THE PRESERVATIVE TREATMENT OF VARIOUS SPECIES PROPOSED FOR POLES AND CROSSARMS

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin

In Cooperation with the University of Wisconsin
The heavy drain that the war has imposed on the forests of America, the backlog of pole requirements that has been built up over the war period, and the present labor shortage have made it impracticable to obtain a sufficient number of poles of the species formerly used.

Up to the present time Southern yellow pine and Western redcedar have been the species most extensively used for poles. Coast Douglas-fir and Northern white cedar are also recognized as good pole woods, but poles of these species have not had the wide distribution nor the extensive use that Southern yellow pine and Western redcedar poles have had. In addition to the woods mentioned, treated lodgepole pine poles have been used to a limited extent in the Rocky Mountain region.

Cedar poles and, in certain localities, some of the less durable species have been used in past years without preservative treatment, but the present discussion will be confined to poles that are to be treated. Since the sapwood of all species has low resistance to decay, the economy of preservative treatment is recognized even for cedar poles that normally have a fairly thin sapwood and that have a naturally durable heartwood.

In order to meet some of the problems resulting from the current pole shortage specifications have recently been prepared covering pole species to be used by the Rural Electrification Administration. The American Standards Association has prepared specifications designated as "American War Standards Specifications and Dimensions for Wood Poles." The specifications mentioned cover miscellaneous conifers that are to be given a preservative treatment and that heretofore have not been included among the recognized standard pole woods.

The proposed substitute woods have been grouped according to the allowable fiber stress in the following order:

**Group I - Fiber stress 5,500 pounds per square inch**

Atlantic white-cedar (Chamaecyparis thyoides)

Spruce (Picea) all species

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1Presented at the 1946 Summer Convention of the American Institute of Electrical Engineers at Detroit, Michigan, June 28, 1946.

2Maintained at Madison 5, Wisconsin, in cooperation with the University of Wisconsin.
Group II - Fiber stress 6,000 pounds per square inch

- Eastern white pine (Pinus strobus)
- Ponderosa pine (Pinus ponderosa)
- Sugar pine (Pinus lambertiana)
- Western white pine (Pinus monticola)

Group III - Fiber stress 6,600 pounds per square inch

- Jack pine (Pinus banksiana)
- Red (Norway) pine (Pinus resinosa)
- White fir (Abies concolor)

Group IV - Fiber stress 7,400 pounds per square inch

- Douglas-fir, other than coast type, (Pseudotsuga taxifolia)
- Eastern hemlock (Tsuga canadensis)
- Western hemlock (Tsuga heterophylla)
- Eastern larch (Tamarack) (Larix laricina)
- Western larch (Larix occidentalis)

The foregoing fiber stresses were obtained from a study made by the Forest Products Laboratory and are based on the American Standards Association recommended stresses for lodgepole pine.

Wood Preservatives for Poles

Creosote

Prior to the war a large proportion of the poles used in the United States were treated with American Wood Preservers' Association specification grade 1 coal-tar creosote with a specified distillation residue of not over 20 to 25 percent above 355° C.

The Federal specification covering creosote for pole treatment limits the residue to 25 percent. Shortages resulting from the war, however, made it difficult to obtain creosote with a low distillation residue, and it became necessary to increase the allowable residue in the Federal specification to as much as 35 percent. This wartime emergency provision has now been discontinued. One of the important reasons for specifying low residue creosote oils for pole treatment is to reduce the tendency to "bleed."

Before the war a large amount of creosote was imported from Europe and Japan. Since this supply has now been practically cut off and because the domestic production will probably not be able to meet the heavy postwar demands, a creosote shortage may exist for some time to come. This situation has forced pole users to consider the use of other preservatives less well known but that offer promising results. In extreme cases it may even be necessary to use treatments that are known to be less economical because of the shorter service life obtained. Such treatments may be less economical because the materials lack the preservative properties suitable for conditions under which poles are used or because of inadequate treatment. Nevertheless there should be few cases where inferior and uneconomical treatment is necessary because of present shortages.
Chlorinated Phenols

During the past 10 years the chlorinated phenols have been receiving considerable attention as possible substitutes for creosote or as materials that can be used in mixtures with creosote. Pentachlorophenol is the best known in this group and has been the most extensively used, but tetra-chlorophenol and 2-chloro-orthophenylphenol, in mixtures with pentachlorophenol, have also been given consideration. Pentachlorophenol has the advantage of a lower water solubility than the other two phenolic compounds. Tests show that these chemicals have a high degree of toxicity, and 5 percent solutions (on a weight basis) are apparently suitable when solution absorptions needed to obtain the necessary penetrations are employed. A 5 percent solution of pentachlorophenol (on a weight basis) is commonly recommended at the present time. This is for absorptions similar to those specified for pole treatment with creosote.

