PRESERVATION OF WOOD BY SIMPLE METHODS

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The purpose of wood preservation is to protect wood from various organisms which render it unfit for service. Wood rotting fungi and insects are the principal causes of deterioration of land based structures in the northeastern United States with fungi usually playing the more important role. Wood used in salt or brackish water may also be attacked by several species of molluscan or crustacean borers. Protection against marine organisms is beyond the scope of this paper. The agencies causing deterioration, their method of attack, conditions favoring their invasion of wood and methods of preventing this invasion are covered comprehensively by Hunt and Garratt (13) and will not be discussed in detail.

There are a number of ways of preventing attack by organisms but by far the most commonly used and practical means is to introduce into the wood some chemical that will inhibit the organism. Usually, but not always, a preservative that is effective against decay organisms will also afford protection against damage by insects. Preservative treatment should be gauged to meet the maximum hazards that may be encountered and may be light or heavy depending on circumstances. The experiments later described were performed for the most part on round timbers to be used in direct contact with the soil where conditions favoring decay are extreme and a high degree of protection is desired. This means getting the chemical into the wood to a depth and in an amount adequate to provide this protection. The two most critical decay points on a post, stake or pole set in the ground are the area extending from about one and one half feet below to one half foot above ground level, and the extreme top end. Experience has shown that in the northeastern United States the above-ground section of a post of non-durable wood is quite susceptible to decay and must be treated if the structure is to give uniformly good service. This point will be demonstrated under the section on "Service Tests".

For some 25 years the Station has conducted research in the introduction of preservatives into wood and studied the results of these treatments on wood under service conditions. Practical application of the results of the experiments has been covered in several bulletins (9, 10, 11, 12) published either solely by the Station or jointly with the Extension Service, University of Connecticut. The purpose of the current bulletin is to present the results of the experiments themselves.

Experimental application of preservatives has been entirely by methods which can be readily used by the small operator. The greater part of the work described below falls more or less naturally into three parts:

(a) Study of the distribution and retention of preservative within the wood under specified conditions of treatment. This phase is accomplished in a comparatively short time.

(b) Determining the life of the treated material in actual use. With well treated wood, it may be 10 years or more before the effectiveness of a treatment or preservative can be evaluated. In addition to material experimentally treated, service tests include a large number of posts which were treated commercially by several methods.

(c) Supplementary investigations covering the phytotoxicity of oil-soluble preservatives and their solvents, seasonal moisture content of red maple and the seasoning of round posts.

METHODS OF TREATMENT

The methods of treatment investigated experimentally were:

Open tank method using coal tar creosote.
Brushing or dipping with coal tar creosote or tar.
Sap stream methods using zinc chloride.
Cold soaking in oil-soluble pentachlorophenol and copper naphthenate.

OPEN TANK TREATMENT TO BUTTS OF POSTS

The open tank method of treatment has been so fully discussed in the literature that only a very brief description of the principles involved are included here. As a reference, see Hunt and Garratt (13).

The wood to be treated is stood upright or immersed in the treating liquid, which is kept at an elevated temperature for several hours during which air and water are driven off. It is then either transferred to another tank containing preservative at lower temperature or is allowed to cool down in the container of preservative in which it was heated. The wood must be seasoned and free of bark before treatment.

A satisfactory treatment by this method is one resulting in a retention of four pounds or more of creosote per cubic foot of wood in the zone under treatment and a minimum lateral penetration of one-half inch or full sapwood penetration if the sapwood is less than one-half inch thick. Preservatives other than creosote may be applied by this method but were not included in the experiments.

Treatment of Pitch Pine, Red Pine, Scotch Pine and Red Maple

Seventy-five posts[1] of each species were cut and peeled and, after approximately one year of seasoning, 43 to 45 of each species were

[1]Although local usage applies the term "pole" to timbers 12 feet long which support tobacco shade tents, the term "post", as used in this paper, applies to any timbers up to 12 feet long and "pole" to timbers more than 12 feet long; also, all timbers referred to in this text are in the round with the sapwood intact.

given a butt[2] treatment with creosote by the open tank method, the balance being used for untreated checks or for other purposes. Diameters ranged from 4 to 8 inches and lengths were either 8 feet or 12 feet. The red and Scotch pine posts were from forest plantations less than 30 years of age and were composed almost entirely of sapwood. The pitch pine and red maple came from natural stands. The sapwood on the former was an inch or more in thickness; the latter was almost wholly sapwood. Prior to treatment, the inner bark was carefully removed from the section that was to receive treatment. The preservative was Grade I A.W.P.A. Coal Tar Creosote.

The equipment consisted of two 100-gallon barrels equipped with steam coils for heating. The depth of liquid was 36 inches in the hot tank and 39 inches in the cold tank.

Treating procedure consisted in placing the posts upright in the hot bath and then either transferring them to another tank in which the temperature of the creosote was maintained at approximately 100° F., (cold bath) or shutting off the heat to the hot tank and allowing the posts to remain in that tank while the temperature gradually decreased, (cooling bath). The results of treatment are shown in Table 1.

It may be noted that, under the conditions of treatment set forth in Table 1, absorption per cubic foot was adequate to excessive for all species. It was extremely heavy in the lower 1 to 2 feet of the post for all species. For the three pines, radial penetration at 3 feet from the butt end (the liquid level in the tank) was quite satisfactory except for some of the Scotch pine posts which were subjected to baths of short duration. Average depth of penetration of maple at the same point was low and, moreover, was quite erratic.

