A PRELIMINARY INVESTIGATION OF
THE SOAKING TREATMENT OF
BLACK COTTONWOOD AND RED ALDER FENCE POSTS
IN PENTACHLOROPHENOL

by

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A PRELIMINARY INVESTIGATION OF 
THE SOAKING TREATMENT OF 
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I. INTRODUCTION

The farms in the United States (1) have in use a total of over two and one-half billion wooden fence posts with an annual replacement estimated at well over three hundred million posts. Oregon alone has on its farms over forty million posts, few of which are given preservative treatment. In recent years, the cost of the more durable post species has become almost prohibitive due to the increasing scarcity of these woods. On the other hand, many species of Oregon woods with low durability, such as black cottonwood and red alder, provide a source of raw material suitable for farm posts or other uses. According to Graham and Baker (18, Table 2), the average service life of black cottonwood and red alder used for fence posts is approximately 4.8 and 5.2 years respectively. If such non-durable species were well treated, to double or triple their service life, the annual cost of fence posts in some areas of Oregon would be much reduced.

The experimental treating of non-durable species of wood for Oregon farm uses was initiated by the School of
Forestry at Oregon State College twenty five years ago when the T. J. Starker experimental fence post farm was established. The preservatives used for treating fence posts include most of the well recognized toxic oils and water soluble salts. Studies carried on elsewhere in the United States in more recent years indicate that pentachlorophenol as a wood preservative lengthens the life of some non-durable species.

A preservative treatment for farm application should be relatively easy to use and should require no elaborate or expensive equipment. For this reason, the cold soaking or hot soaking processes are suggested for those species of wood to which they are adaptable.

The objective of the present study was to investigate cold soaking and hot soaking preservative treatments of black cottonwood and red alder in a 5 per cent pentachlorophenol solution in-as-much-as these species are available in quantity on farms of Western Oregon.

Since there has been little reported work done on the preservative treatment of black cottonwood and red alder several treating variables such as soaking time, treating temperature, effect of incising and rate of end penetration were investigated. An effort also was made to find an effective end coating material that would greatly retard end penetration of the treating solution, to permit
the use of short sections for determining radial penetration.

II. LITERATURE REVIEW

1. Previous results of pentachlorophenol treatments

Hiscock (19, p. 16) mentioned that the species which have shown the best absorption and penetration of pentachlorophenol were the oaks and the pines. Satisfactory treatments of cottonwood, aspen, poplar, ash, elm, willow and cedar by the cold soaking method also have been reported (20, p. 16 and 22).

Hopkins (20, p. 12-13) reported that posts of pine, red gum, red oak, post oak and elm subjected to a 3-hour soak in hot water, then to a 1-hour cold bath in 5 per cent pentachlorophenol-kerosene solution all showed absorptions of 0.24 to 0.33 gallons per post, when the posts were treated for only half of their length. This absorption was considered satisfactory by Hopkins. Red oak soaked 6 hours in a cold 5 per cent pentachlorophenol-kerosene solution absorbed 0.33 gallon per post. Pine soaked 5 hours and red gum soaked 6 hours in the same solution absorbed 0.77 and

*This approximates 4 to 6 pounds per cubic foot for fence posts with an average diameter of 5 inches.
0.58 gallons per post, respectively, or more than the desired amount of solution. A 24-hour cold soaking for elm and a 168-hour cold soaking for post oak in the same solution absorbed 0.50 and 0.40 gallons per post respectively.

Plummer (27, p. 7) has stated that farm fence posts and highway guard-rail posts having a normal service life of 3 to 4 years can be expected to last 10 years or more when treated with about one-half to one gallon of a ready-to-use solution of pentachlorophenol per post.

Practical recommendations for treating posts of lodgepole pine and aspen when using pentachlorophenol have been published by the Utah School of Forestry (29, p. 10).

According to the "Penta Cold Soak" post treating demonstrations and tests made by Wohletz and Revenscroft (36, p. 8-9 and p. 11) the average anticipated service life of lodgepole pine posts was 15 years while untreated posts lasted only 2 to 4 years. The suitability of Idaho timber species for treatment were listed as:

a. Easy to treat—Lodgepole pine, ponderosa pine and white pine

b. Satisfactory (Special conditions and methods necessary)—Aspen, Western red cedar, cottonwood, poplar and grand fir

c. Difficult (Not well adapted to cold treatment)—Larch and Douglas-fir.
A classification of species according to treating results obtained by 48-hour cold soaking in pentachlorophenol solution made by Walters (32, Table 5) was as follows:

a. Very good treatment obtained—Sycamore
b. Good to very good treatment obtained—Eastern white pine, Norway pine and red elm (slippery)
c. Good treatment obtained—Loblolly pine, shortleaf pine, large-tooth aspen, quaking aspen, river birch, black cherry, cottonwood, white (American) elm, hackberry, shagbark hickory, black oak, red oak and white oak
d. Good to poor treatment obtained—Willow
e. Fair to poor treatment obtained—Norway spruce, ash, catalpa and silver maple.

2. Pentachlorophenol solutions as wood preservatives

Petroleum oils commonly are used as solvent carriers for pentachlorophenol because of their low cost. The desirable properties of pentachlorophenol have been presented by many authors advocating its use (9, 10, 11, 26, 27, 30 and 36). These may be summarized to include:

a. High toxicity to fungi, termites and insects but not injurious to higher forms of life
b. Low solubility in water
c. Low vapor pressure at ordinary temperatures

d. Good stability under the influence of light, normal temperatures, soil acids and alkalies

e. Non-corrosive to metals

f. Clean and odorless (depending upon the solvent used)

g. Low fire hazard after solvent has evaporated

h. Readily available at moderate cost.