Both toxicity and permanence are highly important qualities of a good wood preservative; but only long time service tests provide a satisfactory measure of permanence, and such tests are needed to determine fully the relative merits of the chlorinated phenols. The limited number of service tests that have been started during the past few years indicate that the chlorinated phenols have a promising future, but little information is available on the performance of these solutions when applied by the pressure process. Data thus far obtained apparently indicate that solutions of the chlorinated phenols made with the heavier petroleum oils may give better protection than solutions in which the more volatile oils are used. On the other hand, the more volatile oils penetrate the wood more readily when the solutions are applied by non-pressure methods. It has been found that some petroleum oils are more suitable than others both as solvents and from the standpoint of freedom from sludging.

The problem of sludging is also of importance in the use of creosote-petroleum mixtures. Experience has shown that petroleum oils with an asphaltic base are much less likely to give trouble than the oils with a paraffin base. At the present time some pole users are having poles treated with pentachlorophenol mixtures containing varying proportions of coal-tar creosote. These mixtures also have an increased tendency to cause sludging unless a suitable petroleum oil is employed.

Creosote Solutions

Blended preservative oils that have been used successfully for various kinds of timber are the creosote-coal tar and the creosote-petroleum solutions. These mixtures have not been so extensively used for poles as for other types of treated material because of their greater tendency to cause bleeding. They should prove satisfactory for poles, however, where bleeding is not an important consideration.

Bleeding

The problem of bleeding is of particular interest when poles are used in urban line construction where the oily surface may cause damage to clothing and result in public complaint. Bleeding is naturally of less importance in rural lines, but in any case it is objectionable to linemen who must climb the poles when the line is installed and when repairs are required. The bleeding problem may be particularly aggravating.
when the poles have been treated shortly before they are placed in service. While this trouble becomes less acute after the poles have been in service for a time, in some installations bleeding may persist to a variable extent for a considerable period. It must not be assumed that all poles treated with preservative oils bleed, but it is difficult to predict what poles, if any, will bleed and to what extent they will bleed.

Factors that appear to have an important bearing on bleeding are: type of preservative oil used, absorptions obtained, method of treatment, species, and temperature conditions to which the wood is exposed. Heavy absorptions usually cause more bleeding than light absorptions; heartwood will bleed more than sapwood, and species with the more resistant sapwoods will normally bleed more (with the same absorption) than species in which the sapwood is easily penetrated. Bleeding may occur either in summer or winter but is generally most severe in the hot summer months. Straight coal-tar creosote usually gives less bleeding trouble than mixtures of coal-tar creosote and petroleum, or creosote-coal tar solutions. Likewise, creosote with a high residue above 355° C. usually causes more bleeding than low residue creosote oils.

Methods of Treatment

Pressure Treatment

The pressure process is the most effective method of treating timbers of all kinds, since it affords a means of controlling the pressure to any desired amount. By using different initial air pressures a considerable variation in absorption can be obtained, thereby making it possible to get heavy or fairly light absorptions for a given depth of penetration. The principal objection to pressure treatment is that it requires relatively large and expensive equipment and is therefore not well adapted for the treatment of small quantities of timber nor for treating material that would require long distance transportation to the treating plant.

Non-pressure Treatment

Next to pressure treatment the hot-and-cold bath method is the most effective. This treatment depends on atmospheric pressure utilized by first heating the wood in a heating medium and then cooling it in the preservative. When the wood is heated the air contained within its cells is expanded, and part of that in the surface region of the timber is forced out of the lumina or air spaces. In the subsequent cooling bath a partial vacuum is formed and more or less preservative is forced into the wood cells by atmospheric pressure depending upon the permeability of the wood and upon the amount of air forced out by expansion during the heating period. Very little preservative is absorbed during the hot bath, and it is obvious that the pressure forcing preservative into the wood during the cooling period cannot exceed atmospheric pressure. Generally the available pressure will be lower than atmospheric. For this reason the hot-and-cold bath treatment is more suitable for treating round timbers in which only the more easily treated sapwood needs to be penetrated. This method has been extensively used in the butt treatment of Western redcedar poles and is now used to some extent in full-length treatment of these poles. Lodgepole pine poles have also been butt treated by this method for use in the Rocky Mountain region.