From a practical standpoint, it is obvious that the schedules used for the pines would have to be modified to prevent excessive absorption and at the same time increase radial penetration which is sometimes no more than adequate. A possible solution to the problem might be to increase the duration of the hot bath and omit the cold or cooling bath altogether. Although it is generally claimed that most of the absorption takes place during the cold bath, the writers have found that there is a very appreciable intake during the hot bath, frequently as much as 5 pounds per cubic foot. (See Tables 2 and 4.)

A condition similar to the above was observed in sampling a large number of red pine posts treated under pressure to a specified retention of 8 pounds per cubic foot. The pressure period lasted only 15 minutes and the retention was about 20 pounds per cubic foot before and 11 pounds after final vacuum. Even with this absorption, there were a number of posts in each charge which showed radial penetrations at mid-point of only ½ inch to 1 inch. Most, however, showed penetrations of 1½ inches or more.

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[2]For the purposes of this discussion, the "butt" of a post is the end nearest the ground in a standing tree.

TABLE 1. OPEN TANK TREATMENT:
ABSORPTION AND PENETRATION OF CREOSOTE IN BUTT-TREATED POSTS OF PITCH PINE, RED PINE, SCOTCH PINE AND RED MAPLE.

Run No.	Hot Bath Duration, hours	Hot Bath Temp., °F.	Cold Bath Duration, hours	Cooling Bath Duration, hours	Absorption of Preservative,[1] lbs./cu. ft.			Radial Penetration 3 Ft. from Butt,[2] inches		
					Range	Av.	No. of Posts	Range	Av.	No. of Posts
					Pitch Pine					
1	3¾	209	22½	......	12—20	16	11	1.0—2.5	1.3	4
2	4	221	......	15¾	8—28	17	9	0.8—1.5	1.1	4
3	3½	209	20¼	......	11—17	15	11	0.9—1.5	1.2	1
4	4	211	......	15¼	10—19	14	9	0.8—0.9	0.8	1
5	3	197	......	44½	17	17	1	....	....	....
6	4	217	19¼	......	17—27	22	2	1.3—2.6	2.1	1
					Red Pine					
5	3	197	......	44½	20—40	30	12	0.7—1.5	1.2	2
6	4	217	19¼	......	19—43	28	10	0.6—1.9	1.3	3
7	4	207	......	15¾	16—38	26	13	0.4—1.2	0.6	3
8	4	187	19	......	14—38	23	9	0.5—1.7	0.9	4
					Scotch Pine					
10	4½	207	......	19¾	11—18	15	2	0.9—1.3	1.0	1
12	2½	214	2½	......	7—16	12	3	0.2—0.9	0.5	3
13	3	214	3	......	18—20	19	3	....	....	....
14	3½	211	2½	......	12—14	13	3	0.4—0.7	0.6	1
15	3¾	209	1¾	......	16—18	17	2	0.4—0.7	0.6	2
17	2	215	16	......	16—31	22	9	0.4—1.0	0.7	5
18	2	196	2¼	......	8—13	10	9	0.3—0.8	0.5	6
19	2	217	2½	......	10—21	14	8	0.2—1.1	0.5	3
20	2¾	206	2½	......	12—30	18	5	0.5—2.5	1.0	3
					Red Maple					
8	4	187	19	......	11—15	13	4	0.3—0.5	0.4	1
9	4	208	......	14	8—17	11	14	0.2—0.5	0.3	2
10	4½	207	......	19¾	6—11	9	6	0.3—0.6	0.4	2
11	4	213	......	21	11—15	13	10	0.2—0.4	0.3	1
16	4½	212	18	......	8—21	13	9	0.1—0.4	0.2	2
18	2	196	2¼	......	7	7	1	0.1—0.2	0.1	1

[1]Based on volume of wood actually immersed.
[2]Based on 3 borings per post.

The wood of plantation-grown red and Scotch pine is very low in density and the above experiences indicate that routine procedures, used to treat denser wood of these or similar species, need to be modified.

On the basis of a very limited number of tests of other woods under similar conditions, it was observed that the birches, aspens, tulip and elm reacted to treatment in a manner quite similar to red maple. Oak, on the other hand, took treatment very well.

Seven posts of each species, treated as shown in Table 1, with four untreated checks, were installed in a tobacco shade tent in 1933. Service records for the succeeding 11 years are given in a later section of this report (page 59). These posts were 12 ft. long.

On the basis of the experiment described, the State Highway Department revised its post specifications in 1934 to include posts of a number of woods butt-treated with creosote by the open-tank method. Prior to this, chestnut posts had been used almost exclusively in highway fencing. The butts of these posts were given a superficial treatment by brushing with creosote.

Since there were no commercial plants equipped to treat by the open-tank method, the State Forestry Department installed a demonstration plant and, in connection with it, set up three small tanks for experimental purposes. The depth of the small tanks permitted butt treatment over four feet of length with the posts standing upright. Heat was supplied by steam coils.

This paper is not concerned with the operation of the demonstration plant, except that some 3,600 posts treated in it were included in the service tests which will be described later.