Santophen 20, Permatol, Permatox WR and Permatox A are common proprietary preservatives of pentachlorophenol in oil formulated by commercial chemical companies. Dowicide G or Santobrite and Permatox 10-S are water soluble sodium pentachlorophenate used for stain control and soil poisoning (10, 11, 13, 14, 26 and 35).

3. Factors affecting preservative treatments

The factors affecting the preservative treatment of wood may be summarized from several references (3, 6, 8, 21, 29, 32 and 36) as:

a. The species of wood

b. The density of wood

c. The relationship between sapwood and heartwood

d. The relationship between springwood and summerwood
e. The moisture content of the wood
f. The form and size of the timber
g. The surface characteristics of the wood such as
   the presence of bark, resinglaze, blue stain and mold
h. The method of peeling
i. The length and severity of seasoning
j. The effect of incising
k. The properties of the preservative
l. The treating conditions such as temperature, time and pressure.

III. EXPERIMENTAL PROCEDURE

1. Experimental equipment

A. Tanks

The tanks used for cold soaking were three 55-gallon oil drums with covers. Two of these were used as soaking tanks and the other one as a drain tank. A hand-operated barrel pump was used for mixing and pumping the preservative into and out of the tanks.

The equipment used for treatments requiring hot soaking consisted of a steam heater, electric pump, temperature gauge, storage tank and three treating tanks connected as
shown in Figure 1.

B. Incising hammers

Two types of incising hammers were used. Type A had teeth 0.20 inch in diameter arranged in uniform rows with a distance of 0.70 inch between teeth and 0.50 inch between rows. Type B had teeth 0.25 inch in diameter arranged in staggered rows to give a diagonal pattern with a distance of 0.60 inch between rows and a distance of 0.90 inch between teeth. In both types the exposed teeth were 0.70 inch in length. Details of the two types of incising hammers are shown in Figures 2a and 2b.

C. Accessories

Other equipment used in the experiments included: a Tag-Heppenstall moisture meter for measuring the moisture content of wood, a thermometer ranging from 0°F to 200°F for measuring the depth of treating solution, a laboratory Toledo balance for weighing samples, and perforated plates for supporting the treated samples during the draining period.
Figure 1--Arrangement of equipment used in hot soaking treatment
Figure 2-- Types of incising hammer and shape of tooth
2. Preservative solution used

The 1-to-10 concentrate of pentachlorophenol manufactured by the Chapman Co. was the preservative used in this study. This contained approximately 40 per cent pentachlorophenol by weight. When mixed at a 1-to-10 ratio (1 gallon of concentrate to 10 gallons of solvent carrier) a ready-to-use solution containing 5 per cent of pentachlorophenol by weight was obtained. No. 2 diesel oil having a flash point of about 160°F was used as the solvent carrier. The pentachlorophenol-diesel oil solution was so light in color that an indicator was required to determine penetration. An oil soluble red dye (Sudan Red BBA Dye manufactured by the General Dyestuff Corporation, New York, N. Y.), added at a rate of 1½ grams of powdered form to 1 gallon of preservative, proved to be a very satisfactory indicator for these studies.

3. Collections, peeling and seasoning of material

Black cottonwood and red alder trees were felled in the vicinity of Corvallis, Oregon, during the month of June, 1948. These trees were cut into 10-foot bolts with top diameters ranging from 3 to 6 inches inside of bark. The
bolts were peeled immediately by the use of an axe, chisel or drawknife, the drawknife being the most suitable for peeling bolts with tight bark. The posts were cut into 30-inch samples which were cross-piled in an open yard for seasoning. Hollow tile were used as pile foundations. A seasoning period of about 30 days reduced the moisture content of the outer one-half inch shell of the samples to about 24 per cent.

4. Selection of samples

All samples that showed severe seasoning checks or splits were rejected from the study. The remaining material was utilized for test samples. Pieces of different diameters ranging from 3 to 6 inches were allocated to sets of test samples, in order that there would be no marked discrepancy in either the total weight or total volume of those sets assigned to an individual experiment. In tests where short sections were used, sections cut from the same sample were allocated to different sets. Similarly, when half-round or quartered samples were used as test material, those cut from same round sample were allocated to different sets.
5. Measurement of moisture content

The moisture content of each test sample was measured just prior to treatment with a Tag-Heppentall moisture meter manufactured by the C. J. Tagliabue Mfg. Co., Brooklyn, N. Y. The range of moisture contents that could be determined with this meter was from 7 to 24 per cent. In determining the moisture content, the needles of the moisture meter (about 0.25 inch in length) were wholly embedded in the wood. Consequently, the values obtained indicate the moisture content one-quarter inch below the surface and are representative of the average moisture content of the outer one-half inch shell. As radial penetration, even on incised posts, is confined to this outer shell it is the moisture content of this region that is important. Three readings were taken on each sample, one at the middle and one near each end. The average of these readings represented the average moisture content of the outer shell of the sample.

6. Preparation of samples

For certain treatments test samples were partially coated with Fullerglo white paint to retard the absorption of preservative in certain areas. This paint was
selected after a preliminary study of several coating materials. It was applied to the samples by brush, usually in two coats. A drying period of at least 24 hours was provided before the samples were treated with preservative.

