located directly below the drop, because this frequently results in an objectionable amount of splashing with attendant loss of solution; also the fall tends to disarrange the lumber so as to cause jamming. By locating the vat at least a short way below the drop not only are such difficulties avoided but an opportunity is provided for pulling lumber not intended to be dipped. Some mills, which kiln-dry a large proportion of the cut, place the vat at the far end of the green chain, reserving most of the sorting table for kiln items. Separation of stock that is to be dipped from that which is not to be dipped often is accomplished with hand- or steam-operated bypasses, permitting the lumber to be carried through or over the vat, as desired. Such an arrangement reduces the length of sorting table needed ahead of the vat.

Where a concentration yard is maintained, it is frequently desirable to have the vat at this point, thus avoiding duplication of dipping equipment and labor. However, this can safely be done only when dipping is not delayed over 24 hours or, at the outside, 48 hours. Gasoline power is commonly used for vats not operated in direct conjunction with the mill.

### SPRAYING APPARATUS

In the Southern States spray equipment is largely restricted to use on timbers and other large items, but Pacific coast manufacturers employing chemical treatments at present seem to favor sprays (*10*) for treating their green and semi-green surfaced fir, hemlock, and spruce export lumber. Choice of a spraying apparatus for treating green lumber instead of the more conventional dipping vat is sometimes necessitated by space limitations in the sorting table. The dipping vat is ordinarily preferable where it can be utilized, because it is more simply constructed and requires less attention during operation to insure thorough treatment.

Mechanical timber sprayers usually are built around the ordinary roller conveyor leading from the mill to the timber dock (pl. 6, *D*). A pump forces the solution from a perforated pipe or from nozzles with sufficient force to cause it to cover all surfaces of the timber passing through the spray box. Excess solution passes through a strainer and drains back into a mixing reservoir. Canvas flaps at the inlet and outlet of the spray box prevent escape of solution at these points.

As with dipping, the principal aim should be to cover the surfaces of the stock thoroughly. To attain this end with mechanical sprays it is necessary that the spray nozzles be so positioned as to direct the streams of chemical against all four sides. If the sprays have sufficient force behind them there will usually be enough splashing in the treatment chamber to take care of areas not directly hit by the outcoming streams.

Care should be taken to see that the spray solution is adequately strained before it is pumped back through the nozzles. It is not uncommon to see some of the spray outlets clogged with sawdust, resulting in incomplete treatment on one or more sides. If such a condition escapes notice for long, considerable stain may subsequently develop. It is a good plan to inspect frequently the freshly sprayed stock for dry areas.

To further insure correct treatment it is desirable that a mixing tank be provided as an adjunct to the spray equipment. As pointed out previously, without a mixing tank there can be no certainty that the water and chemical are accurately combined in the proper proportions. The old solution can be used again, with the addition of enough fresh solution from the mixing tank to keep the reservoir well supplied. For timber sprays, if the catch pan below the spray chamber is extended a few feet on the discharge side, where the stock is still draining, wastage of the chemical can be considerably reduced.

### PROTECTION OF DIPPING SOLUTION AND TREATED STOCK FROM RAIN

Every effort should be made to have a roof over the dipping vat and drain apron; otherwise serious dilution of the chemical may occur during rainy weather. This word of caution is primarily directed to small-mill operations, which of necessity cannot include the dipping vat under the shelter provided for the saw. If requirements of portability or other features preclude the maintenance of such a roof, it should at least be practicable to keep on hand a board or corrugated-iron cover with which to cover the dipping apparatus when it is not in operation. The desirability of a roof to protect the dipping solution is generally underestimated. However, it is not difficult to see the reasonableness of this precaution when one considers that a ½-inch rain, which commonly occurs in the Southern States within

24 hours, may add as much as 25 to 50 gallons of water to the solution in small hand-dipping vats and 100 or more gallons in mechanical vats.

It is especially necessary that lumber be protected from rain washing after it is dipped. Less than an ounce of solution is initially present on each square foot of board surface and, if the newer treatments are used, only 0.25 to 1 part in 100 of this consists of the chemical. Obviously the effectiveness of the treatment may be greatly reduced if dipped stock is exposed to rains that wash off any of the toxic material. Rain washing is commonly very severe along the green chain. Here buggies are often in the rain from the time the first board is loaded on them until they are filled and hauled into the seasoning yard. At some mills this may take a couple of days for certain items. To aggravate the condition, water from the roof covering the green chain in many cases is allowed to run off directly on the buggies below.

The ideal situation for protecting lumber accumulating along the green chain would be, of course, to have the roof over the chain extend out far enough to shelter the buggies. Where this is not practicable, the next best thing is to install gutters on the roof. This in itself should improve matters considerably.

During rainy weather the manner of piling can be arranged somewhat to alleviate the additional stain hazard. Slowly accumulating piles can be given partial protection after each load is added by temporarily inserting extra boards in the topmost course so as to form a continuous layer of lumber.

## CONSTRUCTION AND ARRANGEMENT OF SEASONING PILES

The following is in no sense an attempt to define or analyze the problems of air seasoning. These are fully treated in numerous publications by specialists in this field. The present discussion deals mainly with very general points of air seasoning which are known to have an important bearing on the control of sap stain. Specific suggestions are based largely on data obtained from the Forest Products Laboratory (*52*).

### PILE COVERS

Tests and observations show conclusively that even with treated stock a reasonably rainproof roof over the seasoning pile is to be recommended usually, especially in the South where precipitation is usually plentiful over the greater part of the year. Experimental piles constructed with and without roofs disclosed that a roof is not essential for good stain control during periods of relatively dry weather; but unfortunately, such periods cannot be anticipated with certainty. In a series of seasoning piles containing 1-inch treated southern pine lumber, from which covers were purposely omitted, it was found that none of the treatments had been able to withstand rain wetting in the upper courses to a satisfactory degree. In the upper eight courses, which represented approximately 1,200 board feet in each pile, an undesirable amount of stain occurred which could have been avoided had the protection offered by suitable pile covers been provided. In the same way, unless precautions are taken to prevent it, rain may cause piles which accumulate slowly to become stained throughout. In this connection it is well to keep in mind that narrow piles can be completed more rapidly than wide ones.

Roofs should be raised high enough to allow ample ventilation over the piles. If they are placed too close to the stock, sap stain may actually be promoted because of the resultant retardation of air circulation and seasoning. Normal air movement in green piles is downward; therefore opportunity must be provided for fresh air to come in at the top. Roofs should project about 1 foot at the front and 2½ feet in the rear to minimize rain wetting in the ends of the pile. If the roof is tight a pitch of about 1 inch to the foot will shed water satisfactorily; if the roof is not tight a greater pitch is ordinarily desirable.

### FOUNDATIONS

It is essential to good stain control that there be free circulation of air through and around the bottom of the pile. This calls first

FIGURE 4.—Short sections, 6 to 8 inches in diameter, make good temporary foundations at small mills. Slabs or planks should never be used in place of elevated foundations if stain and decay in the lower portions of the pile are to be avoided.

of all for durable foundations, with proper elevation and slope, and the eradication of weeds and debris around the piles. The use of slab or plank foundations, laid directly on the ground, is hazardous from the standpoint of both fungus and insect damage and should be avoided (fig. 4).

The proper height for foundations depends somewhat on drainage conditions in the seasoning yard and the closeness of piling. Low yards ordinarily need higher foundations than do well-drained yards, but in any case free circulation under all parts of the pile is necessary. Solid-front foundations, which fortunately are not common, should be avoided, because they permit substantially less air circulation than the usual open-front type.

A foundation slope of approximately 1 inch to each foot of length is generally regarded as adequate.

### ALINEMENT AND SPACING OF BOARDS

Most manufacturers of pine lumber recognize the need for regular alinement of their stock to give continuous vertical flues through which air may move freely. This manner of piling substantially reduces the occurrence of sap stain by increasing the rate of seasoning. In cases where sap stain continues to give trouble after proper chemical treatment the situation invariably can be improved by opening up the piles with continuous flues or, where these are already present, by increasing the spacing between boards.

The amount of space to be allotted pine boards is arbitrary. As a rule it does not appear safe to have more than eight 8-inch boards to the course when using 8-foot foundations. At some mills the use of eight or as few as seven boards is favored, particularly in wet seasons. Other widths are given comparable spacing, the wider the board the greater the separation usually needed. Much depends on the rate of drying desired, the local sap-stain hazard, the width of the pile, and the amount of available yard space. Many operators vary the board spacing to suit the drying conditions in different seasons of the year. This practice is a commendable one, especially for localities in which difficulty with sap stains tends to be seasonal.

A common method of further increasing the rate of seasoning is to erect the piles with wide central chimneys (pl. 7, *B* and *C*). For sap-stain control alone, a special vent for pine piles ordinarily is not needed unless the width is greater than 8 feet.

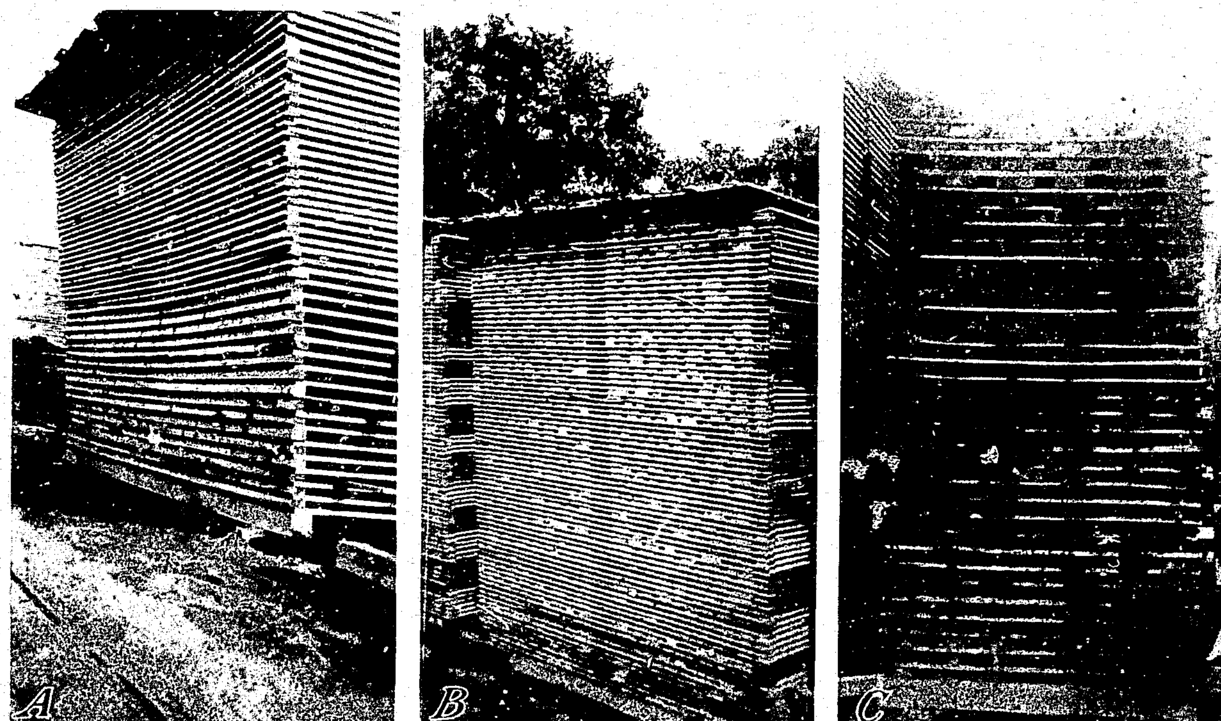
It is standard practice in the Southern States to pile hardwoods in random widths on 6-foot foundations. Because of this there is somewhat less opportunity for modifying piling practices to care for variable sap-stain conditions. Fortunately this is not so necessary with hardwoods as with pine because on the whole they respond more readily to present chemical treatments in periods of adverse drying conditions. At many hardwood mills central chimneys are provided. Very often these taper outward as they go down in the pile, to partly care for the normally poorer drying conditions in the lower courses and also to provide for the greater air drainage in the lower portions of the chimney (pl. 7, *C*). With severe conditions the chemical treatment, in conjunction with a central chimney, or two or three uniformly spaced flues, usually will give adequate control of stain. But if still more ventilation seems necessary, it can often be supplied by using double stickers in portions of the pile that need opening up (pl. 7, *A*).

To retard penetration of rain into the front of the pile it is necessary that the ends of the boards project successively, to give the face of the pile an outward slope of at least 1 inch for every foot of height.

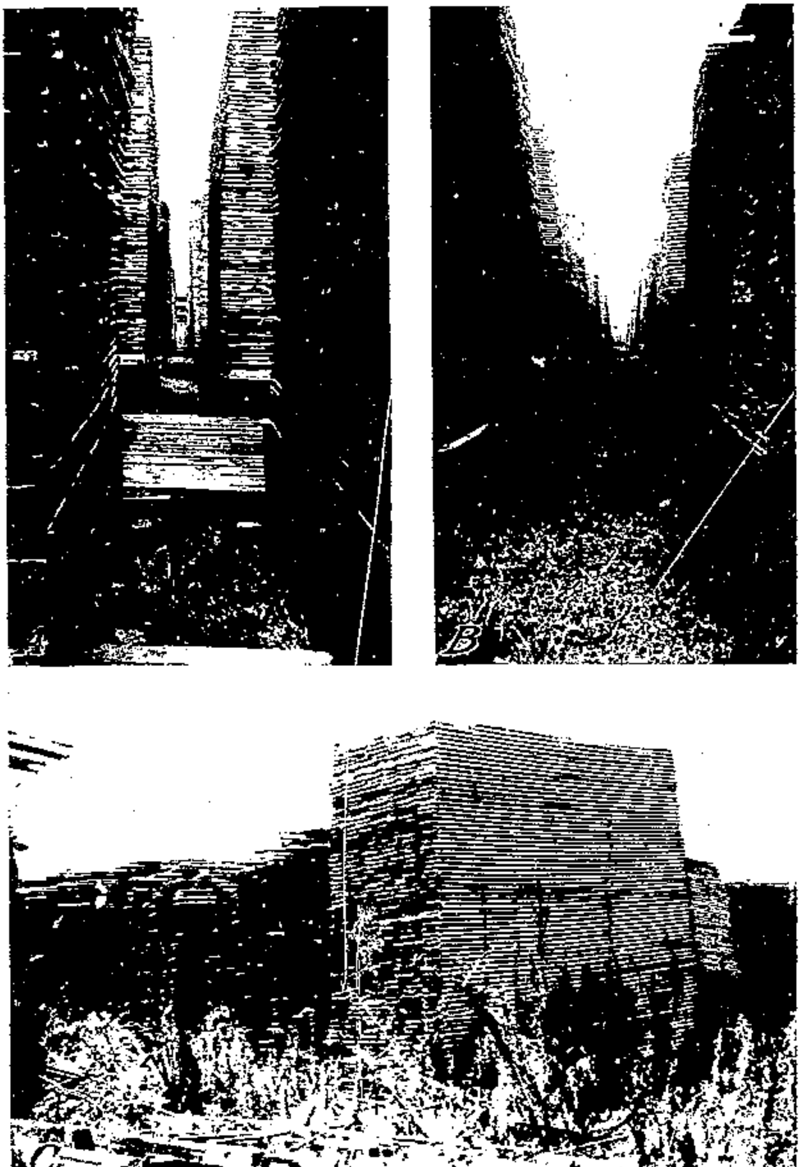
### STICKERS

Separation of courses in the air-seasoning pile is accomplished with narrow seasoned stickers or stickers consisting of the green lumber, commonly of the narrower widths and shorter lengths. The use of seasoned stickers is practically universal with hardwood manufacturers, whereas green-stock stickers are used by softwood manufacturers.

From the standpoint of stain control alone, narrow, dry stickers




Common methods of increasing air circulation in the seasoning pile: *A*, Double or double-thickness stickers are inserted between courses in portions of the pile which dry too slowly; *B*, a central chimney facilitates downward drainage of the moisture as it evaporates from the lumber; *C*, chimney similar to *B* except that it is tapered to give progressively more ventilation as required by seasoning conditions in the pile.