The primary use of the experimental tanks was to work out techniques to be followed in the larger plant. Of the numerous experiments performed, only two are considered of sufficient interest to record in this paper:

(a) Incising of red maple to improve ground line penetration.

(b) The results of treating 110 oak posts under reasonably well-controlled conditions.

The posts in both cases were from 5 to 8 inches in diameter by 8 feet long and were peeled and well seasoned. Treatment was to a distance of 4 feet from the butt.

Incising Red Maple

It has already been noted that the maple treated as shown in Table 1 absorbed an adequate to excessive amount of preservative per cubic foot for the section immersed and that penetration at the liquid level was shallow and erratic.

In an effort to obtain a more even distribution, 79 posts divided about equally among eight runs were incised with a home-made tool and treated according to the schedule and with the results shown in Table 2. No cold or cooling bath was used. Incision was to a depth of approximately ½ inch and covered an area of the post extending from 18 inches below to 6 inches above ground line. Cuts were approximately 2 inches apart longitudinally, ¾ inch apart tangentially and entered the wood at about 45° to the long axis of the stick.

TABLE 2. OPEN TANK TREATMENT: ABSORPTION AND PENETRATION OF CREOSOTE IN THE BUTTS OF INCISED RED MAPLE POSTS; COLD BATH OMITTED.

Run Number	Hot Bath Duration, hours	Hot Bath Temp., °F.	Absorption of Preservative,[1] lbs./cu. ft. Range	Av.	No. of Posts	Radial Penetration 3½ Ft. from Butt,[2] inches Range	Av.
A	4	230	1.9—7.4	4.6	10	0.2—0.6	0.3
B	6	228	3.3—5.7	4.8	10	0.2—1.1	0.4
C	2	225	2.3—6.0	4.1	10	0.1—0.7	0.3
D	6	215	1.9—8.8	6.0	10	0.2—0.6	0.4
E	4	216	0.6—4.9	3.2	10	0.1—0.4	0.3
F	2	215	0.8—3.8	1.0	10	0.1—0.2	0.2
G	4	220	2.0—8.1	4.9	9	0.1—0.7	0.3
H	6	220	2.8—8.4	5.1	10	0.1—0.8	0.4

[1]Based on volume of wood actually immersed.
[2]Based on 3 borings per post.

It will be noted that, except for the runs with bath periods of 2 hours there is some improvement in radial penetration over that shown for maple in Table 1, particularly in the maximum depths attained. It seems possible that longer bath periods could provide quite adequate penetration over the incised zone. It will also be shown later that incising has a marked effect in reducing checks in red maple during seasoning. The most marked effect of changing treating procedure by omitting the cold bath was to greatly reduce absorption of preservative, especially near the butt end of the stick.

In order to produce satisfactory results, incising must be carefully done to insure uniform spacing of cuts over the incised area. To do this with hand tools is quite expensive, and it seems doubtful if the capital outlay necessary to develop a power tool to satisfactorily incise small, round material with irregular surfaces is warranted. The conclusion was reached that, if incising is necessary to secure satisfactory distribution of any given preservative in small, round posts, it is better to change to a preservative which can be satisfactorily used without incising.

Spot inspection of yellow and black birch posts, which were treated in the demonstration plant in large numbers, indicated that these two woods reacted to treatment in the same manner as maple.

Treatment of Oak

A high percentage of the posts treated for highway use in the large plant were members of the black oak group. Table 3 shows the results obtained in 11 separate experimental runs of 10 posts each.

TABLE 3. OPEN TANK TREATMENT: ABSORPTION AND PENETRATION OF CREOSOTE IN BUTT-TREATED OAK POSTS.

Run Number[3]	Hot Bath Duration, hours	Hot Bath Temp., °F.	Cooling Bath Duration, hours	Cooling Bath Temp.,[4] °F.	Absorption of Preservative,[1] lbs./cu. ft. Range	Av.	Radial Penetration 3½ Ft. from Butt,[2] inches Range	Av.
1	6¾	209	17.0	194	2.7—12.7	7.5	0.2—1.0	.37
2	9¼	208	15.0	194	1.8—10.5	7.1	0.1—0.5	.30
3	6½	215	16.9	190	5.0— 6.4	5.2	0.2—0.5	.30
4	6	210	66.3	148	3.6—13.7	10.9	0.1—0.4	.22
5	7½	210	16.0	165	4.6—12.7	9.6	0.1—0.4	.26
6	8	214	15.5	164	3.6— 7.2	4.8	0.1—1.2	.44
7	5½	198	17.9	163	2.0— 7.3	4.5		
8	5	198	18.1	151	4.1—17.6	8.6		
9	3½	212	17.3	184	3.5— 7.4	4.3		
10	6¼	212	16.4	189	4.2— 6.4	5.5		
11	4½	218	18.3	188	3.5—12.7	7.7		

[1]Based on volume of wood actually immersed.
[2]Based on 3 borings per post.
[3]There were 10 posts in each run.
[4]At beginning of cooling period.

The posts in these runs had a relatively thin sapwood and the figures given for depth of radial penetration represent, in most cases, a complete sapwood penetration. There was very little absorption of creosote by the heartwood, even at the extreme butt ends of the posts. The sapwood on oak is, therefore, quite heavily impregnated. Although variations in the treating procedures of the several runs render it impossible to make precise comparisons, it seems apparent that hot baths of 200° to 220° F. maintained for 4 hours or more and cooling baths of 15 to 18 hours duration result in satisfactory absorption and penetration in most cases. There appears to be no advantage in prolonging the hot bath beyond 6 hours or the cooling bath beyond 15 to 18 hours (overnight).