B. Incising

Test samples for certain treatments were incised. This was accomplished by laying a sample on a concrete floor and striking its circumference with one of the two incising hammers. The samples were incised as evenly and uniformly as possible. Since samples were varied in diameter and form some irregularity of incising was unavoidable.

7. Treating conditions

All test samples were numbered with a black wax pencil. Each sample was weighed to the nearest 0.01 of a pound just prior to treating and this value was recorded as the untreated weight.

When the samples were cold soaked they were put into the treating tanks in an upright position with heavy weights on top to prevent them from floating. The well-mixed
preservative solution was then pumped into the tanks to the desired depth, varying with the individual experiment, and that depth was maintained during the course of the experiment. Following treatment, samples were drained for one-quarter to one-half of an hour before weighing to obtain the final weight of the treated samples.

When hot soaking was performed, the steam heater and the circulating pump were started about one-half hour prior to treatment in order to bring the treating solution up to the desired temperature. During the period of hot soaking the temperature of the solution was maintained as even as possible by regulating the valve to the steam heater. The depth of treating solution was maintained at the required level throughout the treating period. Following treatment, the samples were drained for one-quarter to one-half an hour before obtaining their treated weights.

3. Methods used to determine penetration

A. Radial penetration

In order to determine the average radial penetration throughout the zone of treatment each treated sample was cross cut in at least three places. Immediately following this sectioning of the treated sample, the pattern of the
treated area on the freshly cut surface was marked with a black wax pencil. Thus, subsequent measurements would not be distorted by the creep of the solution over the exposed cross-sectional areas; see Plate 2, Appendix.

All measurements dealing with radial penetration were taken to the nearest 0.01 inch. The depth of radial penetration was measured as maximum, minimum and medium as illustrated in Figure 3. In each case several individual measurements were taken to determine the mean of the maximum, the mean of the minimum and the mean of the medium radial penetration. The mean values obtained for the sections were averaged to obtain an average maximum, average minimum and average medium radial penetration for each treated sample. Since several samples made up a group for each set of treating conditions it was necessary to determine the group values of maximum, minimum and medium radial penetration by averaging the values for the samples in each group.

B. End penetration

The extent of end penetration was determined, after draining one-quarter to one-half hour, by sectioning each sample into thin pieces, starting from the butt end, up to the point that showed the treated area to be less than 50
Figure 3-- Illustrating the method of measuring the maximum, minimum and medium depths of radial penetration on a section cut from a treated sample.
per cent of the cross-sectional area of sapwood, or of heartwood, or of both together depending upon the species of wood studied. The distance from the butt end to this point was considered as the height of end penetration.

9. Methods used to determine retention

The retention of preservative was calculated on the basis of pounds per cubic foot of treated wood. The pounds of preservative absorbed by each sample divided by the treated cubic foot volume of the sample revealed the value of retention. The quantity of preservative retained by the treated sample was determined by weighing the sample before and after treatment. The possible additional moisture loss during hot soaking was disregarded, as the moisture content of the affected volume of each sample just prior to treating was considered low enough to result in a negligible error. The treated volume of the sample was calculated as the product of the immersed length and the average basal area of the butt end and top end of the sample. The average basal area was used since the samples showed only a very slight taper from the butt end to the top end and the diametral difference was insignificant.
The general equations used for calculating the volume and pounds retention per cubic foot of treated wood are as follows:

1. Equation for calculating the volume of treated wood

\[ B = \frac{\frac{1}{2}(A \cdot a) \cdot L}{1728} \]

- **B** = Volume of treated wood in cubic feet
- **A** = Area at butt end of sample in square inches
- **a** = Area at top end of sample in square inches
- **L** = Depth of immersion in the preservative in inches
  (considered to be the length of the sample treated).

2. Equation for calculating the pounds of preservative retained per cubic foot of treated wood

\[ C = \frac{W - W'}{B} \]

- **C** = Pounds retention per cubic foot of treated wood
- **W** = Weight of sample after treating in pounds
- **w** = Weight of sample prior to treating in pounds
- **B** = Volume of treated wood in cubic feet.
IV. EXPERIMENTAL RESULTS AND CONCLUSIONS

1. Soaking treatments of black cottonwood

A. The height of end penetration of cold and hot pentachlorophenol solutions attained in black cottonwood samples under different soaking periods.

Quartered samples of black cottonwood, 30 inches long, surface-coated with Fullerglo 520 white paint, except on the ends, were subjected to cold soaking and hot soaking in 5 per cent pentachlorophenol treating solutions for different periods. Each set was composed of 3 samples. The depth of preservative was 20 to 22 inches for cold soaking and 29 inches in hot soaking. The depth of preservative was greater for hot soaking due to the construction of the hot soaking equipment - a factor that was not anticipated at the time cold soaking experiments were conducted. The treating temperature for cold soaking was 75°F to 80°F and for hot soaking was 130°F. After treatment, the samples were cross-cut into one-half inch or sometimes 1-to 2-inch sections for inspection, starting from the butt end. The height of end penetration was measured separately in the sapwood and heartwood. The height was taken as the distance from the butt to a point that showed the treated area
to be less than 50 per cent of the total sapwood area or less than 50 per cent of the total heartwood area. The resulting data are summarized in Table 1 and illustrated in Graph 1.

Table 1- The height of end penetration of cold and hot 5 per cent pentachlorophenol solutions attained in black cottonwood samples under different soaking periods.