A contrast in seasoning-yard conditions: *A* and *B*, Continuous alleys, free from debris, permit maximum circulation of air around and through the seasoning piles, thereby hastening seasoning and reducing blue-stain damage; *C*, irregularly placed piles and alleys obstructed with weeds and debris favor development of stain.

unquestionably are to be preferred. They cover much less space on the lumber and hence interfere far less with drying. The comparatively wide-stock stickers commonly cover from 12 to 15 percent of the lumber surface, and are themselves covered by the long boards to the extent of 60 to 75 percent of the flat surface. Because of the resultant limitation of drying surfaces a favorable moisture condition for the development of stain fungi is maintained in the lumber for

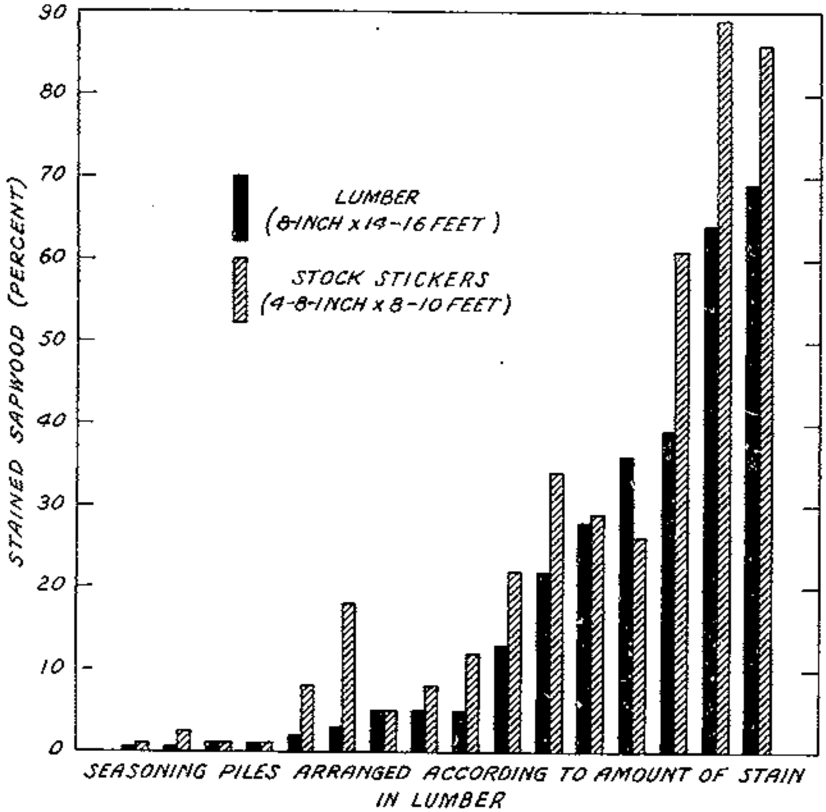



FIGURE 5.—Amounts of sap stain occurring in southern pine lumber and stock stickers from the same seasoning piles.

considerably longer periods than would be the case with narrow sticks, particularly where the boards contact one another.

In order to gain some idea of differences in amount of sap stain likely to be present in green-stock stickers and the rest of the lumber, separate notes were taken on these items in 16 different pine seasoning piles, some containing treated and some untreated lumber. The data, which bear out conclusions reached from the preceding consideration of differences in drying conditions, are given in figure 5.

In only one instance was there less stain in the stock stickers, whereas in at least half of the piles the stickers showed considerably more stain than did the other lumber. Inasmuch as stock stickers commonly comprise 10 to 15 percent, or more, of the total footage in pine piles, it is obvious that the additional stain may be serious.

The preceding is not an argument for the use of special dry sticks in seasoning pine, since it is realized that the inconvenience and cost involved often may be unwarranted. Rather, it is desired to bring out the need for special attention to all other factors important in promoting drying when stock stickers are employed. The disadvantage can be further minimized by limiting the number of such stickers per course. Only under exceptional circumstances, in yards where drying conditions are unusually good, does it appear safe to use more than four with southern pines.

Special narrow sticks are not entirely without disadvantages. Foremost among these is the difficulty of keeping them dry and comparatively free from stain and decay fungi. Since they are used many times they eventually become rotten and break. Long before this, however, infection takes place and, unless a stick in this condition is air dry at the time it is placed in the pile, it is very likely to transmit the sap-stain and decay infection to the sound lumber. Even dipped lumber may at times be susceptible to fungi encountered in this way.

It is uncertain just how special seasoning sticks should be handled to maintain them in a dry condition while they are not in the pile. The least that can be done is to keep them off the ground, which is the first precaution to take in preserving wood of any sort. Some mills maintain simple racks between the foundations, on which to lay the sticks as they are removed from the pile. This appears to be a good practice and promotes a neat-appearing yard. Others believe that the sticks tend to stay drier if they are heaped up in random fashion so as to allow more circulation of air among them. Occasionally the sticks are placed under shelter when they are not in use. This practice should help considerably, but there may be some doubt whether the returns justify the additional cost of handling.

In some instances small portable pine mills use green slabs for stickers. This practice should never be followed if stain control is seriously desired. The presence of bark on slab material encourages not only stain development but also insect damage.

### YARD LAY-OUT

One of the first essentials of a good seasoning yard is that it be located on the driest, best-drained site available and where fullest advantage can be taken of the prevailing winds. In line with the several precautions that have been mentioned for insuring adequate ventilation of the piles, attention should also be given to the arrangement and spacing of the piles on the yard. Piles that are placed in regular rows to form continuous front, rear, and side alleys (pl. 8, *A* and *B*) stand a much better chance of receiving the benefit of general air movements than do piles that are arranged in unsystematic fashion (pl. 8, *C*). Likewise the wider the alleys, the better will be the general circulation of air in the yard.

As to dimensions of the alleys, no specific recommendation can be given. Main alleys are usually laid out in widths of 16 to 20 feet to facilitate transportation and piling of the lumber. These dimensions are at the same time ample from the standpoint of seasoning requirements. Rear alleys vary considerably in width, sometimes being so narrow that piles containing random lengths actually touch one another. Such a condition obviously is conducive to poor air circulation and the development of sap stain. At least 8 feet should be provided to be on the safe side. Similarly, the side spacing between piles differs greatly. This factor is very important so far as stain control is concerned, because it most directly affects the pile along its greater dimension. From 2 to 4 feet side spacing is commonly used at southern mills where chemical treatments are being successfully used. So far as practicable, piles of the same length should be grouped together.

Elevated tramways are sometimes used in the main alleys to facilitate transportation of stock in the yard and to permit erection of higher piles. These tend to retard air circulation, and in some cases there may be a question as to whether their advantages outweigh resultant difficulty in controlling stain.

## USE OF CHEMICAL TREATMENTS AT SMALL MILLS

Although many of the large pine mills in the Southern States have dipped part of their green stock for a number of years, the small sawmills, cutting less than 20,000 board feet per day, until recently have made little use of such treatments. The insistent demand for bright lumber and dimension stock, an increasing dependence on second-growth timber, with its greater amount of stain-susceptible sapwood, general lack of facilities for kiln drying at this class of operation, and the availability of dipping chemicals that can be successfully applied in cold solution have stimulated a large number of small mills to turn to dipping for aid in obtaining a marketable air-seasoned product. This trend not only has benefited the small mills but the entire lumber industry. At present the greater proportion of the pine lumber manufactured in the Southern States comes from small mills, and the percentage output by small mills in western timber regions, although yet small, is increasing. With such a large proportion of small-mill material on the market, it is obvious that it must be of good quality, if public approval of lumber in general is to be maintained at its present level.

### SPECIAL SMALL-MILL PROBLEMS OF STAIN CONTROL

Although the primary requirements are exactly the same, the small sawmill in several respects faces a more difficult problem in controlling sap stain and mold than the large mill. With the exception of certain semiportable types, its power supply is not sufficient to operate a green chain, hence precluding the use of mechanically operated dipping equipment. This leaves hand manipulation as the only recourse when dipping is desired, and raises questions regarding additional labor costs and possible injurious effect of the solutions on the workmen. Dirt roads are more largely depended upon for hauling the freshly cut lumber, a circumstance which in wet weather may prohibit a fixed schedule in transporting dipped stock to the seasoning yard or in transporting the stock to a concentration yard for dipping. Delays in stacking or dipping brought about in this manner present additional hazards in the way of successful use of a chemical treatment.

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Delayed seasoning is also encountered in other connections. For example, it is the small mill which most commonly follows the practice of bulk piling in front of the pile foundations for several days until the lumber can be conveniently stacked. Rain washing in such cases may be detrimental. It is also the small mill which frequently is forced to bulk- or semibulk-pile material for substantial periods, while accumulating dry-kiln charges. Moreover, at some small mills there are further demands on the dipping treatment because of a lack of foundations or roofs, and deficient ventilation in the piles.

### DIPPING PRECAUTIONS

In most instances special small-mill problems can be successfully met without much trouble. The practices and precautions essential to successful use of dipping treatments apply to the small mill fully as closely as to the large mill. Cases necessitating bulk piling for temporary periods can apparently be handled by dipping before bulking and protecting the treated stock from rain.

Dipping should not be delayed more than 1 or at most 2 days after sawing (p. 70). If this cannot regularly be accomplished, a change in handling procedures may be warranted.

Fifty-gallon barrels serve very satisfactorily as mixing tanks in which to prepare accurately the dipping solution. These can be filled in advance with a day's supply of water and hauled to operations where piped water is not available.

To protect workmen engaged in hand dipping, several precautions may be taken. Some of these have been mentioned on page 69. If the mill management is willing to go to sufficient trouble and expense, complete protection can be provided. It is of fundamental importance to see that the hands and forearms do not come in contact with the dipping solution oftener than is absolutely necessary. Heavy rubber gauntlets, such as those manufactured for industrial purposes, are entirely effective when properly used and it is recommended that they be given more extensive trial. Their life can be materially prolonged by washing them free of the chemical at the end of each day, by keeping them out of direct sunlight when not in use, and by employing a little extra care in handling the lumber. At some mills canvas gloves or simply palm pads of leather or belting are worn over the rubber ones; this should strengthen the rubber somewhat and at the same time aid in handling the stock.

At a small mill a simple foot-operated lever arrangement was observed for raising one end of the board out of the dipping vat, where it could be easily grasped without putting the hands into the solution. This apparatus had been in use for several months. Hooks are used to some extent where it is practicable to do so. For handling lumber immediately after it leaves the dip and while it still carries a considerable amount of the solution on the surface, mittens made of rubber inner tubing are sometimes used (fig. 6), so that only the thumbs come in contact with the wet stock.

Often the thighs and legs of workmen become wet with solution as it drains from lumber being removed from the vat by hand. In such cases an apron of heavy belting or other waterproof material should be worn.

## CONSTRUCTION AND USE OF DIPPING VATS AT SMALL MILLS

Most hand-operated vats now in use are little more than wooden troughs (pl. 6, *A*). As a type, little improvement in these seems necessary. However, if waste of the chemical is to be reduced, there should be more extensive use of ample drain aprons and splash boards. The vat illustrated in plate 6, *A*, is an especially good one because it possesses better-than-usual facilities for draining the lumber and for catching solution that splashes over the sides. For operations cutting 5,000 to 10,000 board feet daily, the most practical

FIGURE 6.—Inner-tube mittens which have found some favor as a means of keeping the chemical from the hands while handling freshly treated lumber.

dimensions for a vat of this sort seem to be about 18 by 18 inches by 18 feet or 24 by 24 inches by 20 feet, depending upon board lengths and the maximum rate at which the stock is to be dipped. All the hand vats observed were sufficiently rugged when constructed of 2-inch pine planking.

As a rule, less leakage develops if the ends and bottom of the vat are placed inside the side boards. Bolts are preferable to nails or screws, because they enable the planks to be brought together more firmly, and any looseness that develops in the course of operation or as a result of moving the vat can readily be taken up. Two ⅜-inch bolts passing through the sides and each end section, and similar bolts passing horizontally through the sides and bottom at 18-inch intervals, will give adequate strength and tightness to vats with dimensions comparable to those just mentioned. The strands of a ½-inch cotton rope make good calking material.

At some mills a small roller is placed at the receiving end of the vat, which aids in sliding the lumber into the solution. A roller at the opposite end of the vat is not recommended, because it does not facilitate transfer of the lumber to the drain board; furthermore, it has the disadvantage of allowing more excess solution to be carried out with the boards than if the latter are simply slid over the top of the end section.

The most efficient hand-dipping vats operated in conjunction with the mill are, with no observed exceptions, placed directly behind either the edger or the trim saw, depending upon which operation is performed last or, of course, upon whether the green stock is trimmed. If the vat is also arranged in line with the course of the lumber as it leaves the edger or trim saw, the tail edgerman or off-bearer can readily slip the boards over the near end of the vat into the dipping solution, to be subsequently cared for by the vat operator. At some operations the lumber, instead of being transferred immediately from the edger or trim saw into the vat, is first passed for a short distance over dead rolls. In such cases the vat operator may have to place the material in the vat as well as remove it. When two workmen are required to carry on dipping, the procedure is still much the same except that the men usually stand at opposite ends of the vat and handle the material together. This speeds up the operation considerably, principally by reducing the time required to place the boards on the drain apron and from there on the dollies or loading piles.

After the lumber has been dipped it should be placed on the drain apron for a few seconds before finally disposing of it. To facilitate this, two or three boards may be kept on the apron at the same time, the first on the apron always being removed first. Next the boards are generally placed on dollies standing alongside the drain apron, for transportation to the seasoning yard, or, when the yard is some distance away, they may be thrown on skids or on the ground to be picked up by a truck or wagon crew.

Timbers or similar materials that are not to be treated are usually taken directly from the head saw by means of dead rolls; a set-up of this kind is shown in plate 6, *A*. Few small mills attempt to care for their large stock with mechanical spray equipment. Timbers are usually treated with a hand-operated spray, such as those used by gardeners or orchardists, or a sprinkling can, broom, or brush. These devices are suitable so long as thorough coverage is assured.

Aside from considerations of convenience, the location of the dipping vat may have a bearing on the dipping results. It is safest to maintain the vat at the mill, where the lumber is being sawed, thus removing any need for delays in treating. If dipping is done at a concentration yard, handling practices should be so arranged that the delay in treatment does not exceed the safe limit of 1 or possibly 2 days.

Whether the lumber should be passed through the vat by hand or by means of a green chain will depend on the portability of the plant, power available, and amount of material to be dipped. Both methods are equally satisfactory from the standpoint of controlling stain and mold. With power to spare, and the cut around 15,000 board feet per day, it is advisable to consider the use of a mechanical vat, because its operating cost is considerably cheaper.

## COST OF DIPPING LUMBER

The cost of dipping in a mechanically operated vat will depend on a number of factors, but by far the major item of expense is the chemical itself. At 1939 prices the average cost of chemical is generally estimated at about 15 cents for each 1,000 board feet of lumber dipped. If the proportion of thick stock is high the cost will be lower than if most of the output is 1-inch lumber.

When dipping is done by hand the consumption of chemical tends to run higher, largely because of greater splashing and inadequate provision for draining the lumber. In addition, since a circular saw is employed at most small mills, the surface of the lumber is apt to be rougher than that of band-sawed stock and consequently retains more of the solution. Some cost data obtained at five different mills where experimental hand dipping was in progress are given in table 20. The striking thing brought out here is that careless dipping procedures may more than double the amount of solution consumed.

TABLE 20.—*Solution costs for hand dipping 1-inch shortleaf pine lumber*

| Mill No. | Board-feet dipped | Solution cost per 1,000 board-feet dipped (value of solution, 1 cent per gallon) | Recovery of excess solution |
|---|---|---|---|
| | | *Cents* | |
| 1 | 10,716 | 15¾ | Drain apron on vat; boards carefully drained. |
| 2 | 6,985 | 15½ | Do. |
| 3 | 26,000 | 22½ | Drain apron on vat; boards only partly drained. |
| 4 | 8,000 | 33 | No drain apron on vat; little care taken to drain boards. |
| 5 | 9,000 | 37 | Do. |

With hand dipping, the cost of the extra labor required also must be considered. This generally amounts to more than the cost of the chemical. With wages of $2 per day, the total cost of dipping at a mill cutting 5,000 feet daily will be at least 55 cents per 1,000 board feet. If the cut is greater than this the cost may be less. However, if the daily cut exceeds 6,000 or 7,000 board feet, more than one extra man will generally be needed at the vat. A total dipping cost of at least 40 cents per 1,000 board feet can be expected unless wages are less than the figure used here. Where the cut is less than 5,000 feet daily it is often possible for the man at the dipping vat to do other work also, in this way reducing somewhat the cost chargeable to treating.

The cost of the dipping vat itself is always an item of consideration. One medium-sized pine mill with a daily capacity of 25,000 to 30,000 board feet installed a simple V-shaped iron mechanical vat at a reported cost of approximately $150. In another instance a vat capacity for 80,000 board feet daily, built of 2-inch and 2½-inch cypress, 18 feet long, 12 feet wide, and carrying 13 inches of solution at the deepest part, was built and installed at an estimated cost of $225. These figures do not take into account the cost of labor, practically all of which was supplied by regular mill employees.

The cost of constructing a vat for hand dipping should amount to little more than the cost of the lumber required. Ordinarily not more than 300 to 350 board feet of lumber are needed for the complete equipment of trough, drain apron, and splashboard.