It is interesting to note that, in treating oak, there is a tendency for the preservative to rise uniformly in the sapwood to a distance of a foot or more above the liquid level in the tank. In fact, in some cases creosote appeared at the extreme top, 4 feet above liquid level. This rise of creosote within the post was much more pronounced in oak than in any other species under test.

FULL LENGTH OPEN TANK TREATMENT

After less than five years of service, posts of oak, maple and birch, which had been given an open tank treatment to the butts only, had begun to decay in the tops.

To provide a basis for comparison, some 300 posts of these species were given a full length open tank treatment with creosote as indicated in Table 4. Since the tanks did not permit complete immersion, the butts and tops were treated successively for the periods shown and no cold or cooling bath was used.

TABLE 4. OPEN TANK TREATMENT: ABSORPTION AND PENETRATION OF CREOSOTE IN POSTS OF MAPLE, BIRCH AND OAK TREATED FULL LENGTH; COLD BATH OMITTED.

Species	Number of Posts	Duration of Bath,[1] hours		Absorption of Preservative, lbs./cu. ft.	Radial Penetration at Mid-Point[2]	
		Top	Butt		Range	Average
Oak	106	2 — 4	4 — 5	3.5	0.1—0.8	0.4
Oak	112	4 — 5	4 — 5	3.0	0.1—0.7	0.4
Red Maple	27	2 — 3	4 — 5	4.2	0.1—0.9	0.4
Red Maple	27	4 — 5	5 — 5½	5.3	0.1—0.5	0.2
Birch[3]	28	2 — 3	4 — 5	4.8	0.1—0.4	0.2
Birch[3]	27	4 — 5	5 — 5½	4.8	0.1—0.3	0.2

[1]Bath temperatures 210° to 220° F.
[2]Based on 2 borings per post.
[3]Black or yellow birch.

Even though treatment was performed under somewhat adverse conditions and a cold or cooling bath was omitted, a fairly good absorption of preservative was obtained for all three species. Radial penetration of oak, while somewhat shallow, represented practically as complete sapwood impregnation as in the butt treatments. Red maple and birch, which were not incised, exhibited the characteristically thin mid-point penetration which has been previously noted (page 7). Omission of a cold or cooling bath cut down the total absorptions for these woods to reasonable amounts and prevented excessive absorptions near the extreme ends.

These posts were installed in highway fencing and records of their service life are included under "Service Tests", page 55.

LOSS OF PRESERVATIVE BY EVAPORATION

One experiment was made to determine the loss of creosote by evaporation in relation to temperature. Creosote in a cylindrical tank 47½ inches in diameter was maintained at three temperature levels for three hour periods and the loss by evaporation determined. There were no posts in the tank and the work was done at night when wind movement was at a minimum. Results were as follows:

Temperature Maintained, °F.	Duration of Test, hours	Creosote Evaporated to Atmosphere, gallons	
		Total	Per Hour
210	3	0.95	.32
220	3	1.43	.47
230	3	1.91	.63

Although the liquid surface was at maximum area, it seems obvious that, if temperatures are carried at levels much higher than 210° F., losses from evaporation may become excessive.

SUMMARY OF OPEN TANK TREATMENT

In general summation, it was concluded that there are relatively few local woods that are found in some abundance which can be readily treated with creosote by the open tank method. Native pitch and planted red and Scotch pines come in this category. With these species, the principal problem is to avoid excessive absorptions. Of the hardwoods, oak can be given a full sapwood treatment without excessive absorption at any point. The principal drawback to oak is that frequently the sapwood is quite thin and the treated shell is not sufficiently thick to give good protection to the interior of the post.

SUPERFICIAL TREATMENTS

In some of the earliest experiments, posts of a number of non-durable woods were given a brush or dip treatment with creosote. Some treatments were made only to the butts; in others, the preservative was applied to the full length of the posts. There was virtually no penetration of the wood by the preservative. It was soon found that this type of treatment added very little to the life of either the butts or the tops and no further experimental work has been done with this method. For a great many years, the State Highway Department had brushed the butts of chestnut posts with creosote prior to installation in highway fencing. When chestnut became scarce, the same type of treatment was applied to large numbers of posts of non-durable woods. That this treatment was not satisfactory, is shown later under "Service Tests".

The above statements should not be taken as an unqualified condemnation of superficial treatments. They are quite inexpensive and, when used on naturally durable woods such as chestnut to give a few additional years of service, they may be well justified. They may also give very good results on posts or other structural timbers such as sills where conditions favoring decay are not severe or where the timber may be re-treated periodically. On the other hand, the costs of installing posts in permanent fencing may be several times the value of the post itself and a service life sufficiently long to amortize these costs at a reasonable annual rate must be the goal. Superficially treated non-durable woods with a service life of five years or less will not meet this requirement.

THE SAP STREAM METHODS

The term "sap stream method", as used in this paper, includes any method used to introduce water-soluble chemicals into the normal water-conducting tissue (sapwood) of freshly severed stems or of living trees.