<table>
<thead>
<tr>
<th>Average moisture content in per cent</th>
<th>Soaking period in hours</th>
<th>Average height of end penetration (50 per cent or more of cross-sectional area treated) in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>cold soak</td>
<td>hot soak</td>
<td>cold soak</td>
</tr>
<tr>
<td>14.0</td>
<td>12.0</td>
<td>9.3</td>
</tr>
<tr>
<td>13.0</td>
<td>12.0</td>
<td>10.0</td>
</tr>
<tr>
<td>17.0</td>
<td>14.0</td>
<td>10.7</td>
</tr>
<tr>
<td>13.0</td>
<td>14.0</td>
<td>14.0</td>
</tr>
<tr>
<td>16.0</td>
<td>13.0</td>
<td>15.0</td>
</tr>
<tr>
<td>---</td>
<td>11.0</td>
<td>---</td>
</tr>
<tr>
<td>15.0</td>
<td>---</td>
<td>18.3</td>
</tr>
</tbody>
</table>

Conclusions:

End penetration was more rapid during the first four hours of soaking. The height of end penetration attained in the heartwood was approximately one-third of that attained in the sapwood. Raising the temperature of the
Graph 1- Height of end penetration of a cold and a hot 5 per cent pentachlorophenol solution in black cottonwood.
preservative to $130^\circ F$ produced no significant difference in either the rate or the height of end penetration despite the fact that the depth of preservative was greater in hot soaking.

B. Cold soaking of non-incised, uncoated black cottonwood samples to determine end penetration, radial penetration and retention.

In order to determine the period of cold soaking required to adequately treat non-incised black cottonwood posts by end penetration to the depth of treating solution, a subsequent study of end penetration was made. Round samples, 30 inches long and 3 to 6 inches in diameter, were soaked in a 5 per cent pentachlorophenol solution at $80^\circ F$ under different soaking periods ranging from $\frac{1}{2}$ to 25$\frac{1}{2}$ hours with a treating depth of 22 to 24 inches.

Five sets of samples, with 3 samples in each set, were used. Cold soaking periods of $\frac{1}{2}$, 1, 2, 4, and 6 hours were employed with one set of samples being used for each soaking period. The results reveal that the height of end penetration of preservative attained in the samples soaked for 6 hours did not reach the level of the preservative solution. In order to determine the required soaking period under which samples would be adequately treated by end penetration to the depth of the treating solution an additional
A series of three sets of samples, with 5 or 10 samples in each set, were subjected to cold soaking. Soaking periods of 4, 20½ and 25½ hours were used with one set of samples being used for each soaking period. After soaking, the samples were cut at 4, 10, 16, and 22 inches from the butt to determine the height of end penetration. In this study it was desired only to determine the soaking period required to bring the height of end penetration to the treating level. Therefore, the height of penetration merely was estimated by sectioning at the above mentioned points.

These approximate heights of penetration served to indicate the required soaking period for penetration to the treating level. In each case the radial penetration was measured on the section cut at 22 inches, or treating level. The results are summarized in Table 2 and illustrated in Graphs 2a and 2b.
Table 2--Results of the preservative treatment of non-incised, uncoated black cottonwood posts by cold soaking in a 5 per cent pentachlorophenol solution.

<table>
<thead>
<tr>
<th>No. of samples</th>
<th>Average moisture content in per cent</th>
<th>Average diameter in inches</th>
<th>Soaking period in hours</th>
<th>Average retention in pounds per cubic foot</th>
<th>Approx. average height of penetration in inches</th>
<th>Average depth of radial penetration at treating level in inches</th>
<th>Min.</th>
<th>Max.</th>
<th>Med.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>20</td>
<td>4.57</td>
<td>$\frac{1}{2}$</td>
<td>6.21</td>
<td>6</td>
<td>T*</td>
<td>0.47</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td>3.70</td>
<td>1</td>
<td>6.39</td>
<td>10</td>
<td>T</td>
<td>0.50</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>3.57</td>
<td>2</td>
<td>6.56</td>
<td>14</td>
<td>T</td>
<td>0.73</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>19</td>
<td>3.72</td>
<td>4</td>
<td>9.04</td>
<td>14</td>
<td>T</td>
<td>0.74</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>4.37</td>
<td>6</td>
<td>8.52</td>
<td>14</td>
<td>T</td>
<td>1.10</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>3.92</td>
<td>20$\frac{1}{2}$</td>
<td>12.49</td>
<td>20</td>
<td>T</td>
<td>0.70</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>3.76</td>
<td>25$\frac{1}{2}$</td>
<td>13.21</td>
<td>22</td>
<td>--</td>
<td>---</td>
<td>--</td>
<td>---</td>
</tr>
</tbody>
</table>

*Trace, indicates less than 0.05 inch in depth.

**After 25$\frac{1}{2}$ hours cold soaking the 30-inch samples showed end penetration at the tops of the samples, eight inches above the treating level. Therefore, the radial penetration at the treating level was obscured by end penetration.
Graph 2a- Depth of radial penetration at the treating level of a cold 5 per cent pentachlorophenol solution in non-incised, uncoated black cottonwood.
Graph 2b- Retention and height of end penetration of a cold 5 per cent pentachlorophenol solution in non-incised, uncoated black cottonwood.
Conclusions:

Both the retention of preservative and height of end penetration increased with the increase of soaking period. The rate of increase in end penetration was more rapid during the first two hours of soaking and then continued at a uniform rate. The increase in retention was fairly uniform throughout the range of soaking periods.