## CONTROL OF SAP STAIN IN EXPORT STOCK

To control sap stain in export shipments the material should be shipped dry or else chemically treated. As has been pointed out (p. 38), stock, even though it leaves the mill dry, may pick up some moisture en route to the wharves, in the process of loading, during transit, while being unloaded, or on the wharves at the port of destination. Every practicable attempt should be made to avoid this.

Stock is often maintained dry over the first part of the journey by shipping to the wharves in closed cars. At the receiving and discharging docks it should be placed in sheds or under other suitable cover until loaded on ship or picked up by the consignee. Insofar as possible, loading and discharging of the cargo should be carried out in dry weather. If lighters are used they should be free from leakage and the stock should be protected from high seas by canvas covers.

Whenever possible, dry material should not be stowed in the hold with wet stock, and, where a choice is possible, dry material should not be carried as deck loads. Ordinarily if these precautions are followed and the lumber is dry when loaded into the ship, no stain occurs during transit.

If export stock is to be shipped green, chemical treatment at the time of sawing is the only way available at present of reducing sap stain en route. Treatment should follow the same procedures and precautions as outlined for materials to be air seasoned. Complete coverage is essential, and for large items somewhat higher concentrations of the chemicals are desirable. Also, protection from rain should be attempted. The practice by some mills of storing export timbers in fresh-water ponds prior to shipment has the disadvantage of so reducing the concentration of any chemical initially applied to the surface that little in the way of future chemical protection against sap stain can be expected.

Since conditions of bulk piling are severe, some staining may occur in spite of antiseptic precautions, but on the whole, exporters report substantially more satisfactory stock arriving at import docks than was the case before chemical treatments were used.

A more detailed discussion of fungus defects associated with water transportation of lumber and timbers may be found in reports of special studies in this connection (*10*, *37*).

## CONTROL OF SAP STAIN IN STORED LOGS

The prevention of stain in green logs during storage periods involves practices directed at utilizing the logs rapidly and producing conditions unfavorable for the deteriorating agents. Included in the latter group are practices providing for rapid seasoning of the logs, such as decking on high skids or piling on high ground or in the sun, storage under water, and treating with antiseptic chemical sprays or end coatings. Since climatic conditions in much of the Gulf region permit attack by the deteriorating agents at any season, the time of cutting the logs does not have the same significance as a control measure that it has in northern logging operations.

The most effective way of eliminating losses lies in the immediate conversion of logs into lumber; therefore practices that tend to shorten the interval between felling and milling will aid materially. Placing the logs under conditions that hasten drying, such as decking on high skids, retards fungus development, but favors excessive checking and permits insect attack to some extent. Storage under water is an effective preventive measure against fungi, insects, and end checks, but is not always practicable. Logs handled in this manner must be kept completely submerged, because alternate wetting and drying may produce optimum conditions for the deteriorating agents.

The use of efficient chemical treatments applied as log sprays seems to offer definite promise of results of practical value. Field experiments conducted by the Forest Products Laboratory (*73*) resulted in the recommendation of an end coating composed of 1 part cresylic acid and 10 parts filled hardened gloss oil by weight and a spray material for the entire log made of 1 part cresylic acid and 10 parts kerosene or crude oil. More recent experiments, herein described, included a large number of new mixtures which, it was hoped, would reveal treatments of equal or of greater effectiveness against fungi, and which, in addition, would possess advantages with respect to insect control, cost, and ease of application. In all but insect control substantial improvements were realized.

## EXPERIMENTS WITH CHEMICAL TREATMENTS [28]

### PROCEDURE

Experiments directed at the control of sap stain in logs were conducted both on a small scale, using bolts 4 feet long and 8 to 16 inches in diameter, usually of red gum, and on a commercial scale using regular runs of logs handled in accordance with usual storage practices at logging operations where the tests were established. The small-scale tests permitted more uniform conditions among a large number of treatments and at the same time, because of their greater severity, made it possible to weed out the poorer treatments rather rapidly. The log-treatment tests were necessarily more limited but were intended primarily to ascertain the practical usefulness of effective chemicals rather than as bases for rating the various treatments. They were not continued after sufficient information had been obtained to disclose that the results were substantially the same as those obtained in the simpler bolt tests.

In each small-scale test from 6 to 10 bolts were thoroughly sprayed on all surfaces with solutions of the chemicals in water or kerosene. A few end coatings applied with a brush to the ends and barked areas also were tried. The treated bolts were allowed to remain on the ground in the woods for a period of 40 to 90 days, at the end of which they were split and examined for fungus and insect damage. Each treatment was applied to bolts from three or more trees. This not only aided in avoiding possible differences in stain

[28] Reports of some of the experiments have appeared in lumber trade and professional journals (*44, 48, 49, 63*).

susceptibility between different trees but also served to distribute each treatment over the test area. Care was taken that all bolts were comparably placed with respect to shade and direct sunlight. In some of the later tests all bolts were grouped within a single, comparatively small area so that conditions of exposure would be of greater uniformity (pl. 9, *A*). As a further measure to increase uniformity the different treatments were systematically distributed through the group. No interinfluence of adjacent treatments as a result of such grouping was ever detected, even though bolts were as closely spaced as 6 to 8 inches.

Logs in the commercial-scale tests were treated immediately after felling and either were allowed to remain on the ground in the woods or were subsequently banked along the railroad spur, both methods conforming to established commercial practices. Observations of exterior damage were made at the site of storage; whereas observations of interior damage were made at the mill while the logs were being sawed.

The spray equipment used in most cases consisted of a hand-operated pressure outfit comprising a 3-gallon cylindrical tank with built-in pump and spray nozzle attached by a short piece of rubber hose. This type, which is commonly used for garden purposes, seems ideally suited for commercial log-treatment work because of its sturdiness and portability. The chief requirement for its continuous operation is that water taken from streams or ponds be strained free of twigs and leaf particles before it is put into the tank.

Requirements kept in mind in selecting chemicals for use in log tests were the same as those considered in connection with lumber treatments with the exception that water solubility was not essential. Kerosene solutions, which could not be used in the latter connection because of the prohibitive cost, were regarded as practical for log treatments, because less solution is required to protect the same volume of material. Chemicals chosen for testing included many that appeared promising as lumber treatments. A number of materials were tried solely for what value they might have as insect repellents, in the hope of preventing insect-introduced infections during warm months of the year. Attacks by ambrosia beetles are most troublesome in this connection. Concentrations of the chemicals were higher than those used on lumber, because of the longer period over which the cut surfaces remain green and therefore in a susceptible condition.

### RESULTS OF BOLT TESTS

A list of ineffective treatments tried in the bolt tests is given on page 122. In many cases mixtures of the chemicals shown were also used, but inasmuch as these did not result in improvement only the single treatments are listed. A number of the materials could probably have been applied at sufficiently high concentrations to be effective, but the cost of such solutions would have been excessive.

None of the small group of spreaders and adhesives tested seemed to be helpful. The freshly cut ends of the bolts were readily covered with kerosene as well as water solutions, and penetration in either case was sufficient to give the treatment adequate permanence without the aid of adhesives.

Red gum bolt and log treatment tests. *A*, Gum test bolts randomly arranged with respect to treatments. Note heavy insect attack as denoted by white frass on bark; infection occurring through insect borings constitutes the most serious obstacle to effective chemical treatment of logs. *B*, Gum logs at the end of 90 days' woods storage. The log at the left was not sprayed and shows typical heavy end stain. The adjacent log, which was treated, shows what can be accomplished in the way of stain control when insects are not present.

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Chemicals that were incorporated in the tests, either alone or in combination with others, on the chance that they might serve in some measure as deterrents to wood-attacking insects were alphachloronaphthalene (1.8 percent), monochloro-betanaphthol (5 percent), 2, 5-dichloronitrobenzene (5 percent), orthodichlorobenzene (20 percent), paradichlorobenzene (20 percent), pine oil (25 percent), and pyridine (20 percent). Unfortunately, none of these had the desired effect, at least to any definite degree, nor did any of the other chemicals. Insects still constitute a major obstacle to successful control of sap stain in logs.

Results obtained with several comparatively effective treatments are given in table 21. Test series are listed in the order conducted. In all but series A and C, insect attack (pl. 9, *A*) was considerable, introducing an obstacle in interpreting results. Under the circumstances the condition of the ends of the bolts more correctly represents the comparative effectiveness of the treatments against fungus infection and would be the more reliable basis for predicting the order of success in controlling interior stain if insects were a negligible factor. Evidence of the correctness of this assumption is brought out in figure 7, where it is seen that, in the absence of insect damage, interior stain was essentially proportional to the amount of end stain. Even end stain was governed to some extent by insect operations, especially where the borings were in the ends and permitted stain to develop just beneath the cut surfaces.

TABLE 21.—*Stain occurrence in sprayed 4-foot red gum bolts stored in the woods*

TEST SERIES A—70-90 DAYS' SUMMER STORAGE. INSECT ATTACK COMPARATIVELY LIGHT

| Chemical | Concentration | Solvent [1] | Tests | Average amount of sapwood stained: At ends | Average amount of sapwood stained: Interior |
|---|---|---|---|---|---|
| | *Parts per 100 of solvent* | | *Number* | *Percent* | *Percent* |
| Borax | 6 | W | 4 | 33 | 20 |
| Borax+pyridine+NaOH | 6+12+1.4 | W | 1 | 0 | 7 |
| Cooper's end coating [2] | (3) | | 4 | .3 | 12 |
| Ethyl mercuric phosphate | .06 | W | 4 | 13 | 14 |
| Ethyl mercuric phosphate+pyridine+NaOH | .06+12+6 | W | 2 | .1 | 10 |
| Ethyl mercuric phosphate+paradichlorobenzene+NaOH | .06+12+6 | W | 1 | 6 | 9 |
| Pyridine | 20 | K | 3 | 6 | 7 |
| Sodium tetrachlorophenolate | 4 | W | 4 | 4 | 12 |
| Sodium tetrachlorophenolate+pyridine | 2.5+12 | W | 4 | 1 | 5 |
| Untreated | | | 4 | 94 | 57 |

TEST SERIES B—40-70 DAYS' SUMMER AND FALL STORAGE. INSECT ATTACK MEDIUM TO HEAVY

| Chemical | Concentration | Solvent | Tests | At ends | Interior |
|---|---|---|---|---|---|
| Cooper's end coating [2] | (3) | | 5 | 0.2 | 18 |
| Ethyl mercuric chloride | 0.086 | W | 3 | .9 | 10 |
| Do | .129 | W | 3 | 1.6 | 8 |
| Ethyl mercuric phosphate | .086 | W | 1 | 0 | 18 |
| Sodium tetrachlorophenolate | 4 | W | 5 | 0 | 9 |
| Sodium 2-chloro-o-phenylphenolate | 2 | W | 3 | 8 | 16 |
| 2-chloro-o-phenylphenol | 2 | K | 3 | 5 | 30 |
| Untreated | | | 5 | 100 | 72 |

Footnotes at end of table.

TABLE 21.—*Stain occurrence in sprayed 4-foot red gum bolts stored in the woods*—Continued

TEST SERIES C—90 DAYS' WINTER STORAGE. PRACTICALLY NO INSECT ATTACK

| Chemical | Concentration | Solvent[1] | Tests | Average amount of sapwood stained: At ends | Average amount of sapwood stained: Interior |
|---|---|---|---|---|---|
| | *Parts per 100 of solvent* | | *Number* | *Percent* | *Percent* |
| Ethyl mercuric chloride | 0.10 | W | 1 | 1 | 6 |
| Pyridine | 20 | K | 1 | 0 | 3 |
| Sodium tetrachlorophenolate | 5 | W | 1 | 0 | 3 |
| Sodium 2-chloro-o-phenylphenolate | 5 | W | 1 | 1 | 4 |
| 2-chloro-o-phenylphenol | 2 | K | 1 | 0 | 2 |
| Untreated | | | 1 | 99 | 35 |

TEST SERIES D—75 DAYS' SPRING STORAGE. INSECT ATTACK SEVERE

| Chemical | Concentration | Solvent | Tests | At ends | Interior |
|---|---|---|---|---|---|
| Ethyl mercuric chloride | 0.10 | W | 1 | 13 | 26 |
| Monochlorocresol | 5 | K | 1 | 0 | 90 |
| Monochloroxylenol | 5 | K | 1 | 1 | 63 |
| Sodium tetrachlorophenolate | 5 | W | 1 | 0 | 55 |
| Sodium 2-chloro-o-phenylphenolate | 5 | W | 1 | 1 | 38 |
| Sodium 2-chloro-o-phenylphenolate+ethyl mercuric chloride | 2.5 +.05 | W | 1 | 0 | 0 |
| Untreated | | | 1 | 100 | 71 |

TEST SERIES E—90 DAYS' SPRING STORAGE. INSECT ATTACK SEVERE BUT DELAYED

| Chemical | Concentration | Solvent | Tests | At ends | Interior |
|---|---|---|---|---|---|
| Ethyl mercuric chloride | 0.10 | W | 1 | 0 | 4 |
| Monochlorocresol | 5 | K | 1 | 1 | 30 |
| Monochloroxylenol | 5 | K | 1 | 0 | 21 |
| Sodium tetrachlorophenolate | 5 | W | 1 | 0 | 25 |
| Sodium tetrachlorophenolate+ethyl mercuric chloride | 2.5 +.05 | W | 1 | 0 | 3 |
| Untreated | | | 1 | 78 | 60 |

TEST SERIES F—90 DAYS' SPRING AND SUMMER STORAGE. INSECT ATTACK SEVERE

| Chemical | Concentration | Solvent | Tests | At ends | Interior |
|---|---|---|---|---|---|
| Borax | 4 | W | 1 | 10 | 82 |
| Ethyl mercuric chloride | .12 | W | 1 | 7 | 41 |
| No-D-K[2] | 100[3] | K | 1 | 1 | 96 |
| Sodium monochlorocresolate | 1.8 | W | 1 | 95 | 90 |
| Sodium monochloroxylenolate | 1.8 | W | 1 | 93 | 82 |
| Sodium tetrachlorophenolate | 5 | W | 1 | 0 | 90 |
| Untreated | | | 1 | 100 | [4] 12 |

TEST SERIES G—90 DAYS' SUMMER AND FALL STORAGE. INSECT ATTACK SEVERE

| Chemical | Concentration | Solvent | Tests | At ends | Interior |
|---|---|---|---|---|---|
| Borax | 4 | W | 1 | 0 | 30 |
| Ethyl mercuric chloride | .12 | W | 1 | 1 | 7 |
| Monochlorocresol | 5 | K | 1 | 0 | 28 |
| Monochloroxylenol | 5 | K | 1 | 3 | 27 |
| Sodium tetrachlorophenolate | 5 | W | 1 | 0 | 61 |
| Untreated | | | 1 | 73 | 46 |

[1] W=water; K=kerosene.
[2] Cooper's end coating. (See footnote 2, table 25, appendix.) No-D-K, a wood-tar creosote, furnished by Tennessee Eastman Corporation.
[3] Undiluted.
[4] Sap stain partially obliterated by heavy decay.