Incising before treatment has been found very helpful when the sapwood is somewhat resistant to penetration as in the case of cedar. When the sapwood is very resistant to penetration, as in species like the true firs and spruces, it is doubtful that even when the resistant sapwood is incised it will be possible to obtain satisfactory penetration without the use of pressure treatment.
The principal advantages of the hot-and-cold bath treatment over pressure treatment are: (a) the cost of the treating equipment is small compared with the cost of pressure treating equipment; (b) butt treatment or full length treatment can be used as desired; (c) it is more convenient to treat small quantities of timber by this method; and (d) it is usually possible to make the treatments near where the timber is cut. The principal disadvantages are: (a) the pressure available for forcing the preservative into the wood is limited compared with the wide range of pressures available when the pressure process is used; (b) considerably heavier absorptions are usually required for a given penetration than when the wood is treated by pressure methods, because an initial air pressure cannot be applied as in the Hueping treatment; (c) this method of treatment is not well adapted for round timbers with unusually resistant sapwood nor for species that have a deep sapwood that is easily penetrated, since in species having a deep sapwood undesirably heavy retentions may be obtained or there may be incomplete sapwood penetration, and (d) evaporation of the lower boiling constituents of preservative oils used in the hot bath often causes an appreciable loss of preservative.

Absorptions Specified for the Pressure Treatment of Poles

Most of the Southern yellow pine and Douglas-fir poles treated up to the present time have been treated by the empty-cell process with specified minimum net retentions of about 8 pounds of creosote per cubic foot. Minimum absorptions specified for lodgepole pine poles have ranged from about 4 to 8 pounds per cubic foot. The lower absorptions specified for the lodgepole pine have been possible partly because of the more shallow sapwood in this species. The sapwood of lodgepole pine commonly ranges from about 1/2 to 2 inches in thickness compared with 2 to 4 inches in Southern yellow pine and 1 to 2 inches in coast Douglas-fir poles. Another reason for the use of lower absorptions in lodgepole pine is that poles of this species have been used mostly in the Rocky Mountain states where decay conditions are usually much less severe than those under which the Southern yellow pine and coast Douglas-fir poles are used.

Present American Wood Preservers' Association specifications for the treatment of Southern yellow pine poles permit a minimum net retention of 6 pounds per cubic foot provided the penetration specified for the 8-pound treatment is met and provided the poles are to be used under conditions that do not favor rapid decay. Various power companies have specified net retentions ranging from 10 to 16 pounds of either creosote or creosote-coal tar solutions in Southern yellow pine poles.

The question of obsolescence is usually of more concern to telephone and telegraph companies than to power companies, and it is natural that they do not want to employ preservative treatments that may give a service life well beyond the time their pole lines would become obsolete. On the other hand, it would obviously be unwise and uneconomical to count on obsolescence and later find the service life was too short.

Sufficient service records are not yet available to show the minimum absorptions of different preservatives that can be expected to give satisfactory results for poles of different species when used under various climatic conditions. For this reason it would seem desirable to defer the extensive use of absorptions much lower than those commonly specified until the relative merits of the lower absorptions can be determined from suitable service tests. The following are some of the more important advantages of using absorptions that are known to be adequate as demonstrated by experience:

1. They furnish a better reserve against depletion by leaching and evaporation.
2. They insure better distribution and deeper penetration of the preservative.
(3) When the preservative has a variable toxicity the heavier absorptions serve as a safeguard against deficient toxicity.

(4) They reduce the danger of insufficient absorption because of careless treatment.

(5) They help protect against the possibility of inadequate treatment of the more resistant timbers in a charge or of those of the larger sizes when the charge contains timbers of different dimensions.

(6) They reduce the danger of wide variations between the maximum and minimum penetrations obtained in the same or in different timbers.