The retention of preservative was closely associated with the rate of end penetration since the radial penetration was small in comparison with the end penetration.

The pattern of radial penetration beyond the height of end penetration was uneven, usually leaving some part of wood untreated.

All of the ten posts soaked for 25½ hours were end penetrated up to the treating level. Five of these posts were wholly treated while the other five had some of the heartwood near the immersion level untreated. Actually, all of the ten posts showed some end penetration in the sapwood to the tops of the 30-inch samples.

Since radial penetration obtained in treating non-incised, uncoated black cottonwood posts is so poor, it is necessary to rely upon end penetration for satisfactory treatment. At room temperature, a cold soaking period of at least 24 hours is required in order to insure adequate end penetration throughout that portion of the posts below the level of the preservative solution. However, the high
preservative retention per cubic foot of treated wood obtained may be excessive from the stand-point of cost.

C. Cold soaking of incised, end-coated black cottonwood samples to determine radial penetration and retention.

Round samples, 30 inches long, were incised from a point 5 inches above the butt end to a height of 24 inches with incising hammer Type A. The butt ends of the samples were coated with Fullerglo 520 white paint to minimize end penetration. Six sets of samples, with 4 samples in each set, were used. Cold soaking periods of $\frac{1}{2}$, 1, 2, 4, 6, and $23\frac{1}{2}$ hours were employed, with one set of samples being used for each soaking period. The treating depth was 24 inches and the treating temperature was 80°F.

After treating, draining and final weighing the samples were cut into five 6-inch sections for examination of the depth of radial penetration. Whenever checks were observed to extend beyond the depth of radial penetration in the sections examined the tangential penetration from the checks was measured. The resulting data are tabulated in Table 3. The depth of radial penetration and the retention of preservative are illustrated in Graphs 3a and 3b respectively.
Table 3—Results of the preservative treatment of incised, end-coated black cottonwood posts by cold soaking in a 5 per cent pentachlorophenol solution.

<table>
<thead>
<tr>
<th>No. of samples</th>
<th>Average samples moisture %</th>
<th>Average diameter in inches</th>
<th>Average period in hours</th>
<th>Average retention in pounds per cubic foot</th>
<th>Average depth of tangential penetration in inches</th>
<th>Average depth of radial penetration in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15</td>
<td>4.4</td>
<td>2</td>
<td>2.32</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>4.3</td>
<td>1</td>
<td>3.53</td>
<td>0.19</td>
<td>0.15</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>4.5</td>
<td>2</td>
<td>4.19</td>
<td>0.26</td>
<td>0.22</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>4.5</td>
<td>4</td>
<td>4.95</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>4.7</td>
<td>6</td>
<td>5.09</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>4.5</td>
<td>23½</td>
<td>6.59</td>
<td>0.40</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Min. 0.14  Max. 0.38  Med. 0.25
Graph 3a - Depth of radial penetration of a cold 5 per cent pentachlorophenol solution in incised, end-coated black cottonwood.
Graph 3b—Retention of a cold 5 per cent pentachlorophenol solution in incised, end-coated black cottonwood.
Conclusions:

Both the retention and the depth of radial penetration of the preservative solution increased with an increase of soaking period, but radial penetration increased very little after the first four hours. Retention was at the rate of 1.24 pounds per cubic foot per hour during the first four hours, but only at the rate of 0.08 pound per hour during the next 19.5 hours.

Comparing the results on incised, end-coated samples with the results on non-incised, uncoated samples as reported in part B:

1. The radial penetration was much more uniform and slightly deeper in the incised samples.

2. The average retention of preservative solution by the incised, end-coated samples was approximately 60 per cent of the preservative retained by the non-incised, uncoated samples for soaking periods of one hour or more.

Thus, incised material gives a more uniform protective shell of treated wood. If the incised material is end-coated, this protection may be obtained with a lower absorption of preservative.

The average depth of sapwood of black cottonwood, so far as the test samples were concerned, was about one inch. Thus, by using this method of treatment, one-fourth to one-third of the sapwood was evenly penetrated with preservative.
The depth of tangential penetration from checks was observed to be less than the depth of radial penetration for each period of soaking. Thus, seriously checked posts are apt to expose more areas of shallow penetration with the result that checks may impair the service life of the posts.

D. Hot soaking of non-incised, end-coated black cottonwood samples to determine radial penetration and retention.

Half-round samples, 30 inches long, with the butt ends coated with Fuller Glo 520 white paint were used for this test. Four sets of samples, with 4 samples in each set, were used. Hot soaking periods of $\frac{1}{2}$, 2, 4, and 6 hours were employed, with one set of samples being used for each soaking period. The soaking temperature was $130^\circ F$ and the treating depth was 28 to 29 inches.

After treating, draining and final weighing, the samples were cut into five 6-inch sections to determine the depth of radial penetration. The resulting data are tabulated in Table 4. The depth of radial penetration and the retention of preservative solution are illustrated in Graphs 4a and 4b respectively.
Graph 4a- Depth of radial penetration of a hot 5 per cent pentachlorophenol solution in non-incised, end-coated black cottonwood.

Graph 4b- Retention of a hot 5 per cent pentachlorophenol solution in non-incised, end-coated black cottonwood.
Table 4 - Results of the preservative treatment of non-incised, end-coated half-round black cottonwood samples by hot soaking in a 5 per cent pentachlorophenol solution.