From table 21 it may be seen that the foremost chemicals in controlling stain include the ones that proved most satisfactory for control of stain in hardwood lumber. These are sodium tetrachloro-

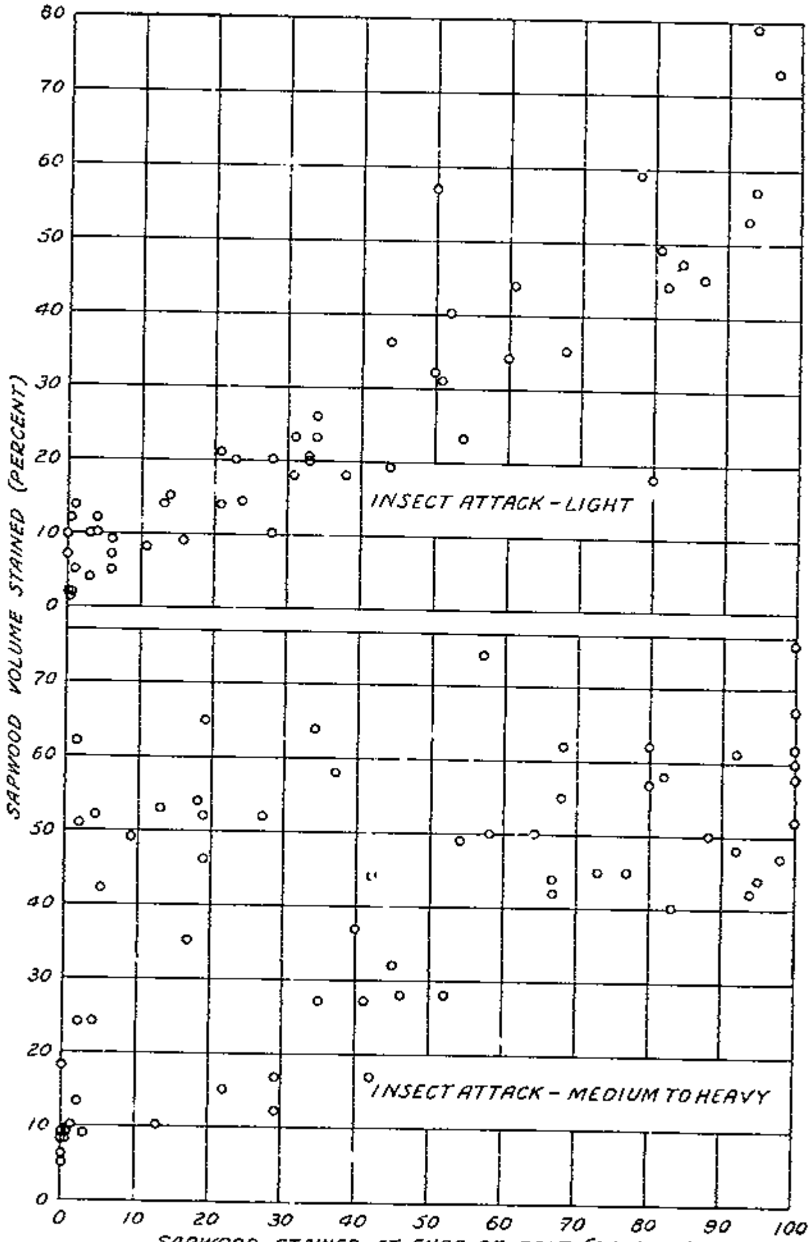


FIGURE 7.—Relation between end stain and total stain development in 4-foot red gum bolts during woods storage for 70 to 90 days.

phenolate, ethyl mercuric chloride, ethyl mercuric phosphate, and borax; the last, however, was less effective relatively than when it was used on red gum lumber. A 5-percent solution of sodium 2-chloro-o-phenylphenolate was much more effective than would have been predicted from the results given by this chemical in hardwood-lumber tests. Apparently the greatly increased concentration renders the compound effective on hardwoods as well as pine. Cooper's end coating (cresylic acid and filled hardened gloss oil) was among the most effective treatments, but its usefulness would be primarily in connection with logs in which control of end checking as well as sap stain was desired.

Of the chemicals other than those tried on lumber, chlorinated cresol and chlorinated xylenol were very promising; however, they showed no advantage over sodium tetrachlorophenolate. Their failure in series F is probably due to the lower concentration used rather than the fact that they were applied in the form of sodium salts. Pyridine also was comparatively successful, but since it gave no indication of controlling insects it probably has less merit than some of the other less costly materials.

Decay as well as sap stain is often serious in stored logs. But as a rule it develops more slowly and in consequence may not be evident until considerably later in the storage period. Fortunately, the treatments that best controlled stain were most effective against decay fungi, making it unnecessary to treat the two types of deterioration as separate problems.

### RESULTS OF LOG TESTS

Results of the log-treatment tests are summarized in table 22. Comparison of the amounts of interior deterioration that took place in untreated logs and in logs sprayed with any of the better chemicals forcefully illustrates the advantages that may be derived from chemical treatment under fall and winter storage conditions in which insect attack is relatively slight. In the first series even the poorest treatment permitted but little more than one-half the volume of sap stain that developed in the untreated logs and of the better treatments two permitted less than one-sixth and two less than one-third of the stain occurring in the untreated logs.

In the second series stain control by most of the treatments was better still. in spite of the fact that the maximum storage period was 120 days instead of 90. In the gum logs on which seven of the treatments were used 7 percent or less of the sapwood volume was stained. and none of the treated oak logs contained more than 3 percent of stain. Control of this sort is encouraging in view of the fact that interior stain development in untreated gum and oak logs in the same test was 33 percent and 23 percent of the sapwood. respectively. Characteristic appearance of the ends of untreated red gum logs and similar logs treated with one of the better chemicals is illustrated in plate 9, *B*.

The better treatments in both series also greatly reduced the occurrence of visible decay in the treated logs.

In addition to red gum and oak, a few logs of beech, poplar, magnolia, elm, hickory, sycamore, and locust also were incorporated in the second series, but their relatively small numbers do not warrant a tabular summary of results. It seems evident that chemical control of fungus damage in logs of these species can be accomplished as satisfactorily as in the case of gum logs.

TABLE 22.—*Sap stain and decay occurrence in sprayed red gum and oak logs banked on the ground along railroad spurs or in the woods*

[Averages of 4 tests in which insect attack was slight]

| Storage period and treatment | Concentration | Solvent[1] | Red gum | | | | Oak | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Logs | Sapwood stained | | Logs visibly decayed | Logs | Sapwood stained | | Logs visibly decayed |
| | | | | At ends | Interior | | | At ends | Interior | |
| | *Parts per 100 of solvent* | | *Number* | *Percent* | *Percent* | *Percent* | *Number* | *Percent* | *Percent* | *Percent* |
| 90 days in fall and winter: | | | | | | | | | | |
| Creosote | 20 | K | 56 | 14 | 13 | 71 | ---- | ---- | ---- | ---- |
| Cresylic acid | 17 | K | 55 | 41 | 16 | 91 | ---- | ---- | ---- | ---- |
| Cooper's end coating[2] | ([3]) | ---- | 55 | 4 | 8 | 40 | ---- | ---- | ---- | ---- |
| Ethyl mercuric phosphate | .06 | W | 15 | 38 | 8 | 27 | ---- | ---- | ---- | ---- |
| Ethyl mercuric phosphate+fish oil | .06+6 | W | 34 | 11 | 12 | 50 | | | | |
| Ethyl mercuric phosphate + NaOH+paradichlorobenzene | .06+6+12 | W | 10 | 32 | 2 | 30 | ---- | ---- | ---- | ---- |
| Ethyl mercuric phosphate+NaOH+pyridine | .06+6+12 | W | 36 | 3 | 4 | 22 | ---- | ---- | ---- | ---- |
| Untreated | ---- | ---- | 18 | 100 | 28 | 89 | ---- | ---- | ---- | ---- |
| 90 to 120 days in fall: | | | | | | | | | | |
| Creosote (coal tar) | 25 | K | 10 | 1 | 8 | 11 | ---- | ---- | ---- | ---- |
| Do | 20 | K | 24 | 1 | 12 | 25 | 1 | 55 | 3 | 0 |
| Cooper's end coating[2] | ([3]) | ---- | 36 | 12 | 7 | 8 | 9 | 36 | 2 | 0 |
| Ethyl mercuric chloride | .10 | W | 47 | 4 | 7 | 0 | 2 | 0 | 1 | 0 |
| Minerec A[2] | 33 | W | 5 | 38 | 40 | 40 | ---- | ---- | ---- | ---- |
| Orthodichlorobenzene | 20 | K | 7 | 100 | 6 | 17 | 4 | 95 | 2 | 0 |
| Paradichlorobenzene | 20 | K | 4 | 94 | 22 | 75 | 4 | ---- | 3 | 0 |
| Paradichlorobenzene + orthodichlorobenzene | 10+10 | K | 1 | 92 | 12 | 100 | ---- | ---- | ---- | ---- |
| Paradichlorobenzene+paraffin | 20+6 | K | 6 | 9 | 10 | 17 | ---- | ---- | ---- | ---- |
| Pyridine | 25 | K | 9 | ---- | 6 | 0 | ---- | ---- | ---- | ---- |
| Do | 20 | K | 30 | 5 | 14 | 10 | 7 | 0 | 3 | 0 |
| Sodium metasylicate | 10 | W | 3 | ---- | 30 | 100 | ---- | ---- | ---- | ---- |
| Sodium 2-chloro-o-phenylphenolate | 5 | W | 22 | ---- | 9 | 4 | 2 | ---- | 1 | 0 |
| Sodium tetrachlorophenolate | 4 | W | 14 | .4 | 2 | 0 | ---- | ---- | ---- | ---- |
| Do | 5 | W | 31 | 0 | 5 | 0 | ---- | ---- | ---- | ---- |
| Untreated | ---- | ---- | 47 | 93 | 33 | 44 | 10 | 100 | 23 | 10 |

[1] W=water; K=kerosene.
[2] Cooper's end coating (see footnote 2, table 25, appendix); Minerec A (see footnote 3, table 24, appendix).
[3] Undiluted.

## COMMERCIAL USE OF LOG TREATMENTS

It is the opinion of the writers that any of the better compounds investigated may be used commercially to definite advantage in controlling sap stain and decay in stored hardwood logs provided treatment is confined to the normal banking season, when insect infestations are less numerous than in the warmer months. Among the suitable chemicals that are now readily obtainable are the following: Sodium tetrachlorophenolate (Dowicide H,[29] ethyl mercuric chloride (Lignasan), borax, and sodium pentachlorophenolate (Santobrite and Dowicide G). Sodium pentachlorophenolate has not been tried in Government log tests, but its showing in private

[29] See footnote 26, p. 67.

tests and its established effectiveness on lumber justify placing it in this list.

An antiseptic end coating alone, such as Cooper's end coating, or any suitable coating in combination with one of the effective antistain chemicals may be used if it is desired to reduce end checking as well as fungus deterioration.

If occasion arises for woods storage of pine logs, there is little doubt but that here also suitable chemical treatments can be used to considerable advantage. Because there was no indication at the time tests were being made that there might be need for treatment of pine logs, no extensive pine tests were established. However, enough pine bolts were treated at one time or another to indicate that control of stain and decay is attainable. Among the commercial treatments worthy of trial on pine logs are: Santobrite, Lignasan, Dowicide G, Dowicide H, and a mixture of sodium tetrachlorophenolate and sodium 2-chloro-o-phenylphenolate (Dowicide P).

With the exception of borax, which is soluble only to the extent of about 4 percent in cold water, the concentrations of chemicals for log treatment should be considerably higher than those for lumber treatment. Increases of about five times in the case of the chlorinated phenolate products and eight times in the case of Lignasan appear to be adequate.

If insects are not active, as is commonly the case during the normal banking season for hardwoods, efficient control of stain and decay may be accomplished by simply spraying the ends and barked areas. However, for logs stored in the Southern States between March and November an entire log spray that is effective against both insects and fungi is needed. Until such a treatment is developed the only safe procedure during spring and summer is to deliver logs to the mill promptly. When this cannot be done, treatment with one of the chemicals just mentioned possibly would still be worth while if only for its effect in limiting the development of end stain. A few trials under local storage conditions would answer this question. Insect as well as fungus damage at such times may be reduced by storing the logs off the ground on skids, in as small piles as possible, and by placing them where they will receive plenty of sunshine and ventilation.[30]

If a treatment is to be effective it must be applied to the log shortly after it is cut. Twenty-four hours is probably a safe limit. Treating can be done in the woods or at the time of unloading the logs at the banking location. Treatment at the mill is practicable only if the logs are brought in immediately after cutting. Slightly delayed treatment, to take advantage of a certain amount of drying out of the ends, apparently does not increase absorption of the chemical enough to show in the results. So far as could be determined, treatment with either kerosene or water solutions was not noticeably impaired by rainfall, no matter how closely the latter preceded or followed spraying.

To prevent injury to the operator more than ordinary care is necessary in using present lumber treatments on logs, because of the

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[30] ST. GEORGE, R. A. BRIEF INFORMATION ON INSECT DAMAGE TO GREEN GUM LOGS AND LUMBER IN THE SOUTHERN ATLANTIC AND GULF STATES AND SUGGESTIONS RELATING TO ITS PREVENTION. U. S. Bur. Ent., Forest Ent. Brief No. 50, 3 pp. 1923. [Mimeographed.]

considerably higher concentrations needed. Careless handling of the powder or of the solutions after they are prepared should be strictly avoided.

#### COST OF LOG TREATMENTS

The cost of the chemical for spray treatment of ends and barked areas of logs in the Southern States should amount to no more than about 5 or 6 cents a thousand feet log scale if present proprietary sap-stain preventives are used. The total cost of log treatment, including labor, is estimated to average about 12 cents a thousand feet log scale. However, at many operations it is probable that the work could be done by the checkers or scalers, reducing the labor costs considerably.

## EFFECT OF STAIN CONTROL ON THE DISTRIBUTION OF STAIN, NUMBER OF STAINED BOARDS, AND AVERAGE AMOUNT OF STAIN SUSTAINED BY INDIVIDUAL BOARDS IN THE SEASONING PILE

#### VERTICAL AND HORIZONTAL DISTRIBUTION OF STAIN IN THE PILE

In addition to the more pressing questions relating to the sap-stain problem, it was desired to know in what parts of the seasoning pile stain is likely to be heaviest and hence most difficult to control. This information was obtained by systematically recording the stain occurrence so that it could be summarized by courses and vertical rows in the pile. Figure 8 graphically portrays the vertical distribution of stain encountered in a number of treated and comparably situated untreated piles. Amounts of stain are given in units of one-twelfth of a square foot; this unit of measure was used throughout the commercial-scale tests because of the greater convenience afforded in estimating the smaller areas of stain.

Without exception the amount of stain increased downward in the piles, reached a maximum at some place in the lower quarter, and in most cases dropped off sharply in the lowermost courses. In 9 of the 11 piles, the point of maximum intensity lay below the tenth course from the bottom, which is somewhat farther down than had been expected from general observations. Above the position of maximum intensity the trend of stain occurrence was variable, in some cases dropping off sharply while in others comparatively heavy stain persisted for substantial distances upward in the pile.

The curves show clearly that chemical treatment may influence not only the amount of sap stain (indicated by the area under the curves) but also its distribution in the pile. For example, the ethyl mercuric chloride treatment permitted very little stain above the lower 3 to 12 courses, whereas large amounts of stain occurred practically to the top in adjacent untreated piles. In the same tests moderately effective treatments, such as soda and sodium tetrachlorophenolate, permitted an intermediate amount of stain in the upper portion of the piles.

It is probable that the type of stain distribution in effectively treated piles is not due to any peculiar influence of the treatment, but rather is more or less typical of all seasoning piles which for any reason contain a small amount of stain. This is indicated by the fact that there were no essential differences between the vertical distribution of stain in ethyl mercuric chloride-treated piles at mills No. 1 and No. 6, and untreated piles at mills No. 2 and No. 3.

At mills No. 1 and No. 6, elevated tramways were present, terminating at the level of the twenty-ninth course and twelfth course, respectively. A study of the curves discloses no characteristics of the associated stain distribution that can be ascribed to the presence

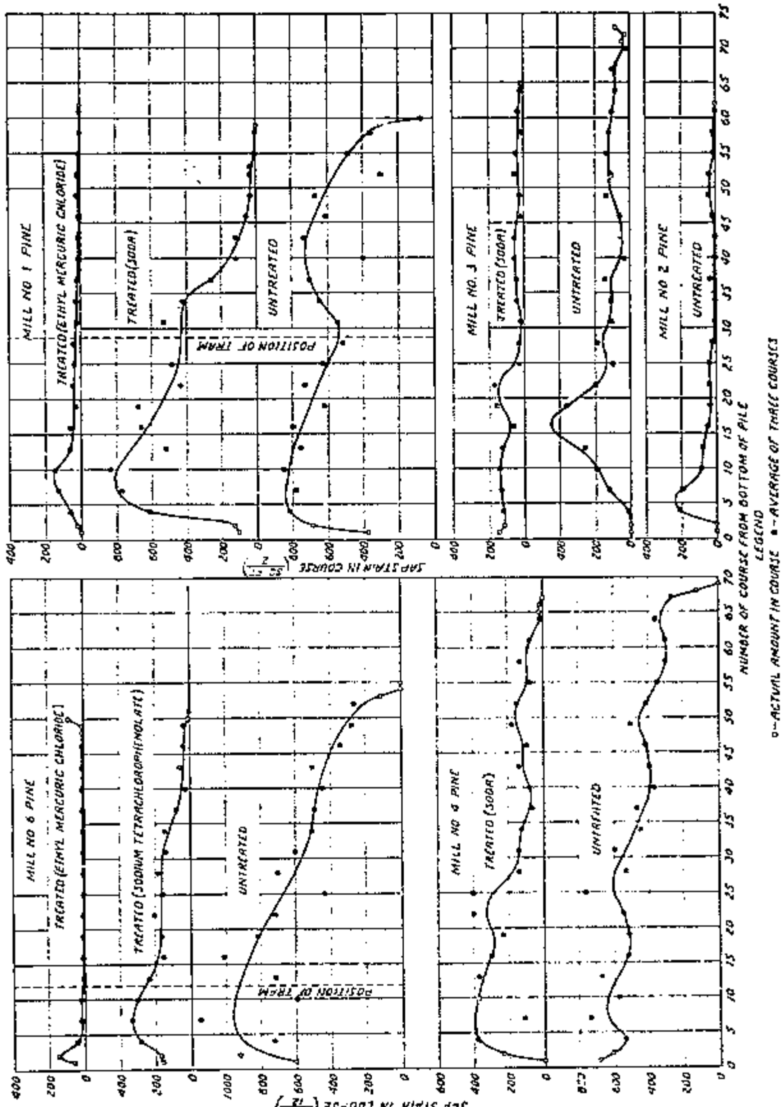


FIGURE 8.—Examples of vertical distribution of sap stain in southern pine seasoning piles.

of these trams. Whether these are representative cases may be questioned, since the general opinion seems to be that elevated trams should have a distinguishable effect on stain distribution. Nevertheless, even if they do not always exhibit such an effect, it is probable that they tend to increase the amount of stain according to the degree to which they restrict general air movement in the pile. This could be demonstrated, however, only by means of specially constructed tests in which piles fronting on elevated trams are compared with nearby and comparably situated piles without trams.