Materials introduced into severed stems or stem sections are usually applied to protect the wood against insects and decay organisms when it is subsequently put into use. They may also be introduced into living trees for the same purpose. Materials may also be applied to living trees in the same way to kill the trees, to feed them, or to protect them with systemic poisons against insects or with chemotherapeutants against vascular diseases.

Injection techniques are many and it is beyond the scope of this paper to describe them in detail. They may, however, be rather broadly classified into three groups:

(a) Introduction through the ends of freshly severed stems with or without foliage attached.

(b) Introduction through bore holes or incisions in the sapwood of the trunk of standing trees.

(c) Introduction through the root system of standing trees by application to the soil or through the leaves by foliar sprays.

Since this paper deals with the introduction of chemicals into the woody stem, or a section thereof, as a practical measure for protecting wood against attacks by fungi and insects, no attempt will be made to review extensively the literature dealing with the injection of standing trees for other purposes.

The principle of injection is not new. Frederick Moll (15) cites the research of Magnol (1709) and Hales (1730) on the rise of sap in plants and especially in trees. A little over a century later (1838-40) Boucherie developed a scheme for injecting living trees with preservatives (5). He soon abandoned this method because of technical difficulties but shortly thereafter perfected a method of treating green poles with copper sulfate for which he was honored by the French government. Boucherie's technique differed in no essential detail from the tire-tube method which will be described later.

Since Boucherie's time, a number of methods have been advocated for the injection of standing trees with preservatives or dyes. Some of these techniques have been described by Craighead *et al.* (7) and Wilford (19). There is little doubt that these techniques can be used to introduce preservatives into living trees which are subsequently felled but they appear to be less practicable for wood preservation purposes than essentially similar methods which have been developed for the injection of severed stems or stem sections. The latter can be readily used by the small operator although it is doubtful if they will ever be used commercially. Those methods that bear on the research described below are cited as follows[1]:

In 1937, Craighead, St. George and Wilford (7) and, in 1944, Wilford (19) described two methods for injecting preservatives into severed stems with foliage attached which they termed "stepping" and "capping".

In 1938, Hunt and Wirka (14) published the results of their work on a modification of Boucherie's process known as the tire-tube method.

In 1940, Dunkelberg *et al.* (8) described a process for treating unseasoned posts with water soluble preservatives by the "barrel" or "trough" method.

Since 1938, the Connecticut Station has done an appreciable amount of experimental work on all of the methods described immediately above except "capping". In part, this work was to determine to what extent the methods were applicable to native woods under local climatic conditions, with or without modification, and in part to inquire into some of the more fundamental aspects of these techniques.

The inherent features of all sap stream methods are that the wood must not have been seasoned to any appreciable extent before treatment, that initial penetration is confined almost wholly to the sapwood and that the preservative must be soluble in water. It is probably also better if the bark is left intact, since its removal without severing some of the sapwood elements is difficult; also the bark apparently retards leaching to some extent. It should also be mentioned that since the chemicals are soluble in water, solutions of them must penetrate the wood deeply, otherwise they will soon be leached out. Consequently, only those woods that have a thick sapwood are considered suitable for treatment.

When the work on the sap stream methods was begun in 1938, it was decided to limit it to a relatively few woods on the basis of two criteria:

(a) The availability of the wood and its suitability for use as posts, stakes and poles.

(b) A favorable reaction to treatment as determined by screening tests.

Subsequent to the preliminary trials, work has been confined largely to members of the hard pine group and certain diffuse porous hardwoods. A major part of the work has been done on red maple and red pine.

In the experimental work described herein, zinc chloride, either with or without dichromate, is the only preservative that has been used in any appreciable amount. It is cheap, readily obtainable, only

[1]Within recent years, a number of agencies have issued publications on various sap-stream methods. These reports, for the most part, deal only with the application of research and they will not be cited except in cases where it is necessary to give the agency prior credit for advancing an idea or method.

slightly corrosive to ferrous metals and quite safe to handle. Furthermore, it has well-demonstrated preservative value. Of the other well-known water soluble preservatives—mercuric chloride, copper sulfate and sodium fluoride—the first two are highly corrosive to ferrous metals and the first and third are rather dangerous to handle.

In theory, there appears to be no reason why any water soluble salt should not be applied by sap stream methods. However, it has been demonstrated by a recent series of well controlled laboratory experiments that there is a difference in the rate at which various chemicals in solution move through the water conducting elements. Of some 30 chemicals so tested, zinc chloride rates near the top in its rate of movement.

In 1938 an acceptable standard for retention of zinc chloride, when applied by pressure methods, was ¾ pound of dry zinc chloride or ⅝ pound of dry chromated zinc chloride per cubic foot of wood treated. Since the sap stream methods are not subject to the more rigid controls that are possible in commercial processes, the goal in the experimental work has always been the retention of at least 1 pound of zinc chloride or ¾ pound of chromated zinc chloride per cubic foot of wood treated. In recent years specifications for pressure treatment have been increased to 1¼ pounds per cubic foot for the straight, and 1 pound for the chromated salt. If a wood is susceptible to treatment by sap stream methods, these goals are quite readily attained. In fact, if the treating procedure is not well regulated, absorptions may be excessive. This is, of course, extremely wasteful of preservative.