The principal disadvantages of heavier absorptions are the somewhat higher initial cost of treatment and the possibility of objectionable bleeding when oily preservatives are used. The higher initial cost of treatment, however, does not necessarily mean that the annual charge will be higher over the period the timber is in service. Within reasonable limits the higher first cost may be much more than offset by the increased service life and consequent reduced cost of renewals.

There are a variety of factors that should be kept in mind in deciding upon the net retention that will prove most economical or most desirable because of other considerations.

The thickness of sapwood will also have a definite bearing on the absorptions that should be specified. Woods with deep sapwood, like that of ponderosa pine, red pine, and the southern pines, naturally have a greater proportion of wood that can be treated than poles of thin sapwood species, like the cedars, Western larch and mountain type Douglas-fir. Figure 1 shows the proportion of sapwood in the total volume of poles of different average diameters ranging from 4 to 22 inches. These curves were computed from the relation that if $t$ is the average depth of sapwood and $D$ is the average diameter of the timber, the percentage of the sapwood $P$, based on the total volume,

$$P = \frac{4t(D-t)}{D^2} \times 100$$

If $P_t$ is the percentage of sapwood in the total volume when the average sapwood thickness is $t$ inches, and $P_T$ is the percentage of sapwood in the total volume when the average sapwood thickness is $T$ inches, then

$$\frac{P_t}{P_T} = \frac{t}{T} \left[ \frac{D - t}{D - T} \right]$$

For example, assume $D = 10$ inches, $t = 0.75$ inch, and $T = 3$ inches. Then the ratio

$$\frac{P_t}{P_T} = \frac{0.75}{3} \left[ \frac{10 - 0.75}{10 - 3} \right] = 0.33$$

In other words, a 10 inch diameter pole with a sapwood thickness of 0.75 inch would have about 33 percent as much sapwood as a pole timber of the same diameter with a sapwood thickness of 3 inches. Equation (A), or figure 1, shows that the percentage of sapwood in the total volume of a timber 10 inches in diameter with a sapwood thickness of 0.75 inch is about 27.7 while the same diameter timber with an average sapwood thickness of 3 inches would have about 84 percent sapwood in the total volume. For the same concentration of preservative it might be assumed that poles with a sapwood thickness of 0.75 inch would require only 33 percent as much
preservative as when the sapwood is 3 inches thick. It should be borne in mind, however, that there is a greater opportunity for more rapid loss of preservative from thin sapwood through leaching and evaporation because the preservative is concentrated closer to the surface. In the latter case somewhat heavier absorptions would help compensate for this difference in depth of penetration.

Equation (B) will be found convenient for comparing the relative proportions of sapwood in a timber of any given diameter, when different depths of sapwood are assumed.

**Treating Conditions and Specifications for Pressure Treatment**

In addition to specifying the preservative, the average absorption and penetration required, and the method of seasoning or conditioning the poles for treatment, it is desirable to specify the maximum preservative temperatures and pressures to be used, since these have an important bearing on the success of treatment. Some species will withstand more severe treating conditions than others.

**Conditioning**

Green Southern yellow pine poles are commonly conditioned for treatment by the steaming and vacuum process. Although the average amount of water removed is usually not more than about 5 to 6 pounds per cubic foot, the removal of this amount of water and the heating of the wood to a favorable treating temperature as a result of the steaming make this method a very satisfactory means of conditioning Southern yellow pine poles. This method, nevertheless, is not well adapted for conditioning other woods commonly treated, because either the other woods are more easily injured by the temperatures and heating periods required in steam conditioning, or the final moisture content may still be too high for good penetration after the steaming treatment is applied.

Green Coast Douglas-fir poles are conditioned by the Boulton, or boiling under vacuum, process. In this process round timbers are usually boiled under vacuum with a specified maximum preservative temperature of 220°F. Since water is evaporated during the boiling period, the wood temperature is usually considerably lower than the temperature of the heating medium. This process is also applied in the conditioning of other species in the green condition and has the advantage that it removes water from green material under mild temperature conditions.

Air seasoning is, of course, the most widely used method of conditioning wood preparatory to treatment.