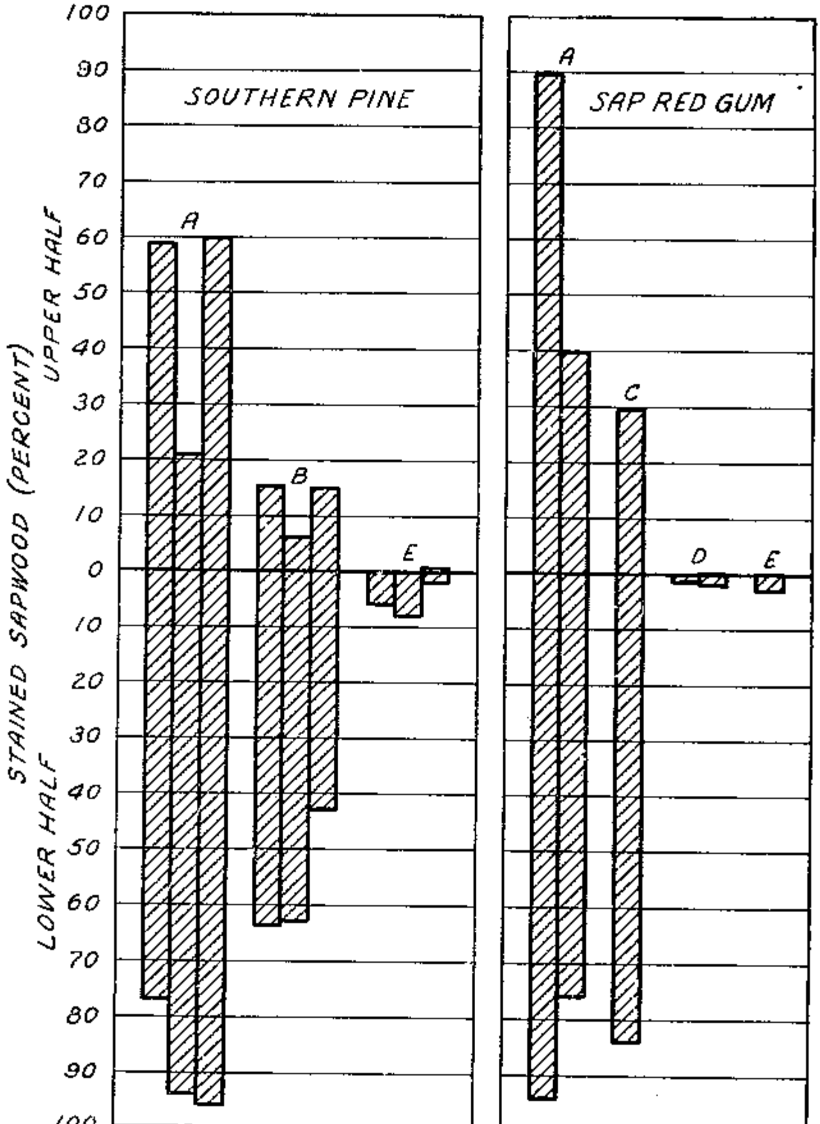


FIGURE 9.—Sap-stain occurrence in upper and lower halves of the seasoning pile: *A*, Untreated (pine tests 1–2–4, gum tests 3–4); *B*, soda (pine tests 1–2–4); *C*, sodium o-phenylphenolate (gum test 3); *D*, borax (gum tests 3–4); *E*, ethyl mercuric chloride (pine tests 1–2–4, gum test 4).

Figure 9, which shows the amounts of sapwood stained in the upper and lower halves of several seasoning piles, is based on additional observations and is intended to supplement figure 8. It brings out more sharply the contrast in stain development above and below the center of the pile and also emphasizes the comparative influence of chemical treatment in these two portions. The greater the degree of stain control, the greater seems to be the proportional difference between upper-half and lower-half stain occurrence.

Figure 10 is presented to give some idea of how much variation in stain may be encountered horizontally through pine piles containing even-width lumber arranged in continuous rows. The records include only portions of the piles in which stain was plentiful. All the piles contained stock treated with the same chemical.

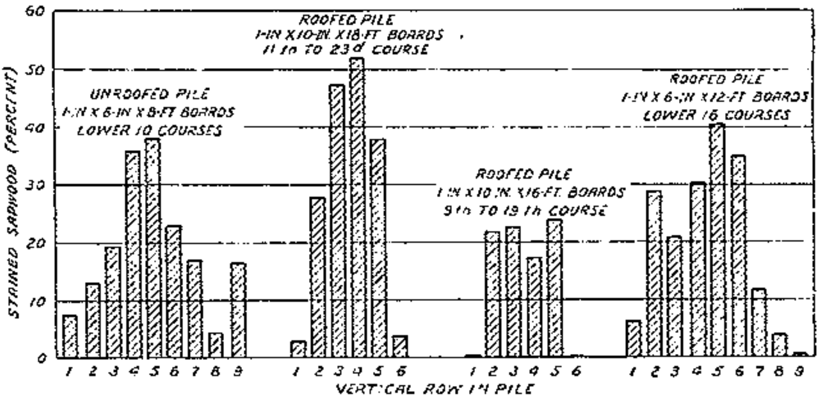


FIGURE 10.—Examples of horizontal distribution of sap stain in pine air-seasoning piles, the lumber of which had been given the same chemical treatment.

As would be predicted from what is known of drying rates, rows nearest the outside of the piles generally stain less than those farther in. The actual differences in this respect will vary a great deal according to the closeness of piling, pile spacing, exposure, and any other factors that influence the comparative rates of drying on the inner and outer portions of the pile.

#### NUMBER OF BOARDS IN THE SEASONING PILE WITH DIFFERENT AMOUNTS OF STAIN [n]

Up to this point sap-stain occurrence in treated and untreated lumber has been considered only in terms of the proportion of stained and bright wood in the seasoning pile. Measurement of stain in this way probably furnishes the most practical index of the usefulness of chemical treatments, but to complete the picture necessitates information about the comparative numbers of stained boards and the amounts of stain on them. For example, it is of interest to know whether the stain tends to be concentrated on a relatively few boards

[n] For a general description of the lumber upon which the data for this and the following discussions of frequency distribution are based, see footnote 22, p. 43. In interpreting the relations brought out it should be kept in mind that they do not take into consideration variations in the type of lumber as regards total amounts and distribution of heartwood and sapwood, or in other determining factors. The only justification for attempting analyses of this sort is based on the assumption that the construction, composition, and exposure of southern seasoning piles are sufficiently alike to permit a limited amount of practical generalization.

or is spread over a large number of boards; in the latter case the proportion of the lumber degraded would generally be greater. It is also of interest to know how many of the boards are likely to be heavily stained, moderately stained, or lightly stained, and whether the situation is the same in treated and untreated piles.

Considering first the relative numbers of boards having different amounts of stain, the curves of figure 11, for pine seasoning piles, indicate that for both treated and untreated pine lumber the largest number of boards had from about 1 to 4 percent of their surface stained. Boards having greater amounts of discoloration were pro-

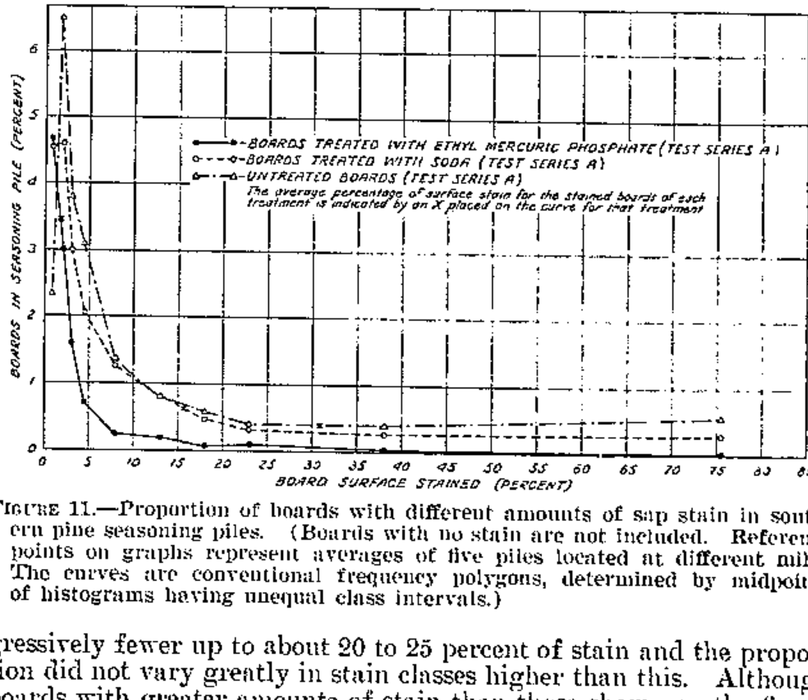


FIGURE 11.—Proportion of boards with different amounts of sap stain in southern pine seasoning piles. (Boards with no stain are not included. Reference points on graphs represent averages of five piles located at different mills. The curves are conventional frequency polygons, determined by midpoints of histograms having unequal class intervals.)

gressively fewer up to about 20 to 25 percent of stain and the proportion did not vary greatly in stain classes higher than this. Although boards with greater amounts of stain than those shown on the figure were present they were not numerous enough to permit establishing a frequency relation.

It is evident that the effect of chemical treatment on the frequency distribution was mainly to reduce the number of boards occurring in all stain classes, with the possible exception of classes in the range below 2 percent of stain. The major reductions apparently were with boards developing from 2 to 10 percent of stain, principally the smaller percentages. Treatment seemed to have no effect on the essential trends in the frequency distribution.

Two of the curves indicate that there was a drop-off in the number of boards in stain classes below 2 percent. The same tendency appears in the curves for red gum lumber (fig. 12). It is suggested by way of explanation that most of the boards became infected early and most of the individual infections spread sufficiently to carry the boards at least into the 2-percent class.

Curves for the red gum lumber (fig. 12) have much the same essential characteristics as those for the pine, except that they do not show such large differences between numbers of boards in the upper and lower stain classes. In the case of the treated piles this is no doubt largely due to the fact that the total stain was less than in the corresponding treated pine piles. On the other hand, in the untreated piles the reverse was true; hence it must be concluded that in the untreated gum piles the various stain classes were more evenly distributed among the boards than was the case with pine.

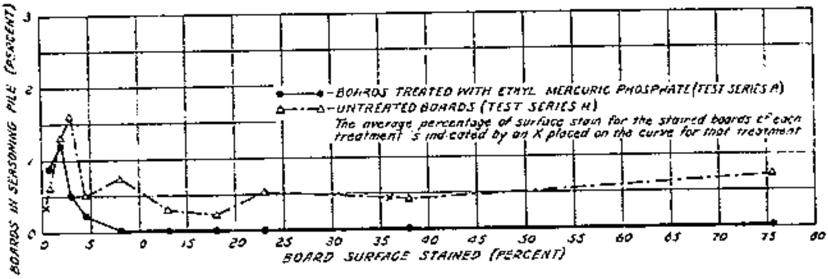


FIGURE 12.—Proportion of boards with different amounts of sap stain in red gum seasoning piles. (Boards with no stain are not included. Reference points on graphs represent averages of three piles located at different mills. The curves are conventional frequency polygons, determined by midpoints of histograms having unequal class intervals.)

## RELATION BETWEEN TOTAL STAIN IN THE PILE AND NUMBER OF STAINED BOARDS

In this section the proportion of stained wood in the seasoning pile and the proportion of boards with various amounts of stain are considered simultaneously. Figure 13 shows the total number of boards having any amount of stain, number of boards with more than 5 percent stain, and number of boards with more than 15 percent stain, which were present in pine test piles having different total amounts of stain. Since the relative number of boards appears to have been determined mainly by the total amount of stain present in the pile, and little or not at all by any specific influence of the treatment itself, it seemed permissible to draw curves through the plotted values and to assume that these represent relationships which might be found in other southern air-seasoning piles having similar composition and construction (see footnote 22, p. 43), regardless of treatment used. If sufficient data were available to determine them correctly, similar curves could be made for practically any stain category desired. Five percent and fifteen percent stain are used as lower limits in the present illustration, because they happen to be specified as lower limits of stain tolerance in some of the Southern Pine Association grading rules.

Looking at the upper curve of figure 13, it is evident how difficult it is to prevent all traces of stain with present treatments. For instance, with as little as 1 percent of the total sapwood stained, over 10 percent of the boards may have some stain, and with 2 percent of the sapwood stained the number of stained boards may amount to as much as 20 percent of the pile. Just a slight increase or decrease in total

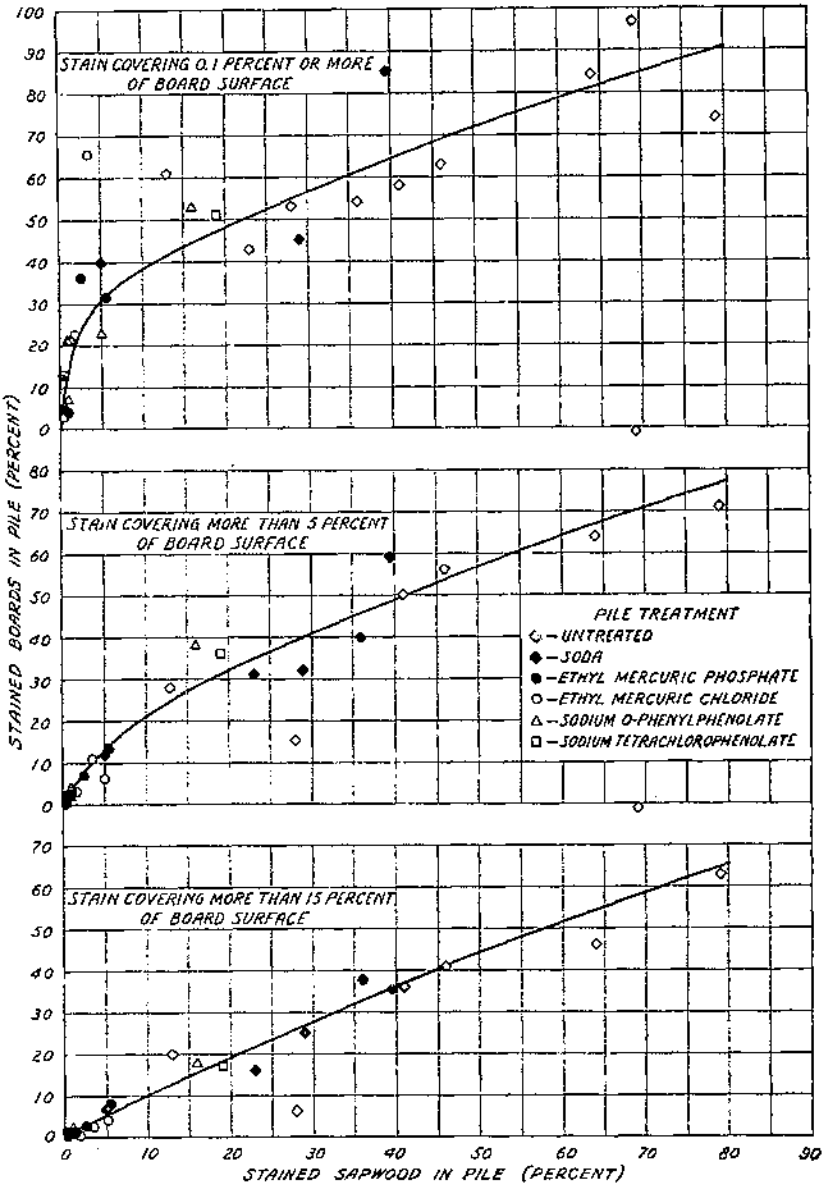


FIGURE 13.—Percentages of stained boards in relation to total stain in southern pine seasoning piles.

stain in the lower ranges, say 0 to 10 percent, is accompanied by a much more rapid increase or decrease in the number of boards involved than a similar variation in the ranges above 10 percent stain. A similar relation exists, as will be pointed out later, between total stain and the average amount of stain on individual discolored boards. For these reasons the value of stain control tends to become progressively greater with each additional step of improvement; this within limits, of course, since the commercial importance of stain is not directly proportional to the amount of board surface discolored.