<table>
<thead>
<tr>
<th>No. of samples treated</th>
<th>Average moisture content in per cent</th>
<th>Average radius in inches</th>
<th>Average Soaking period in hours</th>
<th>Average retention in pounds per cubic foot</th>
<th>Average depth of radial penetration in inches</th>
<th>Min.</th>
<th>Max.</th>
<th>Med.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15</td>
<td>2.32</td>
<td>$\frac{1}{2}$</td>
<td>2.62</td>
<td>0.05 0.20 0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>2.02</td>
<td>2</td>
<td>3.90</td>
<td>0.06 0.37 0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>2.40</td>
<td>4</td>
<td>3.94</td>
<td>0.05 0.35 0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>2.38</td>
<td>6</td>
<td>3.45</td>
<td>0.06 0.36 0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions:

The minimum and medium depth of radial penetration in non-incised end-coated samples did not increase with an increase in the soaking period up to six hours. However, the maximum depth of radial penetration was obtained during the first two hour soaking period, beyond which there was no increase of depth of penetration due to longer soaking.

Similarly, the retention of preservative showed the same relationship to the soaking period as that of maximum depth of radial penetration. Accordingly, in hot soaking of non-incised, end-coated samples, there will be no marked improvement in either retention or in the depth of radial penetration beyond a 2-hour soaking period; see Plate 3, Appendix.
The average maximum and medium depths of radial penetration obtained by cold soaking were two to three times as great as the average values obtained by hot soaking. This occurred despite the fact that the measurements of radial penetration on the hot soaked samples were made throughout the submerged portions of the sample, whereas those measurements on the cold soaked samples were made only at the treating level where the effect of hydrostatic pressure on penetration is nil.

E. Hot soaking of incised, end-coated black cottonwood samples to determine radial penetration and retention.

Half-round samples, 30 inches long, with the butt ends coated with Fullerglo 520 white paint were used for this test. Four sets of samples with 4 samples in each set were used. Hot soaking periods of $\frac{1}{2}$, 2, 4, and 6 hours were employed with one set of samples being used for each soaking period. The samples were incised with incising hammer Type B. The soaking temperature was $130^\circ F$ and the treating depth was 28 to 29 inches. After treating, draining and final weighing the samples were cut into five 6-inch sections to determine the depth of radial penetration. The resulting data are tabulated in Table 5. The depth of radial penetration and the retention of preservative solution are
Graph 5a- Depth of radial penetration of a hot 5 per cent pentachlorophenol solution in incised, end-coated black cottonwood.

Graph 5b- Retention of a hot 5 per cent pentachlorophenol solution in incised, end-coated black cottonwood.
Illustrated in Graphs 5a and 5b.

Table 5—Results of the preservative treatment of incised, end-coated, half-round black cottonwood samples by hot soaking in a 5 per cent pentachlorophenol solution.

<table>
<thead>
<tr>
<th>No. of samples</th>
<th>Average moisture treated content per cent</th>
<th>Average radius in inches</th>
<th>Average soaking period in hours</th>
<th>Average retention in pounds per cubic foot</th>
<th>Average radial penetration in inches</th>
<th>Min.</th>
<th>Max.</th>
<th>Med.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15</td>
<td>2.47</td>
<td>½</td>
<td>3.00</td>
<td>0.13</td>
<td>0.36</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>2.32</td>
<td>2</td>
<td>3.19</td>
<td>0.14</td>
<td>0.40</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>2.12</td>
<td>4</td>
<td>4.83</td>
<td>0.18</td>
<td>0.41</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>2.42</td>
<td>6</td>
<td>4.70</td>
<td>0.20</td>
<td>0.46</td>
<td>0.29</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions:

The hot soaking at 130°F of incised black cottonwood samples gave retentions and depth of radial penetration quite comparable to those obtained by cold soaking at 80°F for equivalent soaking periods. Therefore, nothing is gained by heating the preservative for the treatment of incised black cottonwood posts.

Comparing the results of hot soaking incised, end-coated samples with the results on hot soaking non-incised, end-coated samples.
(1) The average minimum and average medium radial penetration on incised, end-coated samples were more than double those obtained on non-incised, end-coated samples, resulting in greater uniformity of penetration; see Plate 2 and 3, Appendix.

(2) The average retention was somewhat higher in incised, end-coated than in non-incised, end-coated samples.

Summarizing the results of soaking black cottonwood in a 5 per cent pentachlorophenol solution:

(1) Non-incised, uncoated posts appear to be satisfactorily treated by end penetration during cold soaking provided the soaking period exceeds 24 hours.

(2) Hot soaking showed no advantage over cold soaking; see Plate 3, Appendix.

(3) Samples that were incised and end-coated received a uniform treatment throughout the portion immersed with a relatively short soaking period. The quantity of preservative used was considerably less than that used for treating non-incised, uncoated posts by end penetration.
2. Soaking treatments of red alder

A. The height of end penetration of cold and hot pentachlorophenol solutions attained in red alder samples under different soaking periods.