**Treating Temperatures**

Both laboratory experiments and subsequent studies under commercial treating conditions have shown that treating temperatures of 190°F to 200°F are much more effective in obtaining good penetrations than lower temperatures. This applies when either preservative oils or water solutions are used. Temperatures a little higher than 200°F can often be used to advantage for some species, such as the southern pines.
Preservative Pressures

Preservative pressures should be kept low enough to prevent objectionable checking and collapse. Some species, as for example Southern yellow pine and some of the hardwoods, can withstand treating pressures considerably higher than many other woods. Whenever objectionable checking or collapse occurs as a result of the temperature and pressure conditions employed, the preservative temperature should be maintained in the range of 190° to 200° F. and the treating pressure should be lowered as may be needed to prevent unnecessary checking or collapse.

Specifications

The American Wood Preservers' Association has, for many years, had specifications covering the pressure treatment of Southern yellow pine and Coast Douglas-fir poles, and these specifications have been revised at various times. In recent years this Association has prepared specifications for the pressure treatment of Western redcedar, lodgepole pine, jack pine, and red pine poles.

Treatment of Species Listed in the Various Groups

The recommendations made in the subsequent discussion are based on experiments made by the Forest Products Laboratory in a study of the treatment of the species named.

Species in Group I

Atlantic white-cedar has a sapwood depth about the same as that of Western redcedar (about 1/2 to 1 inch for most timbers) and can be treated under the same conditions as specified for Western redcedar. (A.W.P.A. specification.)

The spruces are resistant to penetration in both the sapwood and heartwood, and it is also difficult to distinguish the sapwood from the heartwood. Sapwood of the freshly cut timbers usually has a high moisture content in the range of 140 to 165 percent or over. In order to avoid objectionable checking and collapse in the spruce species it is desirable to limit the preservative pressure to about 150 pounds per square inch when the Rueping process is used and to about 120 to 130 pounds per square inch when the Lowry, or full cell treatment, is applied.

Species in Group II

The sapwood of ponderosa pine usually ranges from about 2 to 3 inches in thickness, and the sapwood moisture content of the freshly cut wood is relatively high, averaging about 150 percent. This is one of the few softwood species that is comparatively easy to treat in both the sapwood and heartwood when air seasoned.

The sapwood of the white pines commonly ranges from about 1 to 2 inches and occasionally to 3 inches in thickness.

In general, the treating conditions specified for the southern pines will be suitable for the pines listed in group II.

Species in Group III

Jack pine has a sapwood that commonly ranges from about 1-1/2 to 2-1/2 inches in thickness, although poles grown in some regions may have sapwood considerably less than 1 inch in thickness. Like lodgepole pine, this species is more easily injured by high pressures than some of the other pine species, and the maximum treating pressure should not exceed 150 pounds per square inch and in most cases should be somewhat lower. The treatment of poles of this wood is covered in the American Wood Preservers' Association specification for the pressure treatment of jack pine poles.

Red (Norway) pine has a fairly deep sapwood that ranges from about 2 to 4 inches in thickness. This species has a high average moisture content of about 135 percent in the sapwood, when the timber is freshly cut. The treatment of poles of this species is covered in the American Wood Preservers' Association specification for the pressure treatment of red pine poles.

The white firs, like the spruces, are very resistant to treatment in both the sapwood and heartwood, and the sapwood is not distinguishable from the heartwood. Treating conditions previously discussed for the spruce species will also apply for the true firs, such as white fir (Abies concolor).

Species in Group IV

The sapwood of Douglas-fir poles grown in the region between the Pacific Coast and Cascade Mountains normally has a range in thickness of about 3/4 to 2-1/4 inches. In most cases it will average between 1.3 and 1.4 inches. The moisture content of the sapwood in freshly cut timbers will usually average around 115 percent. The treatment of the Coast-type Douglas-fir poles is covered in the American Wood Preservers' Association specification for the pressure treatment of Coast Douglas-fir poles.

The Mountain-type Douglas-fir has a thinner sapwood than the Coast type and is usually about 1 inch or less in thickness. The so-called Inland Empire or intermediate type that grows between the Coast and Rocky Mountain region has a sapwood thickness ranging from about 1 to 2 inches.

While the heartwood of the timber that grows in the Rocky Mountain region is far more resistant to treatment than the heartwood of the timber grown in the Coast region, the sapwood of the Mountain type can be satisfactorily treated by the pressure process. Although the mountain type wood has a lower mechanical strength than the Coast wood, the timber grown in the Mountain region will withstand a somewhat higher treating pressure without showing a marked increase in checking and collapse. Treating pressures as high as 140 to 150 pounds per square inch can generally be used for the Rocky Mountain wood, while it is usually desirable to use pressures 25 to 30 pounds lower for the Coast material.