Quantitative analyses to determine the amount of zinc chloride present in wood were made by methods described by Bateman (3) and by Carter *et al.* (6) or by spectrographic analysis. Qualitative tests to determine the presence or absence of the salt were made by spraying the wood with a mixture containing equal parts of the following solutions:

Potassium ferricyanide	1%
Potassium iodide	1%
Soluble starch	5%

If zinc chloride is present, the wood will turn dark purple. This test is very sensitive but not at all quantitative. The starch must be dissolved in water which is slightly below 212°F. After cooling, a few drops of chloroform may be added to prevent souring. If kept in separate bottles, the solutions will remain good for a long time. The mixture of the three, however, will turn dark after a few hours. It should then be discarded, the atomizer thoroughly washed and a new mixture made up. It is also very necessary to avoid outside contamination by zinc chloride of both the wood to be tested and the spray apparatus. To avoid "dragging" of chloride from treated to untreated areas, the spray had best be applied to split surfaces.

The sap stream methods are quite fully described in the literature already cited. Consequently, the techniques will be treated here quite briefly and emphasis will be placed on departures from the techniques as originally described.

The methods all have a common feature in that the preservative salt in solution moves through the normal water-conducting elements of the sapwood. The techniques of application, however, differ widely and for that reason, the several methods will first be described separately[1] together with such modifications as have been found necessary for adaptation to native woods under local conditions. There are, however, certain characteristics, in particular the distribution of salt immediately after the initial intake and its subsequent movement during seasoning, which are more or less common to all the methods. To avoid repetition, these features will be discussed following the description of the several methods.

The Tire Tube Method

This method consists of fastening a section of old tire tube over the end of a post, laying the post on a rack so that the input (tube) end is about 18 inches above the exit end, attaching the open end of the tube to a rail located some 2 feet above the input end and filling the tube with a specified amount of solution.

The original recommendations (14) called for the use of 10 pounds of 10% solution per cubic foot of wood regardless of species. The objectives sought were for the treating solution to push the free water out of the stick and carry through to the exit end by the time all the solution had moved out of the tube. To insure a positive treatment at the exit end, there should be a little zinc chloride in the drip.

It soon became evident that the amount of solution recommended was not equally applicable to all species. This fact was recognized in a revision of the original recommendations in 1940 (20). When 10 pounds of 10 per cent solution was introduced into some woods, it was found that the chloride had not moved all the way through the stick by the time the tube was empty. This difficulty was overcome by increasing the amount of solution. Emphasis is on the amount of solution and not on its strength. Strength of solution may be varied over wide limits but if the amount of solution used is kept constant, there is relatively little variation in the amount of salt collected in the drip. If the amount of solution per cubic foot is too great, there will be an excess of chloride in the drip; if the amount of solution is too small, the exit end of the stick will not be adequately treated. If the amount of solution is about right to carry salt through the stick and the concentration is too high, the retention of salt per cubic foot will be too high.

The results of two experiments are introduced at this time because they bear directly on the points discussed immediately above. In both, posts 12 feet long were butt-injected by the tire tube method with either 15 pounds of 10 per cent solution or 16 pounds of 6 per cent solution to obtain a retention of 1½ pounds or of 1 pound of dry salt per cubic foot of wood, respectively. Immediately after treatment the

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[1]Since the data on stepping large trees is used by permission, all information pertaining to this method is included as a unit.

posts were sampled qualitatively by color test to determine the presence or absence of salt.

One experiment included posts of Norway spruce, red pine and Scotch pine; the other, of red maple, black birch and gray birch. Record of treatment is shown in Table 5.

It will be noted that the amount of drip collected from the conifers is very much less than the input. This is reflected in radial penetration which is given in the last section of the table. In most cases penetration becomes erratic at distances of 7 feet or more from the input end.

Of the three hardwoods which were injected with about the same amount of solution of 6 per cent or 10 per cent strength, amount of drip was recorded only for gray birch, but from other experiments it is reasonable to expect similar results from black birch and red maple. This amount is only slightly less than the input. With virtually no exceptions, penetration at 7 feet from the input end is excellent; at 10 feet, good to excellent with very few erratic tendencies; at 12 feet, fair to good with a moderate number showing erratic behavior. After input, all posts were seasoned in a horizontal position for several months to a year before setting and were finally set with the input end down. The significance of these points will become more evident later when Angell's and Olson's findings (see pages 26-32) and the behavior of these posts in actual service (see page 60) are discussed.

On the basis of the above experiments and numerous other trials, it was decided that satisfactory treatment of maple and birch by the tire tube method could usually be obtained by using about 14 pounds of 7 per cent solution per cubic foot of wood. For red and Scotch pine wood of low density and very high sapwood content, it was necessary to use about 20 pounds of 5 per cent solution. Evidence will be presented later (pages 36-40) to show that treating behavior is influenced to some extent by season of treatment, especially for maple and, if sufficient data were available, the above figures would unquestionably need some revision. In the absence of such data, it is believed that they may be used with the expectancy of obtaining good results under most operating conditions; also that, respectively, they would apply to many other diffuse-porous and coniferous woods of essentially similar structure and density provided these species had a high sapwood content.