The upper curve of figure 13, when projected, passes through a point about 100, 100. Attention is called to this because it indicates that if 100 percent of the sapwood were stained, approximately 100 percent of the boards would have been involved. This could be the case only if practically all boards in the pile contained some sapwood. The effect of additional all-heart boards would have been to depress the left-hand (ordinate) scale values on all three of the curves in proportion to the number of such boards present. Provided that practically all the boards still had some sapwood, a greater average proportion of heartwood than was present in the piles here represented (approximately 37 percent) would not necessarily affect the upper curve greatly, but it would tend to make the other two curves lower than as shown. On the other hand, if the boards were to average higher in sapwood, the lower two curves would tend to be higher, presumably approaching as a limit characteristics something like those of the upper curve.

If all boards having 5 percent or less of their surface stained are excluded from consideration, the relation between total stain and number of boards will be represented by the middle curve of figure 13. If grading rules that permit no more than 5 percent stain on a board are strictly followed, this curve will give an idea of the proportion of boards that would have to be rejected from the particular grade in piles having various total amounts of stain. Thus, if a particular chemical treatment holds stain occurrence to 5 percent of the sapwood in the pile, no more than about 13 percent of the boards would have to be dropped to a lower grade; but if 30 percent of the sapwood is stained, about 41 percent of the boards would be dropped, etc. Here again the advantage of each step in stain control is progressively more pronounced in the lower total-stain brackets, represented by the steepest part of the curve.

If specifications permit up to 15 percent stain on boards in still lower grades, an approximation of the proportion of rejects is offered by the lowermost curve of the figure. In this case, for total sap stain of 5 percent and 30 percent, the number of boards below grade would be about 5 percent and 28 percent, respectively. This curve has a gradual change in slope throughout, indicating that the number of comparatively heavily stained boards is more nearly proportional to total sap stain than is the case when boards with lesser amounts of stain are included. It is probable that curves based on more limited stain classes would show much more pronounced but similar differences in slope.

Corresponding curves, based on fewer data, are presented in figure 14 for red gum piles. The relations are apparently much the same as with pine and, therefore, need little additional comment. Although sap stain is technically no defect in red gum lumber, 5 percent and 15 percent were again used as lower limits of two of the stain classes in order that the two sets of curves might be compared if desired.

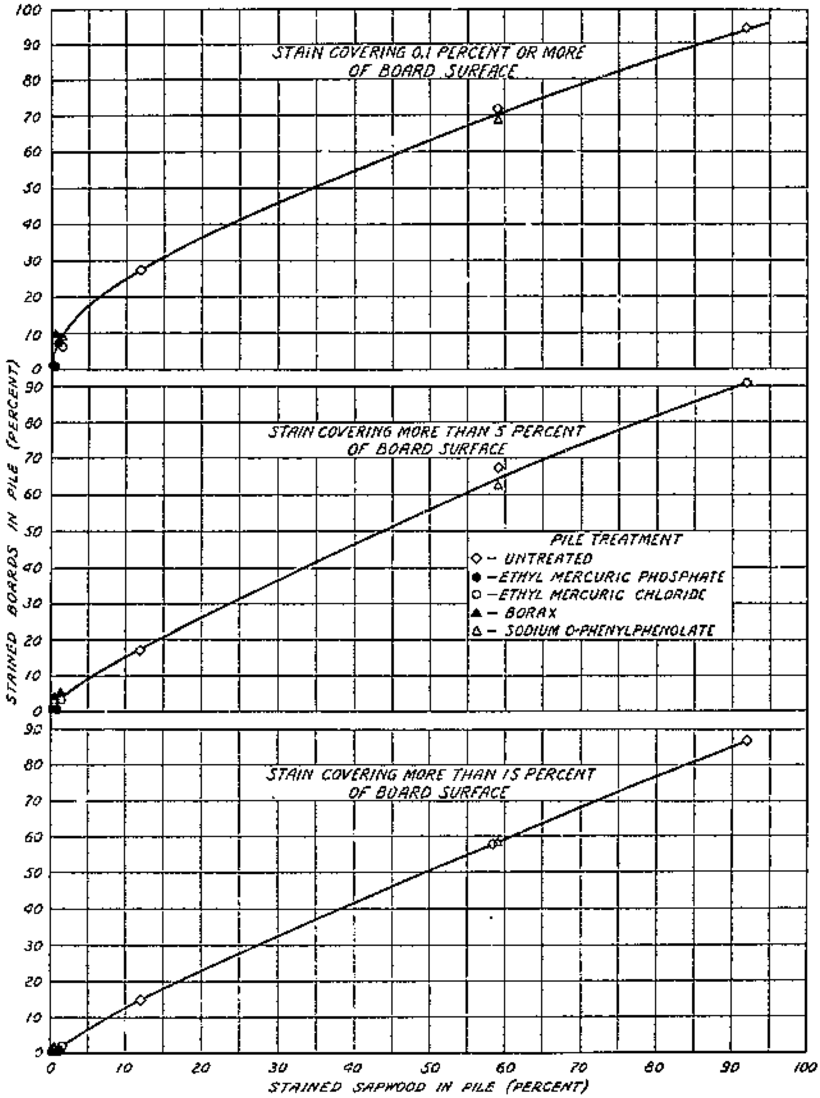


FIGURE 14.—Percentages of stained boards in relation to total stain in red gum seasoning piles.

In the discussion of the frequency curves of figure 12 attention was called to the fact that there were proportionately fewer boards in the lower stain classes and proportionately more in the higher stai classes in the untreated gum piles than there were in the untreated pine piles. Comparison of corresponding values on the uppermost curves of figures 13 and 14 and values on the lowermost curves of the same figures bears this out and indicates further that this situation may hold for treated material as well.

#### RELATION BETWEEN TOTAL STAIN IN THE PILE AND AVERAGE AMOUNT OF STAIN ON EACH BOARD

It is possible in some measure to predict from a given amount of stained sapwood in the pile not only how many boards may be stained but also how much stain each board may have. In working out these relations certain assumptions must be made which are contrary to conditions as they actually exist. For example, it is assumed that all boards in the piles contain some sapwood, as was essentially true for the test material; also that the proportion of sapwood on each board is the same. It is further assumed that the stain is divided equally among the boards in which it occurs. In other words averages are dealt with throughout. Such averages are unquestionably greatly depreciated in significance by the wide variation which existed in sapwood and stain occurrence in the material observed. Nevertheless, they furnish a means of measurement which can be readily understood and which for the present purpose is probably satisfactory.

It is axiomatic that the average amount of sapwood stained on each board in a seasoning pile containing stock of uniform character will be of the same percentage as the total amount of sap stain in the pile. But if not all the boards in the pile are stained, it is obvious that the average amount of stain on the stained boards exclusively will be greater than the average based on the total of both bright and stained boards—this by virtue of the fact that the stain is necessarily concentrated on fewer than 100 percent of the boards. Furthermore the stained-board average will be related to the percentage stain for the pile in inverse ratio to the proportion of stained boards in the pile. To illustrate, a pine pile may have 30 percent of its sapwood stained but only about 56 percent of the boards involved (fig. 13, upper curve); the average amount of sapwood stained on each discolored board would then be $30/0.56=53.6$ percent.

In figure 15 expected average amounts of sapwood stained on boards from seasoning piles having different amounts of total stain are given. It is clearly brought out by these curves that differences between average amounts of stain on the discolored boards are more pronounced in the lower ranges of total stain than in the higher ranges. It is interesting to note in this connection that reduction in total amount of stained sapwood is accompanied by a proportionately smaller reduction in average amount of stain in the discolored boards until total stain is reduced to 25 to 30 percent of the pile sapwood. Below this, any reduction in total stain is accompanied by a proportionately and progressively more rapid dropping off of the average amount of stain in the discolored boards.

Subject to the limitations of the assumptions that have been made regarding the uniformity of seasoning-pile characteristics, it is possible to extend the information in figure 15 so that instead of considering only the average proportion of sapwood stained, an approximation of the average proportion of stain with respect to the entire board surface can also be made. The latter viewpoint is in a sense more practical, because it more nearly conforms to grading criteria. Average percentages of board surface stained may be computed by multiplying the average percentage of board sapwood stained (as shown by the curve) by the percentage of sapwood in the respective piles. This probably completes the information of possible practical significance which may be extracted from the data at hand. It is

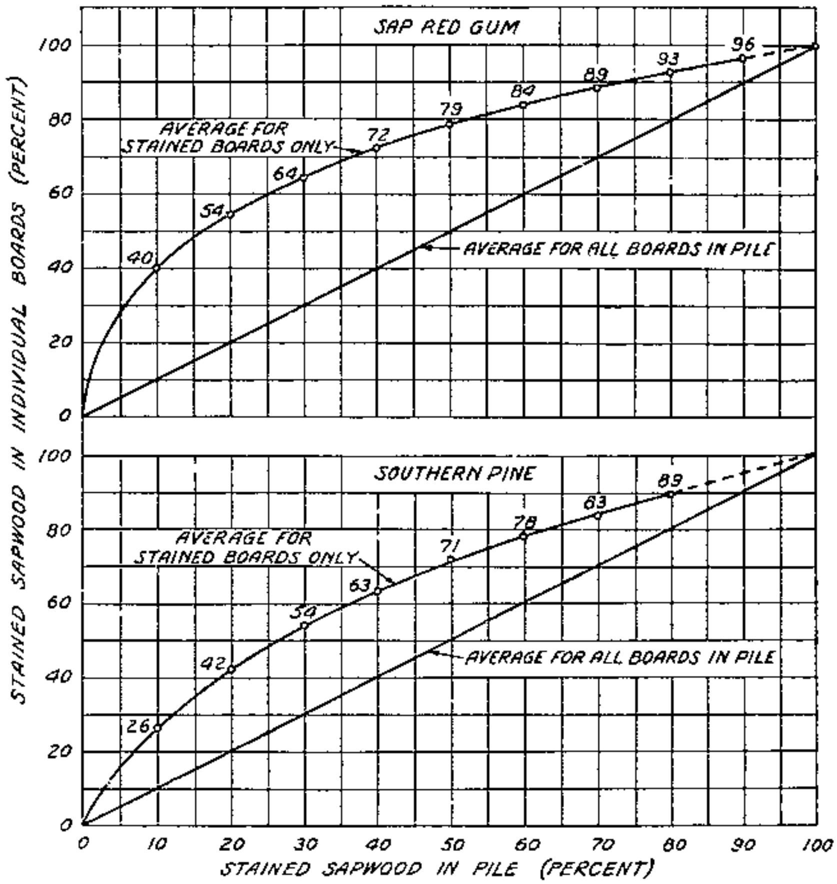


FIGURE 15.—Relation between total sap stain in the seasoning pile and the average amount of sapwood stained on individual boards (values based on upper curves of figs. 13 and 14).

not intended that figures 11 to 15 be drawn upon for purposes of prediction, since they are derived from examination of a comparatively limited amount of material and are based on certain broad assumptions which permit only limited application. However, it is believed that they are sufficiently representative to be useful in obtaining a fuller concept of what can be accomplished by way of improvements in stain control.

## PRESENT TRENDS IN COMMERCIAL USE OF CHEMICAL TREATMENTS FOR STAIN CONTROL

### LUMBER TREATMENT

Since their introduction on the market in 1931 and 1933, respectively, the organic mercurial and chlorinated phenolate treatments have stimulated a marked upward rise in chemical stain control by lumber manufacturers. At the same time handling and piling practices that have a bearing on stain control have been noticeably improved at progressive mills. It is estimated from the amounts of chemical used for this purpose that 3,000,000,000 feet of pine and hardwood lumber were dipped or sprayed in 1936 (*12*). The value of chemical treatment is in fact becoming recognized to the extent that dipped stock is commonly specified in orders for air-seasoned material.

However, there is still ample room for improved surface treatments of lumber. Present commercial materials, although giving a generally high degree of stain control, nevertheless tend to give erratic results when seasoning conditions are severe. A treatment having a wider margin of control safety would fill a real need at many mills. No doubt a number of compounds could be found which, in sufficiently high concentrations, would accomplish this end, but the problem remains of doing this without violating the several other requirements of a satisfactory anti-sap-stain material. Of chief consideration in this respect would be the cost, and the avoidance of injury to workmen handling the treatment. As already pointed out, even some of the treatments now in use are not entirely free from the danger of skin injury.

The increasing demand for bright lumber and the success attained with dips and sprays in the Southern States have encouraged the use of chemical treatments elsewhere. This has been particularly true in portions of the far West where considerable amounts of sugar pine, ponderosa pine, and western white pine are air seasoned. Furthermore, some need seems to be arising for treatment of Douglas fir, hemlock, and other Pacific Northwest species that are shipped green or air seasoned. Similar extension in the use of chemical treatments is becoming evident in other sections, such as the Lake, Central, and Southwestern States, wherever stain losses may at times be a problem.

### TREATMENT OF POSTS, POLES, AND PILING

There is some demand, particularly in the Southern States, for a surface treatment to protect peeled round stock from sap stain, mold, and decay during the seasoning period preceding pressure treatment. Sap stain and mold, while they do not importantly affect the strength of such products, are nevertheless commonly objectionable from the standpoint of appearance. They are not always obliterated by creosoting and are particularly evident if a light-colored preservative is used. Poles and piling are occasionally given a preliminary pressure treatment with creosote in order to insure their freedom from fungus defects at the time full treatment is applied.

Several attempts were made to work out a method for taking care of the problem by using treatments, such as have proved practicable for lumber and logs, but they were only partly successful. While poles are being sprayed to some extent with antistain chemicals for the purpose of keeping the surface bright, the control of stain and decay during long seasoning periods by such a procedure still remains a problem. A prompt dipping treatment followed by spraying as seasoning checks developed was found to offer some promise in the latter connection. The chief practical difficulty lies in protecting the stock after seasoning checks develop and in arranging to treat the material soon enough after it is cut and peeled.

In the case of posts, drying is more rapid; hence, even though seasoning checks develop, there is less opportunity for extensive interior infection. Although in the tests conducted dipping did not prevent posts from developing interior stain, it did keep the surfaces fairly bright and free from mold growths for several months. In most cases the amount of decay was small. That chemical treatment of posts may be of definite value is evident by the fact that one producer of southern pine posts is now dipping all his green material prior to stacking it for seasoning. A simple mechanical dipping apparatus and one of the chemical treatments regularly employed on pine lumber are used. This practice is being considered by other producers.

### TREATMENT OF VENEER

A number of veneer mills in the Gulf States have adapted the method of applying chemical solutions to the requirements of their type of operation. The need for a chemical treatment is especially acute at plants that depend to a considerable extent on air seasoning. In fair weather drying will usually take place sufficiently rapidly to exclude stain and mold fungi, but if 2 or 3 damp days occur in sequence severe damage may be incurred, particularly if the yard is extensive and large amounts of stock are placed to dry at one time.

Chemical treatment of green veneer represents a noteworthy advance in the use of antiseptics for reducing stain and mold damage, and points to the diversity of materials in the field of forest products that may be successfully protected in this way. The use to be made of a product, such as for food containers, should of course be considered in determining whether such treatment can be safely and profitably adopted.

### TREATMENT OF STAVES, HOOPS, SHINGLES, AND LATH

Staves and hoops are commonly air-seasoned and hence subjected to conditions favorable to stain development. Chemical treatments are being used by a number of stave and hoop mills to reduce losses from this source. Methods of application vary considerably, spraying being more prevalent at the present time. In addition, chemical treatment of stave bolts and logs is proving practicable in controlling end stain during storage periods. Procedures are essentially the same as those already described for logs (pp. 86–95). In the case of staves also it should be remembered that the use made of the staves is a determining factor in deciding whether chemical treatment can safely be employed.

Southern and western mills have found it desirable to dip their shingles, lath, and car strips that are to be air-seasoned. Dipping is done promptly after the material has been bundled, there being apparently no difficulty in getting the solutions to flow into the bundles and thoroughly cover the individual pieces. Dipping solutions used for treatment of pine lumber serve equally well for shingles and lath, although higher concentrations are sometimes employed.