The sapwood of Eastern hemlock is difficult to distinguish from the heartwood and, like the heartwood, is relatively resistant to treatment. The average moisture content of the sapwood of the eastern species is in the neighborhood of 120 percent in freshly cut wood. Poles of this species should be air seasoned for treatment.

The sapwood of Western hemlock is sometimes lighter in color than the heartwood and is usually not much over an inch in thickness. The average moisture content of the sapwood of the western species is considerably higher than that of the eastern species and averages around 170 percent. Both hemlock species can be treated using pressures up to about 150 to 160 pounds per square inch.
The sapwood of both Eastern and Western larch is usually less than 1 inch in thickness; hence the sapwood thickness of these woods is similar to that of the cedars, Rocky Mountain Douglas-fir, and Western hemlock. The average moisture content of the sapwood of freshly cut Western larch is in the neighborhood of 125 percent.

Treating pressures as high as 175 pounds have been used in treating larch timbers. This species can usually withstand somewhat higher treating pressures than most of the softwoods grown in the western states.

The purpose of the foregoing outline discussing treating conditions and specifications is to point out some of the more important variables that should be considered in the preparation of specifications for pressure treatment. It should be borne in mind that if the best results are to be obtained, the treating conditions should be adjusted to meet the structural variability of the different woods.

**Crossarms**

The suitability of a given species for crossarms will depend largely on the strength properties and freedom from such defects as cross grain and knots.

Up to the present time Southern yellow pine and Coast Douglas-fir have been considered the standard woods for crossarm material. The southern pines usually have a larger proportion of sapwood; and, since the crossarms of this species are used in large quantities in the south where service conditions are more severe, it is customary to pressure treat them. The absorptions commonly specified range from around 8 to 12 pounds of creosote per cubic foot.

Coast Douglas-fir crossarms are generally used without treatment because they normally have little sapwood and are more widely used in the northern and western states where decay conditions are less severe than in the southern states.

Conditions under which crossarms are used are generally less favorable to decay than where wood is in contact with the soil. For this reason the heavier absorptions used for timbers exposed to the more severe service conditions are not so important for crossarms. The shortage of Southern yellow pine and Douglas-fir arms that, as in the case of poles, has developed as a result of the war, has made it necessary to consider substitute species.

In the pole species listed under groups I to IV, the conifers that seem most promising for crossarm material include Western larch, Mountain or intermediate type Douglas-fir, Western hemlock, and red pine.

**Treatment of Crossarms**

Species that have a considerable proportion of sapwood or that do not have good durability in the heartwood should be treated if good service life is to be obtained. Woods of this kind include Western hemlock and the various pine species.
Crossarms made from Western larch or the Rocky Mountain and intermediate type Douglas-fir would have little sapwood because of the thin sapwood in trees of these species. The heartwood of these woods is similar to the Coast type Douglas-fir heartwood from the standpoint of natural durability. When heartwood crossarms are pressure treated it is probable that it would be difficult to keep the net retentions much below 5 to 6 pounds per cubic foot because of the large amount of surface area in proportion to the volume. Pressure treatment, however, should give deeper penetrations in heartwood material and when there is a considerable amount of sapwood should require somewhat lower net retentions than when the open-tank treatment is used.

One of the larger pole using companies has now revised its crossarm specifications to include open-tank-treated red pine, jack pine, lodgepole pine, and the inland or intermediate Douglas-fir. Jack pine and lodgepole pine are somewhat lower in strength properties than the other species named, but it is assumed that they will provide suitable crossarms for the lighter service conditions. This company has treated several thousand arms of these woods using a hot bath of coal-tar creosote and a cold bath of 5 percent pentachlorophenol in an aromatic petroleum oil. These treated arms have been installed in service and an examination of their condition is to be made at various periods.

Although the use of the pentachlorophenol solutions is still in the experimental stage, it would seem that an open-tank treatment, such as that mentioned, should give good results. The open-tank treatment of crossarms appears to be the most suitable substitute treatment where pressure treatment with creosote or with solutions of creosote and pentachlorophenol is not feasible or does not seem necessary for the conditions of service to which the crossarms are exposed.

Figure 1. The relation of sapwood depth and percentage of sapwood in the total volume of timbers of different diameters