Quartered samples of red alder, 30 inches long, surface-coated with Fullerglo 520 white paint, were subjected to cold soaking and hot soaking in 5 per cent pentachlorophenol treating solutions for different periods. The samples were divided into sets of three, each set being used for a different soaking period. The depth of preservative was 20 to 22 inches in cold soaking and 29 inches in hot soaking—these being the depths that were maintained for similar treatments of black cottonwood. The treating temperature for cold soaking was 75°F to 80°F and for hot soaking was 130°F. After treatment, the samples were cross-cut into one-half inch or sometimes 1- to 2-inch sections for inspection, starting from the butt end. The length measured from the butt end up to the point that showed the treated area to be less than 50 per cent of the total cross-sectional area was considered as the height of end penetration. End penetration was measured over the entire cross-sectional area because it is practically impossible to distinguish sapwood form heartwood in red alder. However, it was noted that the height of end penetration was greater
near the outside of the samples. The data are summarized in Table 6 and illustrated in Graph 6.

Table 6—The height of end penetration of cold and hot 5 per cent pentachlorophenol solutions attained in red alder samples under different soaking periods.

<table>
<thead>
<tr>
<th>Average moisture content in per cent</th>
<th>Soaking period in hours</th>
<th>Average height of end penetration (50 per cent or more of cross-sectional area treated in inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cold soak</td>
<td>hot soak</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td>9.0</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>10.2</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>12.0</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>14.2</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>15.3</td>
</tr>
<tr>
<td>---</td>
<td>13</td>
<td>15.3</td>
</tr>
<tr>
<td>12</td>
<td>--</td>
<td>17.3</td>
</tr>
</tbody>
</table>

Conclusions:

End penetration was more rapid during the first four hours of soaking. Raising the temperature of the preservative solution to 130°F had no significant influence on the rate of end penetration.

The rate of end penetration of the preservative in red alder was quite comparable to the rate of end penetration in the sapwood of black cottonwood.
Graph 6- Height of end penetration of a cold and a hot 5 per cent pentachlorophenol solution in red alder.
B. Cold soaking of non-incised, uncoated samples of red alder to determine end penetration, radial penetration and retention.

The procedure for this treatment was the same as was followed for the cold soaking of non-incised, uncoated samples of black cottonwood as described on page 23.

Five sets of round samples, 30 inches long, with four samples in each set, were used. Cold soaking periods of $\frac{1}{4}$, 1, 2, 4, and 6 hours were employed with one set of samples being used for each soaking period. A 5 per cent penta-chlorophenol solution was used with a treating temperature of 75°F and a treating depth of 22 inches. After treating, draining and final weighing the samples were cut at 4, 10, 16, and 22 inches from the butt to determine the approximate height of end penetration. Radial penetration was measured on the section cut at the treating level. The resulting data are tabulated in Table 7 and illustrated in Graphs 7a and 7b.
Table 7--Results of the preservative treatment of non-incised, uncoated red alder samples by cold soaking in a 5 per cent pentachlorophenol solution.

<table>
<thead>
<tr>
<th>No. of samples treated</th>
<th>Average moisture content per cent</th>
<th>Average diameter in inches</th>
<th>Average Soaking period in hours</th>
<th>Average retention in pounds per cubic foot</th>
<th>Approx. average height of end penetration in inches</th>
<th>Average depth of radial penetration at treating level in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
<td>4.5</td>
<td>½</td>
<td>3.08</td>
<td>4</td>
<td>T**</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>4.9</td>
<td>1</td>
<td>3.74</td>
<td>8</td>
<td>T**</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>4.6</td>
<td>2</td>
<td>5.12</td>
<td>10</td>
<td>T**</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>4.9</td>
<td>4</td>
<td>6.11</td>
<td>12</td>
<td>T**</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>4.7</td>
<td>6</td>
<td>9.41</td>
<td>16</td>
<td>T**</td>
</tr>
</tbody>
</table>

*T**Trace, indicates less than 0.05 inch in depth.
Graph 7a- Depth of radial penetration at the treating level of a cold pentachlorophenol solution in non-incised, uncoated red alder.

Graph 7b- Retention and height of end penetration of a cold 5 per cent pentachlorophenol solution in non-incised, uncoated red alder.
Conclusions:

The rate of increase in end penetration was more rapid during the first hour of soaking and then continued at a uniform rate.

The retention of preservative increased at a uniform rate throughout the range of soaking periods. This is similar to the behavior of black cottonwood except that the absorption during the first one-half hour of soaking was somewhat lower in red alder.

Similar to black cottonwood, the retention of preservative was closely associated with the rate of end penetration as the radial penetration was small in comparison.

The pattern of radial penetration beyond the height of end penetration was uneven and considerably less than for black cottonwood as indicated by the lower maximum and medium radial penetration values for red alder. This indicates that red alder is more refractory to radial penetration than is black cottonwood.

Based upon a comparison with black cottonwood, when treating non-incised, uncoated red alder posts at room temperature a soaking period of at least 24 hours is required in order to insure adequate end penetration throughout that portion of the posts below the level of the preservative solution.
C. Cold soaking of incised, end-coated red alder samples to determine radial penetration and retention.

The procedure of this treatment was the same as was followed for the cold soaking of incised, end-coated samples of black cottonwood as described on page 29. The only exceptions were that the depth of preservative was 22 inches and the treating temperature was 75°F. The resulting data are shown in Table 8. The depth of radial penetration and the retention of preservative are illustrated in Graphs 8a and 8b.
Table 8—Results of the preservative treatment of incised, end-coated red alder samples by cold soaking in a 5 per cent pentachlorophenol solution.