## TREATMENT OF EXTERIOR MILLWORK

Within recent years there has been a demand for sash and other exterior millwork treated for the purpose of controlling stain and decay (fig. 16). Deterioration from these causes has increased in some northerly localities because of excessive moisture accumulation in the products, induced by the maintenance of higher interior relative humidities and the incorporation of special features to reduce heat losses. This has led to some surface treating of sash, frames, and other items with toxic chemicals that do not interfere with subsequent finishing processes.

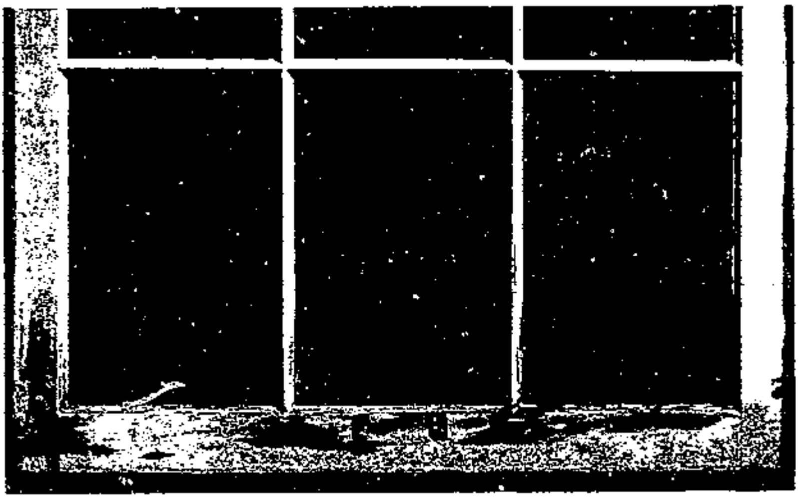

FIGURE 16.—Stain in untreated window sash occurring after moisture had condensed on the panes and run down into the wood.

Among treatments now being used on exterior millwork are those containing as their principal ingredient one or more of the present phenolic sap-stain preventives (*35*). These are applied in oil solution to the dry wood. The use of oil is necessary in order to attain maximum penetration and at the same time avoid swelling of the wood. The requirements of such a preservative treatment are strict in that protection over a good portion of the life of the building is called for. Consequently it is necessary that the millwork be submerged in the treating bath for substantially longer periods than are needed to protect lumber during seasoning.

## MISCELLANEOUS PRODUCTS

Practically any sapwood product that is to be air-seasoned is potentially subject to staining and may be benefited by chemical treatment if the need arises. Vehicle stock, specialty items, and furniture squares may be mentioned as examples. In addition, sapwood that has been dried may stain under moist conditions of storage, hence at times may be profitably treated for temporary protection.

## SUMMARY

The sapwood of probably all domestic species of wood, when placed under certain conditions, is subject to objectionable bluish-black, steel-gray, and sometimes brownish discolorations of fungus origin usually known as sap stain or blue stain. These stains penetrate the wood, causing permanent blemishes which seriously impair the value and marketability of the affected stock. Its prevalence throughout the United States, particularly in certain lumbering regions, makes blue stain of great importance, not only as a problem of producers of wood products but as a factor operating against the fullest conservation of forest resources. Occasional brighter-colored fungus discolorations also are found in wood, but they are usually of little consequence.

Some discolorations are known to arise purely from chemical changes in the wood, occurring in either the log or the lumber but more generally the latter. In many cases they are associated with oxidation processes that begin when the green wood is exposed to the air. Foremost among the chemical stains are the natural discolorations that take place in the sapwood of many hardwoods. Some of these are unobjectionable, whereas others are intense enough to be degrading factors. Persimmon, magnolia, black gum, basswood, birch, and maple sometimes develop chemical discolorations that resemble blue stain. Softwoods are for the most part free from objectionable chemical stains. Notable exceptions are those of brown color, which frequently occur in western and eastern pines during air seasoning or kiln drying.

Blue stain is caused by a group of fungi that mainly attack the wood rays and therefore do not have the same destructive effect as decay organisms. The suitability of blue-stained wood for uses where appearance is not a factor is for the most part unimpaired. The toughness of heavily stained wood may be reduced significantly whereas other strength properties seem to be but little altered. Blue stain has no practical effect on the resistance of sapwood to decay. With the possible exception of the stain that develops in living trees attacked by bark beetles, it does not interfere with preservative treatment of dry wood and it has no adverse effect on the drying rate and equilibrium moisture content of wood. Regarding the manufacture of paper, moderate amounts of blue stain do not seriously affect the utility of ground-wood and sulfite pulps for newsprint, nor of sulfate pulps for kraft paper, board, and bleached high-grade paper. Large amounts of stain tend to cause objectionable discoloration in all pulps. It apparently has no noticeable effect on the mechanical properties of paper. The gluing qualities of stained wood are not noticeably different from those of bright wood. The paintability and paint-holding qualities of stained wood are not inferior unless the wood is wet enough for continued growth of the causal fungi, in which case the fungi may exert some pressure and aggravate the tendency of the excessive moisture to cause blistering of the paint film.

Blue-stain problems are greatest in timbered regions where climatic conditions are most suitable for growth of the causal fungi. Most important of the natural factors influencing development of blue-stain fungi are moisture and temperature. Although suitable moisture content for stain development exists in green and semigreen sapwood

of sawed materials, its duration depends in large measure on the drying conditions of the surrounding air. These in turn are considerably governed by climatic conditions, especially by rainfall. In the Gulf States and lower Mississippi Valley, where high temperatures and an abundance of rainfall exist throughout the greater portion of the year, staining affects the lumber industry most seriously. Although temperatures around seasoning piles in this region are at times too high for stain development, within the piles of drying lumber conditions are usually suitable; winter temperatures, although having a retarding effect, are seldom inhibiting factors. Blue-stain occurrence in mountainous and more northerly regions of the United States, characterized by lower winter temperatures and greater variation in moisture conditions, is markedly seasonal. Outside of the Southern States, blue stain is most troublesome in the California pine region and in the northern Idaho and surrounding area, but presents a problem of various degrees of importance in practically all lumber regions.

Practical control of blue stain lies in rapid seasoning or in surface treatment of the freshly cut stock with chemicals that prevent growth of the stain fungi. Wood that contains no more than 20 percent of water, based on its dry weight, will not stain. Using special air-seasoning methods in fair weather, this moisture content usually can be quickly reached in the surface layers of lumber. Higher moisture contents are not common in air-dry wood under ordinary conditions of storage or service. Previous drying does not preclude the occurrence of blue stain in the event that wood again becomes wet. The use of chemical treatments permits seasoning in properly constructed flat piles of the conventional type with greatly reduced danger of stain occurrence during unfavorable weather, and at a cost usually substantially lower than that required by special air-seasoning procedures.

Chemicals that, at tested concentrations, appeared to be most effective in controlling stain in both pine and hardwood lumber were a number of organic mercury compounds, sodium pentachlorophenolate, and a mixture of sodium tetrachlorophenolate and sodium 2-chloro-o-phenylphenolate. Commercial soda and ammonium fluoride were effective on pine alone. Borax, certain compounds with the borate radical, and sodium tetrachlorophenolate were the most effective chemicals on hardwoods alone. Differences in the effectiveness of some treatments on pine and hardwoods have not been explained. Certain important stain fungi have been found more commonly on pine lumber and others more commonly on hardwood lumber, suggesting that there may be a differential tolerance of pine and hardwood fungi to the treatments in question.

Chemicals from the group of tested materials now extensively used for stain control are (1) Lignasan (ethyl mercuric chloride plus inerts), (2) Dowicide P (1–1 mixture of sodium tetrachlorophenolate and sodium 2-chloro-o-phenlyphenolate plus excess alkali), (3) Dowicide H (sodium tetrachlorophenolate plus excess alkali), and (4) Santobrite and Dowicide G (sodium pentachlorophenolate plus excess alkali.[32] Nos. 1, 2, and 4 are for use on both softwoods and hardwoods and No. 3 for use on practically all species except

[32] See footnote 26, p. 67.

southern pines in the immediate Gulf region. In addition, hot soda solutions, the standard treatment prior to these tests, are being employed at some pine mills. All the newer chemicals are comparable in effectiveness, although each has certain advantages and disadvantages that may have a bearing on its suitability for a particular operation.

The use to be made of a product, such as for food containers, should, of course, be considered in determining whether a particular chemical treatment can be safely and profitably adopted.

For satisfactory results with any dipping or spraying treatment, certain practices and precautions should be carefully followed. Stain-free logs, prompt treatment, thorough coverage of the stock, adequate concentration of the chemical, protection of treating solution and treated stock from rain, and good seasoning methods are essential. Observations both of the rates of penetration of stain fungi and of chemical solution, together with actual field tests, show that treatment as a rule cannot be safely delayed longer than 24 or at the most 48 hours. Greater delays may result in considerable interior stain. Solution concentrations should never be lower than those recommended, but during unfavorable weather may sometimes be increased to advantage.

Some of the treatments tend to irritate the skin to an objectionable degree unless special care is exercised in using them. Precautions that are recommended generally include: (1) That the powder or solutions in concentrated form be kept from contact with the skin; (2) that treating solutions be kept from splashing on the face; and, in the case of the more irritating chemicals, (3) that resistant individuals be selected for the treating operations and handling of the wet lumber; and (4) that rubber gloves or gauntlets, and waterproof aprons, if necessary, be used when dipping by hand and in handling the freshly dipped lumber.

Chemical treatments can be used successfully at small mills as well as at large mills. The same practices and precautions are necessary. Treating equipment at both types of mill is discussed.

Lumber treated with a number of chemicals now in use apparently can be bulk-piled for as long as 4 weeks without the occurrence of objectionable stain. Although it has not been ascertained to what extent this practice may jeopardize subsequent stain control during the period in which the material is stacked for drying, tests in better-than-average drying weather disclosed no harmful effects from previous bulking.

Data are presented pointing to certain relations between the percentage of stained sapwood in the seasoning pile and the proportion of boards with different amounts of stain.

Chemical treatment of logs that cannot be sawed promptly is a practicable means of reducing stain that commonly occurs as a result of infection through the ends and barked areas. Insect attack introduces other avenues of infection and is the most serious obstacle to successful treatment of logs during the warmer months. However, in the absence of serious insect attack, satisfactory stain control has been accomplished for storage periods as long as 90 to 120 days by spraying the ends and barked areas. Treatments suitable for use on logs include, among others, the same materials that are most effective on lumber; in general, the concentrations should be from about four to six times as great, depending on the chemical. The chemicals may be applied with a hand-operated pressure spray.

Present antistain treatments are being extended commercially to green posts, ve..., hoop stock, shingles, lath, and other materials as a means of protecting them during seasoning.

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## APPENDIX

TABLE 23.—*Summary of field and laboratory experiments by other investigators on chemical control of sap stain and mold in lumber and other wood products (United States)*

| Chemicals | Concentration | Investigator [1] | Year | State | Kind of material treated | Results reported |
|---|---|---|---|---|---|---|
| | *Percent* | | | | | |
| Ammonium fluoride | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Promising against stain but not mold. |
| Do | 2.5 | Pettigrew, 19 | 1917 | Mississippi | Southern pine lumber | Do. |
| Betanaphthol+caustic soda+naphthalene. | 0.48+0.36+0.12 | Hubert, 19 | 1923 | Wisconsin | Wood for food containers | Promising. |
| Bleaching powder | 1 | Howard (*32*) | 1918 | do | Red oak blocks | Poor. |
| Borax | 1 | do | 1918 | do | do | Variable to poor. |
| Do | 5 | Von Schrenk and Bessey.[2] | 1906 | do | White and red pine lumber. | Do. |
| Do | 5 | Weiss and Barnum (*78*). | 1907–9 | Louisiana | Longleaf pine lumber | Do. |
| Do | 5 | Howard (*32*) | 1918 | Missouri and Wisconsin. | Red oak spokes | Do. |
| Do | | Brundage (*8*) | 1928 | California. | California sugar pine lumber. | Do. |
| Borax+boric acid | 3+2–3 | Hedgcock (*29*) | 1909–10 | Maryland | Hardwood veneer stock | Good in laboratory tests; poor in factory storage. |
| Borax+boric acid+sodium carbonate. | 3+3+8.5 | do | 1909–10 | do | do | Good in factory storage. |
| Calcium chloride | 5 | Weiss and Barnum (*78*). | 1907–9 | Louisiana | Longleaf pine lumber | Poor. |
| Calcium silicofluoride | 0.5–0.75 | Pettigrew, 19 | 1917 | Mississippi | Southern pine lumber | No practical value. |
| Carbolic acid | 2–5 | Weiss and Barnum (*78*). | 1907–9 | Louisiana | Longleaf pine lumber | Poor. |
| Carbolic acid+potassium hydroxide | 0.7+0.7 | Hedgcock (*29*) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Copper acetate+acetic acid | 1+1 | do | 1909–10 | do | do | Do. |
| Copper chloride+hydrochloric acid | 1+0.1 | do | 1909–10 | do | do | Good to unsatisfactory. |
| Copper sulfate | 0.5–5 | Weiss and Barnum (*78*) | 1907–9 | Louisiana | Longleaf pine lumber | Unsatisfactory; also discolored wood. |
| Do | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Do. |
| Copper sulfate+sulfuric acid | 1+0.1 | Hedgcock (*29*) | 1909–10 | Maryland | Hardwood veneer stock | Good to unsatisfactory. |
| Creosote+kerosene | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Promising against stain, but not mold. |
| Do | 10 | do | 1918 | Missouri | do | Do. |
| Cresol+potassium hydroxide | 0.5+0.7 | Hedgcock (*29*) | 1909–10 | Maryland | Hardwood veneer stock | Unsatisfactory. |
| Cresol+sodium hydroxide | 0.48+0.20 | Hubert, 19 | 1923 | Wisconsin | Wood for food containers | Promising; discolored slightly. |
| Dichlorobenzene+naphthalene+rosin | 1+0.35+1.3 | do | 1923 | do | do | Promising. |
| Ethyl mercuric chloride | 0.015 | Brundage (*8*) | 1928 | California | California sugar pine lumber. | Good. |
| Formalin | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Poor. |
| Fungimors (proprietary) | 0.4–0.6 | Brundage (*8*) | 1927–28 | California | California sugar pine lumber. | Moderately effective. |
| Lead acetate | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Unsatisfactory. |
| Lead nitrate | 1 | do | 1918 | do | do | Do. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lime (unslacked) | | do | 1918 | Missouri | Red oak spokes | Do. |
| Lime+sulfur | 10+10 | Hedgcock (29) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Lysol (proprietary) | 1 | Howard (32) | 1918 | Wisconsin | Red oak blocks | Do. |
| Magnesium chloride | 5 | Weiss and Barnum (78) | 1907–9 | Louisiana | Longleaf pine lumber | Poor. |
| Magnesium silicofluoride | 0.5–0.75 | Pettigrew, 19 | 1917 | Mississippi | Southern pine lumber | Unsatisfactory; molded badly. |
| Do | 1 | Howard (32) | 1918 | Wisconsin | Red oak blocks | Do. |
| Mercuric chloride | 0.01 | Hubert, 19 | 1924 | Minnesota | Red pine lumber | Good at higher concentrations; fair to unsatisfactory at lower concentrations. |
| Do | .05 | Von Schrenk, Bessey, and Spaulding.[2] | 1905–6 | Missouri | Shortleaf pine lumber | Do. |
| Do | .05 | Von Schrenk and Bessey.[2] | 1906 | Wisconsin | White and red pine lumber | Do. |
| Do | .1 | Hedgcock (29) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Do | 0.1–1 | Weiss and Barnum (78) | 1907–9 | Louisiana | Longleaf pine lumber | Do. |
| Do | 0.35 | Brundage (8) | 1928 | California | California sugar pine lumber. | Do. |
| Mercuric chloride+hydrochloric acid | 1+1 | Howard (32) | 1918 | Wisconsin | Red oak vehicle stock | Effective against stain and mold. |
| Mykantin (proprietary) | 1 | Pettigrew, 19 | 1917 | Mississippi | Southern pine lumber | Effective against stain and mold, but discolors wood. |
| Do | 1 | Howard (32) | 1918 | Wisconsin | Red oak blocks | Do. |
| Naphthalene | Flakes | Weiss and Barnum (78) | 1907–9 | Louisiana | Longleaf pine lumber | Poor. |
| Nekyan (proprietary) | 2 | Brundage (8) | 1928 | California | California sugar pine lumber | Moderately effective. |
| Orthonitrophenol | 1 | Howard (32) | 1918 | Wisconsin | Red oak blocks | Unsatisfactory. |
| Phenylsalicylate | 0.3 | Hedgcock (29) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Pine oil, soap, naphthalene emulsion | 25+4+4 | Hubert, 19 | 1923 | Wisconsin | Wood for food containers | Promising. |
| Potassic-alum | 1 | Howard (32) | 1918 | do | Red oak blocks | Effective at high concentrations; poor at low concentrations. |
| Do | 10 | Hedgcock (29) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Potassium chlorate | 1 | Howard (32) | 1918 | Wisconsin | Red oak blocks | Poor. |
| Rongalite (proprietary) | 1 | do | 1918 | do | do | Unsatisfactory. |
| Sodium benzoate+benzoic acid | 0.2–0.3+0.1–0.6 | Hedgcock (29) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Sodium bicarbonate | 1–10 | Rumbold (59) | 1910 | Missouri and Louisiana. | Pine and sap gum lumber | Variable; fair to good at higher concentrations. |
| Do | 2.25 | Knowlton, 18 | 1914 | Louisiana | Longleaf pine lumber | Do. |
| Do | 2.5 | Von Schrenk and Bessey.[2] | 1906 | Wisconsin | Red pine lumber | Do. |
| Do | 2–4 | Hubert (34) | 1922 | Mississippi and Louisiana. | Southern pine lumber | Do. |
| Do | 5 | Von Schrenk, Bessey, and Spaulding.[2] | 1905–6 | Missouri | Shortleaf pine lumber | Do. |
| Do | 5–10 | Weiss and Barnum (78) | 1907–8 | Louisiana | Longleaf pine lumber | Do. |
| Do | 8 | Hubert, 19 | 1924 | Minnesota | Red pine lumber | Do. |
| Do | 10 | Hedgcock (29) | 1909–10 | Maryland | Hardwood veneer stock | Do. |
| Sodium bisulphite+sodium fluoride | 13+4.5 | Hubert, 19 | 1924 | Wisconsin | Ponderosa pine lumber | Good. |

[1] Italic numbers in parentheses refer to Literature Cited, p. 112; Arabic numbers refer to footnote citations throughout text.
[2] Reported by Hubert (*34*, *p. 60*).