The woods of many species were eliminated during the initial screening process either because they have thin sapwood or are not available in sufficient quantity. The results obtained with them will not be recorded except for those of two genera which are of special interest. When oak is treated with 10 pounds of 10 per cent solution, the liquid moves so rapidly through the large pores in the sapwood that frequently as little as 20 per cent of the salt introduced is retained in the stick. In addition to this, oak usually has a very thin sapwood and, even if it is well impregnated, the treated zone is too

TABLE 5. TIRE TUBE METHOD: DISTRIBUTION OF ZINC CHLORIDE SHORTLY AFTER INPUT OF SOLUTION.

Species	Number of Posts	Solution Used per Cu. Ft.	Average Intake per Post, pounds	Average Drip per Post, pounds	Radial Penetration[1] (in inches) at Various Distances from Input End							
					4′		7′		10′		12′	
					Range	Average	Range	Average	Range	Average	Range	Average
Red Pine	5	15 lbs. of 10%	38.2	24.3	0.8–2.2	1.6	0.0–1.3	0.8	0.0–1.0	0.4	0.0–2.0	0.3
Scotch Pine	5	15 lbs. of 10%	34.0	19.7	1.1–2.6	1.9	0.4–1.8	1.1	0.0–1.3	0.5	0.0–2.3	0.3
Norway Spruce	5	15 lbs. of 10%	42.1	30.6	0.9–2.5	1.6	0.0–1.6	1.0	0.0–1.4	0.6	0.0–1.7	0.4
Red Maple	25	16 lbs. of 6%	33.4	......[2]	1.1–3.0	2.0	0.4–2.6	1.8	0.0–2.4	1.5	0.0–2.8	1.2
Black Birch	10	15 lbs. of 10%	30.0	......[2]	1.6–3.0	2.2	1.1–2.7	2.0	0.5–2.5	1.7	0.5–2.2	1.2
Gray Birch	10	15 lbs. of 10%	29.3	26.3	1.3–2.6	2.1	1.3–2.5	1.8	0.4–2.4	1.4	0.0–1.9	0.7

[1]Based on four borings at each level.
[2]Not recorded.

thin to provide adequate protection by a water-soluble salt. Ash takes treatment only in the very outermost rings of the sapwood, probably because the pores in older wood become plugged with tyloses. As with oak, only a very small percentage of the salt input is retained.

The tire tube method is the surest of the sap stream methods in that each post is treated individually. It is well adapted to experimental work but not to bulk treatment. Fastening of the tubes to the posts, while not particularly difficult, is somewhat tedious and seems to be the chief reason why the method has not been put to wider use in this region. It can be used at temperatures as low as 20° F., although the movement of solution is quite slow at temperatures below 40° F. It follows from Olson's findings (see page 31) that treatment by the tire tube method can be materially improved if, subsequent to input, the posts are seasoned in a vertical position with the input end up for a month or more.

Barrel or Trough Method

As far as is known, this method was originated at the South Carolina Agricultural Experiment Station about 1939. Various aspects of it were reported in the annual reports of that station (18) and in publications of Clemson Agricultural College (2,16). The basic features of the method as described are essentially as follows: The butt ends of southern pine posts, 7 feet long, are immersed in a barrel or other container in a solution made up of 2 pounds of either copper sulfate or zinc chloride per gallon of water and allowed to remain immersed until the posts have taken up solution in the amount of 2 quarts per cubic foot of wood to be treated. During the intake period the preservative rises in the post to a relatively short distance and, in order to secure a satisfactory distribution, it is necessary to season the posts in a vertical position with the butt or intake end up for 30 days. A modification of the technique is to stand the butts of posts in the container until about half the desired amount of solution has been taken up and then reverse the posts to allow the balance of the solution to be taken up through the top end. Seasoning is with the butt end up as before.

The Connecticut Station has been interested in this method because of its simplicity and has performed numerous experiments for the purpose of adapting its features to woods indigenous to this region. The conclusions from these experiments are given below.

It was soon evident that, under northern conditions and for the species under consideration, it was virtually impossible to obtain, within a reasonable time, sufficient intake of solution of 20 per cent strength by weight to provide for a retention of 1 pound of zinc chloride per cubic foot of wood treated. Preliminary experiments indicated that, in order to obtain this retention of salt, solution strengths would have to be increased to between 30 per cent and 50 per cent and recommendations for the higher strength have been made (12). The use of such strong solutions may seem rather drastic but, if the posts are stacked in a vertical position with the intake end up immediately after removal from the container, there is a fairly rapid movement of salt longitudinally through the stick which reduces the concentration at the intake end. This will be more fully discussed later under "Distribution and Movement of Salt". No marked damage to wood has been observed at the time of treatment although, as will be noted later under "Service Tests" for Wolman salts, zinc chloride appears to cause surface deterioration of wood after 5 to 10 years of actual service in the ground. The areas so affected turn brown and become brittle, almost as if the wood had been charred.

If intake of solution is through the butt end only and the posts are seasoned in a vertical position with the butt end up, there is frequently a small core at the extreme tip which is not impregnated with salt. Since posts frequently decay at this point, treatment of the top end is imperative. This was accomplished in the modification described above by reversing the posts in the container during intake. This is effective but the extra handling adds to the cost of treatment. Another quite effective means of insuring positive top-end treatment is to sprinkle about two ounces of dry salt on the top end of the post when the butt end is immersed in the solution. This salt will take up enough moisture from the air to permit it to penetrate downward for several inches during the period of solution intake at the butt. This scheme was developed by a private operator in Connecticut who called it "buttering".