<table>
<thead>
<tr>
<th>No. of samples</th>
<th>Average moisture content in per cent</th>
<th>Average diameter in inches</th>
<th>Soaking period in hours</th>
<th>Average retention in pounds per cubic foot</th>
<th>Average depth of tangential penetration in inches</th>
<th>Average depth of radial penetration in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>14</td>
<td>4.5</td>
<td>½</td>
<td>2.16</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>4.8</td>
<td>1</td>
<td>2.30</td>
<td>0.15</td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>4.6</td>
<td>2</td>
<td>2.58</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>4.5</td>
<td>4</td>
<td>2.79</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>4.6</td>
<td>6</td>
<td>3.55</td>
<td>0.22</td>
<td>0.15</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>4.7</td>
<td>24</td>
<td>5.88</td>
<td>0.20</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Graph 8a- Depth of radial penetration of a cold 5 per cent pentachlorophenol solution in incised, end-coated red alder.
Graph 8b- Retention of a cold 5 per cent pentachlorophenol solution in incised, end-coated red alder
Conclusions:

Both the retention and the depth of radial penetration of the preservative solution increased with an increase of soaking period. Radial penetration increased more rapidly during the first six hours of soaking, after which it appears to fall off to a very much reduced rate; see Plate 4 and 5, Appendix. Following an initial absorption during the first one-half hour of 2.16 pounds per cubic foot the retention of preservative increased uniformly throughout the range of soaking periods.

The depth of tangential penetration from checks was observed to be less than the depth of radial penetration for each soaking period, being about one-half to one-third of the values for radial penetration.

Comparing the results of incised, end-coated samples with the results on non-incised, uncoated samples of red alder as presented in part 2B:

1. The radial penetration was deeper and much more uniform in the incised samples. The average medium depths of penetration were approximately twice as great as those of non-incised samples. The minimum depth of radial penetration also showed marked improvement.

2. The average retention of preservative solution by the incised, end-coated samples was approximately 50
per cent of the preservative retained by the non-incised, uncoated samples for soaking periods of one hour or more. Thus, incised materials give a more uniform protective shell of treated wood; see Plate 5, Appendix. If the incised material is end-coated, this protection may be obtained with a lower absorption of preservative.

In comparing the results of this experiment with the results of identical treatment on black cottonwood for soaking periods of six hours or less:

1. Red alder showed lower retention;
2. The medium depth of radial penetration was less for red alder;
3. The uniformity of radial penetration in red alder was less due to lower minimum values, this is illustrated by comparing Plate 3 with Plates 4 and 5, Appendix.

For longer soaking periods the depth of radial penetration was greater in red alder and the retention approached that obtained in black cottonwood.
SUMMARY OF CONCLUSIONS

1. Round, seasoned red alder and black cottonwood posts can be successfully treated by soaking in an unheated 5 per cent pentachlorophenol-diesel oil solution. Such treatment, which relies on end penetration alone, requires that the depth of the treating solution be equal to or greater than the height of treatment desired. When the depth of solution was 22 inches a soaking period of 24 hours was required to obtain a satisfactory penetration to a height of 16 to 22 inches in the samples. Retentions of about 13 pounds per cubic foot of wood were obtained and the sapwood was completely penetrated.

2. Incising the posts doubled the depth of radial penetration in red alder and increased the radial penetration about 10 per cent in black cottonwood to give a radial penetration of approximately 0.30 inch for each species at the end of 6 hours soaking. Even more important was the fact that radial penetration was more uniform in incised posts of either species thus reducing the chances of thin spots in the protective shell of treated wood.

3. A reduction in retention is possible in incised posts of these species because the uniform radial penetration
obtained makes it unnecessary to rely on end penetration. The quantity of preservative retained by incised samples, end-coated with white paint (Fullerglo 520), ranged from 37 to 60 per cent of that retained by non-incised, uncoated samples for soaking periods of 4 to 6 hours.

4. In experiments where comparisons could be made, there was no significant difference between hot soaking and cold soaking for either black cottonwood or red alder. Consequently, cold soaking rather than hot soaking is recommended as the more suitable method of treatment.

5. It appears likely that incised, end-coated black cottonwood can be satisfactorily treated by a somewhat shorter soaking period in a cold solution than can red alder, possibly 4 hours as compared with 6 hours. For soaking periods of 24 hours or more there is little difference in the treatability of the two species.

6. The protective value of those treatments that appear promising, based on these experiments, should be checked by service tests to determine whether or not the penetrations and retentions are actually adequate.


Plate 2- Illustrating the shallow, non-uniform pattern of radial penetration that occurs in treating non-incised, end-coated samples. (The heavy black line was drawn immediately after the sample was sectioned to preserve the pattern of radial penetration. The creep of the preservative over the surface of the sections, which occurred later, is apparent.)
Plate 3- Illustrating the more uniform pattern of radial penetration that occurs in treating incised, end-coated samples. (Compare with Plate 2) The above plate also illustrates the fact that radial penetration was not improved by increasing the temperature of the treating solution to 130°F.
Plate 4—The first two of a series of four pictures showing the increase of radial penetration with time in cold soaking incised, end-coated red alder samples. (Compare with Plate 5) The horizontal rows of samples are four sections from the same post cut at different distances from the butt end of the sample to assure a good average measurement of radial penetration.
Plate 4
Plate 5- The last two of a series of four pictures showing the increase of radial penetration with time in cold soaking incised, end-coated red alder samples. (Compare with Plate 5) The horizontal raws of samples are four sections from the same post cut at different distances from the butt end of the sample to assure a good average measurement of radial penetration.