TABLE 23.—*Summary of field and laboratory experiments by other investigators on chemical control of sap stain and mold in lumber and other wood products (United States)*—Continued

| Chemicals | Concentration | Investigator | Year | State | Kind of material treated | Results reported |
|---|---|---|---|---|---|---|
| | *Percent* | | | | | |
| Sodium carbonate | 1-10 | Rumbold (*59*) | 1910 | Missouri and Louisiana. | Pine and sap gum lumber | Poor to fair; somewhat less effective than sodium bicarbonate. |
| Do | 6.5-10 | Hedgcock (*29*) | 1909-10 | Maryland | Hardwood veneer stock | Do. |
| Do | ---- | Brundage (*8*) | 1928 | California | California sugar pine lumber | Do. |
| Sodium carbonate+lime | 4+2 | Weiss and Barnum (*78*) | 1907-9 | Louisiana | Longleaf pine lumber | Fair. |
| Sodium bifluoride | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Effective against stain but not mold. |
| Do | 2.5 | Pettigrew, 19 | 1917 | Mississippi | Southern pine lumber | Do. |
| Sodium fluoride | 0.4-2.93 | Knowlton, 18 | 1914 | Louisiana | Longleaf pine lumber | Fair against stain but not mold. |
| Do | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Do. |
| Do | 2.5 | Pettigrew, 19 | 1917 | Mississippi | Southern pine lumber | Do. |
| Sodium fluoride+sodium bicarbonate | 2+2 | do | 1917 | do | do | Effective against stain and mold. |
| Sodium hydroxide | 5 | Weiss and Barnum (*78*) | 1907-9 | Louisiana | Longleaf pine lumber | Unsatisfactory. |
| Sodium sulfite+sulfuric acid | 3+0.1 | Hedgcock (*29*) | 1909-10 | Maryland | Hardwood veneer stock | Do. |
| Zinc chloride | 1-5 | Weiss and Barnum (*78*) | 1907-9 | Louisiana | Longleaf pine lumber | Do. |
| Zinc chloride+hydrochloric acid | 1-3+0.1 | Hedgcock (*29*) | 1909-10 | Maryland | Hardwood veneer stock | Do. |
| Zinc silicofluoride | 1 | Howard (*32*) | 1918 | Wisconsin | Red oak blocks | Do. |

TABLE 24.—*Chemicals which, at concentrations used in small-scale lumber tests, were ineffective in controlling stain in both pine and red gum sapwood*

**METALLIC COMPOUNDS**

| Inorganic: Chemical | Inorganic: Concentration | Organic: Chemical | Organic: Concentration |
|---|---|---|---|
| | *Percent* | | *Percent* |
| Aluminum ammonium sulfate | 0.72 | Copper phenylsulfonate | 0.45 |
| Aluminum potassium sulfate | 7.1 | Ethyl mercuric cyanide | .010 |
| Aluminum sulfate | 7.2 | Mercuric salicylate | .11 |
| Arsenic trioxide | .24 | Zinc phenylsulfonate | .9 |
| Barium carbonate | 8.0 | | |
| Barium hydroxide | 6.0 | | |
| Barium sulfide | 2.4 | | |
| Cadmium sulfate | .3 | | |
| Calomel | .6 | | |
| Copper carbonate | 1.2 | | |
| Copper sulfate | 3.6 | | |
| Ferrous fluoride | 1.0 | | |
| Magnesium silicofluoride | .6 | | |
| Manganese borate | .48 | | |
| Manganese chloride | .72 | | |
| Mercurous fluosilicate | .5 | | |
| Nickel ammonium sulfate | .72 | | |
| Nickel chloride | .15 | | |
| Thallium sulfate | .05 | | |
| Zinc ammonium sulfate | .48 | | |
| Zinc fluoride | 3.2 | | |
| Arsenic pentoxide+sodium bichromate | 0.37+.37 | | |
| Bordeaux mixture | 1.2 | | |
| Copper sulfate+ammonium hydroxide | 3.0+.6 | | |
| Mercuric chloride+potassium iodide+soda | 0.028+0.022+2.4 | | |

**SODIUM COMPOUNDS**

| Chemical | Concentration | Chemical | Concentration |
|---|---|---|---|
| Sodium bisulfite | 7.2 | Sodium benzene sulfonate | 1.0 |
| Sodium hypochlorite | 4.2 | Sodium benzoate | 1.2 |
| Sodium hyposulfite | 4.2 | Sodium formaldehyde sulfoxylate | 1.0 |
| Sodium phosphate (tri basic) | 6.0 | Sodium naphthionate | .21 |
| Sodium silicate | 6.4 | Sodium phenylsulfonate | .9 |
| Sodium silicofluoride | .9 | Sodium 2, 4-dichlorophenol, 6-sulfonate | 1.0 |

**PROPRIETARY COMPOUNDS** [1]

| Chemical | Concentration |
|---|---|
| | *Percent* |
| A. C. S. 79-22-12 | 2.0 |
| A. C. S. 79-22-24 | 2.0 |
| A. C. S. 79-22-28 | 2.0 |
| Arochlor 1242 [2] | .72 |
| Dipdust | .48 |
| Diversol | 2.4 |
| Fungimors | .30 |
| Germicide G-3 [1] | 1.0 |
| Germicide G-6 [1] | 1.0 |
| Germicide G-7 [1] | 1.0 |
| Inline | .24 |
| Mathieson's H. T. H | .72 |
| Mercurophen | .3 |
| Metaphen | .4 |
| Minerec [2] | .24 |
| Nekyan | 2.7 |
| Nekyan KB | .5 |
| Palustrex "B" | 1.0 |
| Palustrex "C" | 1.0 |
| Pine oil emulsion | 2.4 |
| Schäffer's salt | 1.0 |
| Semesan | .48 |
| Shirlan NA | .5 |
| Shirlan 50-percent paste | .9 |
| Shirlan powder | .2 |
| Somol | .72 |
| Solbar | .4 |
| Sterilac | .15 |
| Termitcol | 3.0 |
| Tritreat [1] | 3.3 |
| Minerec A+borax | 0.5+2.0 |
| Minerec B+sodium carbonate | 1.0+1.0 |
| Palustrex B+sodium tetrachlorophenolate | .5+.5 |

See footnotes at end of table.

TABLE 24.—*Chemicals which, at concentrations used in small-scale lumber tests, were ineffective in controlling stain in both pine and red gum sapwood*—Continued

| SODIUM COMPOUNDS—Continued | | | | PROPRIETARY COMPOUNDS [3] | |
|---|---|---|---|---|---|
| Inorganic | | Organic | | | |
| Chemical | Concentration | Chemical | Concentration | Chemical | Concentration |
| | *Percent* | | *Percent* | | *Percent* |
| Sodium sulfide | 1.0 | | | | |
| Soda+sodium bisulfite | 3.8+2.0 | | | | |
| Sodium fluoride+sodium bisulfite | 1.0+3.5 | | | | |
| MISCELLANEOUS COMPOUNDS | | | | | |
| Ammonium bichromate | 0.48 | Benzoic acid | 0.9 | | |
| Ammonium borate | 1.6 | Colloidal creosote | .9 | | |
| Ammonium thiocyanate | 1.0 | Cresylic acid [1] | 1.9 | | |
| Formaldehyde | 1.2 | 2-chlorodiphenyl [2] | .72 | | |
| Lime-sulfur | .6 | 4-chlorodiphenyl [2] | .72 | | |
| Potassium borofluoride | 2.0 | Ethylchloracetate | .21 | | |
| Potassium sulfide | 3.0 | Ethylene chlorhydrin | 1.0 | | |
| Pyroligneous acid | 1.0 | Furoic acid | 1.0 | | |
| | | Hydrofuramide | 1.0 | | |
| | | Methyl-oxyethel-mercury chloride | .012 | | |
| | | Monochlorobetanaphthol [1] | .6 | | |
| | | Monochloro-o-cresol [1] | .3 | | |
| | | Monochloro-o-xylenol [1] | .6 | | |
| | | Monochlorophenol [1] | .6 | | |
| | | Parachlorothymol [1] | .20 | | |
| | | Paradichlorobenzene [1] | 1.45 | | |
| | | Paratertiarybutylphenol [1] | .5 | | |
| | | Phenyl salicylate [2] | .6 | | |
| | | Salicylic acid | 1.8 | | |
| | | Thymol [1] | .24 | | |
| | | Trichlorophenol [1] | .6 | | |
| | | Xylenol [1] | .6 | | |
| | | Betanaphthol [1]+naphthalene | 5.6+.40 | | |

[1] Sufficient sodium hydroxide added to bring the material into solution.

[2] Used as an emulsion procured with the aid of soap. Solid compounds first dissolved in kerosene.

[3] A. C. S. 79-22-12, 79-22-24, 79-22-28: Preparations of sodium mercaptobenzothiazole, mixture of sodium mercaptobenzothiazole and sodium normaldibutyldithiophosphate, mixture of cadmium secondarybutylxanthate and soda ash, respectively; furnished by American Cyanamid & Chemical Corp. Arochlor: Chlorinated diphenyl compounds; furnished by Swann Chemical Co. Dipdust: Patented disinfectant consisting of 6 percent hydroxymercurichlorophenol sulfide and 2 percent of hydroxymercurinitrophenol sulfate. Diversol: Patented sterilizing agent composed of 2.5 percent of sodium hypochlorite and 92.5 percent of alkaline sodium phosphate. Fungimors: Patented German stain preventive understood to be mercurial. Germicides G-3, G-6, G-7: Patented materials of phenolic composition; furnished by the Monsanto Chemical Co. Ialine: A reversible colloidal sulfur. Mathieson's H. T. H.: A calcium hypochlorite preparation. Mercurophen: Sodium oxymercuri-o-nitrophenoxide; furnished by the H. K. Mulford Co. Metaphen: 4-diacetoxymercuri-2-nitro-cresol. Minerec: (also Minerec A and B): Flotation reagents consisting of 10 percent of xanthic anhydride and 90 percent of ethyloxycarbonyl sulfide; furnished by the Minerec Corporation. Nekyan and Nekyan KB: Patented Swedish stain preventives; furnished by Bergstrom Trading Co. Palustrex "B" and "C": Compounds containing copper resinate and a mixture of copper resinate and nicotine, respectively; furnished by the Wood Chemical Products Co. Pine oil emulsion: A steam-distilled, emulsified pine oil; furnished by Johnston-Mackie Co. Schäffer's salt: Sodium b-naphtholsulfonate. Semesan: A patented disinfectant (hydroxymercurichlorophenol). Shirlan compounds: British antimildew materials used in conditioning cotton yarn. Somol: Patented French compound containing essentially coal tar, potassium dichromate, and an additive creosote compound. Solbar: Principally bariumsulfide; furnished by the E. I. du Pont de Nemours & Co. Sterilac: An alkaline chloroamine mixture used for disinfectant purposes. Termitcol: Product of destructive distillation of wood, furnished by Termitcol Corporation of Louisiana. Tritreat: Furnished by the Bruce Chemical Co.

TABLE 25.—*Chemicals which, at concentrations used, were ineffective in controlling sap stain in gum bolts stored in the woods for 40 to 90 days*

| Chemical | Concentration |
|---|---|
| | *Parts per 100 parts of solvent*[1] |
| INORGANIC SALTS | |
| Ammonium fluoride | 5 |
| Bordeaux mixture | 3 |
| Lime-sulfur | 3 |
| Potassium bichromate | 5 |
| Sodium arsenate | 5 |
| Sodium fluoride | 5 |
| Sodium metasilicate | 1.5 |
| Thallium sulfate | 5 |
| Zinc metal arsenite (commercial solution) | 300 |
| COAL-TAR PRODUCTS AND BENZENE DERIVATIVES | |
| Asphalt chromate emulsion | Undiluted |
| Cannel coal oil | 100 K |
| 2-chlorodiphenyl | 5 K |
| 4-chlorodiphenyl | 5 K |
| Coal tar creosote | 20 K |
| Colloidal creosote | 25 K |
| Cresylic acid | 20 K |
| 2, 5-dinitrobenzene | 5 K |
| Diphenylphenol | 5 K |
| Diphenylphenol (pentachloro-) | 5 K |
| Phenol (monochloro-) | 5 (Na salt) |
| Phenol (dichloro-) | 5 (Na salt) |
| Phenol (trichloro-) | 5 (Na salt) |
| Sodium benzene sulfonate | 5 |
| Sodium dinitrophenolate | 5 |
| Sodium dinitro-o-phenylphenolate | 5 |
| Xylenol | 5 (Na salt) |
| Xylenol | 5 K |
| MISCELLANEOUS COMPOUNDS | |
| Colloidal sulfur | 0.72 |
| N-butylphthalate | 6 K |
| Triethanolamine | 10 |
| Shale oil | 30 K |
| Shale gas oil | 25 K |
| Shale oil composite | 20 |
| PROPRIETARY COMPOUNDS[2] | |
| Arochlor 1242 | 5 K |
| Arochlor 1268 | 3 K |
| Cooper's end coating (diluted for spray use) | 20 K |
| Cabinol | Undiluted |
| Dutox | 5 |
| Kolofog | 10 |
| Minerec A (also B) | 50 K |
| Nekyan KB | 5 |
| Palustrex B (also C) | 5 |
| Pictrebor | 100 |
| Somol | 3 |
| Solignum | 20 |
| Turpentine foots | 15 |
| Termite special | 20 |
| Tritreat | 25 |
| Wolman salts | 5 |

[1] All chemicals dissolved in water unless indicated by a K, signifying kerosene.

[2] Cooper's end coating: Mixture of cresylic acid and filled hardened gloss oil; furnished by V. M. Cooper Co. Cabinol: Product of wood distillation; furnished by Hercules Powder Co. Dutox: Patented insecticide consisting largely of barium fluosilicate; furnished by Grasselli Chemical Co. Kolofog: A colloidal sulfur compound; furnished by Niagara Sprayer & Chemical Co. Pictrebor: Mixture of salts of heavy metals, primarily; furnished by Pictrebor Chemical Co. Solignum: Furnished by McEverlast, Inc. Termite special: Asphalt preparation; furnished by McEverlast, Inc. Turpentine foots: A product of wood distillation. Wolman salts: A commercial wood preservative consisting of sodium chromate, dinitrophenol, and either sodium fluoride or sodium arsenite; furnished by American Lumber & Treating Corporation. For others see footnote 3 of table 24.

TABLE 25.—*Chemicals which, at concentrations used, were ineffective in controlling sap stain in gum bolts stored in the woods for 40 to 90 days*—Con.

SPREADERS AND ADHESIVES USED WITH A NUMBER OF PRECEDING TREATMENTS

| Chemical | Concentration |
|---|---|
| | *Parts per 100 parts of solvent*[1] |
| Casein | 1.5 |
| Coconut oil | 6 and 12 |
| Fish oil | 6 |
| Soap emulsion | 3 |

[1] All chemicals dissolved in water unless indicated by a-K, signifying kerosene.

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