One very serious drawback to the barrel method is the danger that, through negligence, or misunderstanding, the posts will not be properly handled subsequent to the intake of solution. As indicated by the originators, there is very little rise of solution in the posts during intake. If the posts are seasoned in a vertical position with the *intake end down* or, as will be indicated later, if they are seasoned in a horizontal position, there is little or no longitudinal movement of salt and the treatment will be of very little value. Seasoning in a vertical position with the *intake end up* is a vitally important part of the operation.

Experience in the laboratory injection of large numbers of miniature stem sections with solutions of various kinds had indicated that such sections could be injected from either end with about equal facility. Preliminary trials with full sized material showed also that a satisfactory intake of solution could be obtained by immersion of either end. These experiments indicated to the authors that it might be possible to treat a post by intake through the top end and set it immediately with the butt end down. This was tried out on a fairly large scale with full sized posts. The experimental results will be discussed later under "Distribution and Movement of Salt". At this point it is sufficient to say that this modification of technique seems to be entirely practicable under northern conditions. It eliminates one or more handlings and makes possible the immediate use of the post. If the post is to be set by driving with the top end down, intake should be through the butt end with setting taking place immediately.

It is, of course, also quite possible to void treatment in this manner by improper handling but the likelihood of this happening is less than where there is an appreciable time lapse during a seasoning period. When treated in this manner, movement of salt down the post is fairly rapid and within less than 45 days will reach the critical ground line area of posts 7 to 8 feet long in appreciable quantities. This appears to be soon enough to give the post adequate ground line protection before the occurrence of decay in northern latitudes. It might not be soon enough in warmer, more humid regions.

The barrel method is not suitable for use at temperatures below freezing. Both intake and subsequent movement during seasoning are quite slow and there is some evidence that the quality of treatment obtained is not as good as at higher temperatures.

When intake is through one end only with subsequent seasoning accomplished with the intake end up, the barrel method has been used successfully on posts up to 12 feet long.

In summation, the authors are of the opinion that the barrel method has a great deal to commend it. It has certain drawbacks and, when improperly used, can give very poor results. On the other hand, it is an extremely simple operation requiring a minimum of equipment and, when intelligently handled, can result in good treatment. Most excellent results have been obtained in treating red pine under a wide variety of conditions. Red maple, black and yellow birch and aspen also take treatment well, although the quality and ease of treatment vary somewhat more with season, strength of solution and other factors. Rather poor results were obtained with elm and gray birch.

Stepping

As described by Craighead *et al.* (7) and Wilford (19) stepping is accomplished by severing a tree leaving the foliage intact and inserting the butt in a container of preservative solution.

Stepping Small Trees

The Station's work with this method has been confined solely to stems up to three inches in diameter which are of a size suitable for stakes or light fencing. The only preservative used was zinc chloride. The work has been of a demonstration nature and no treatment records have been kept. In midsummer when the transpiration rate is high, intake of solution is very fast and positive tests for the salt can be obtained in the small branches 15 feet or more above the liquid level in a matter of hours. The solution used has been 14 pounds of 7 per cent strength per cubic foot of stemwood for hardwoods and 20 pounds of 5 per cent solution for pine. A wide variety of woods have been treated and, while no actual service records have been kept, there is evidence that stakes so treated will last upwards of 10 years. The method is somewhat wasteful since some solution is drawn into the branches and lost but the cost of treating stemwood is so little that this waste can probably be neglected. In the authors' opinion there is no cheaper, easier or better way of treating small round material than by stepping.

Stepping Large Trees

Between 1946-1949 McKusick[1] and Fenton[2] stepped some 600 trees ranging in diameter from 3 to 12 inches at breast height. The authors participated in this work only to the extent of assisting in the quantitative analyses for zinc chloride. They have asked and obtained permission to include in this paper the conclusions reached by McKusick and Fenton together with data on the distribution of salt within 24 stepped trees.

The work was confined almost wholly to red pine growing in plantations of medium to full density. The procedure followed was to "hang up" the tree to be stepped at an angle of about 70° to the horizontal, ease the butt into a container of five-gallon or greater capacity and add the salt solution. Both zinc chloride and chromated zinc chloride were used in amounts sufficient to give a retention per cubic foot of stemwood to be treated of 1 pound of the former and ¾ pound of the latter. The strength of the solutions used was either 5 per cent or 10 per cent. The bulk of the work was performed during the mid-summer months although some trees were stepped as late as mid-October.

Intake by stepping is much faster than by other sap stream methods. Handling to obtain suitable distribution of salt becomes unwieldy, if not impossible, in material much over 12 feet in length with any of the other methods. The principal objective of this work was to determine the feasibility of stepping as a means of treating round poles up to 30 feet in length to be used intact for small utility poles or similar purposes or to be subsequently cut into shorter lengths.

The following tentative conclusions on stepping red pine are presented:

Intake time for either a 5 per cent or 10 per cent solution is usually between 20 and 30 hours with 5 per cent taking the longer time because of its greater quantity. Subsequent to intake, the movement of salt upward is much faster with 5 per cent solution, reaching heights of 20 feet or more in 4 days. Ten per cent solutions required 14 days to reach 20 feet or less. Since there was no perceptible difference in behavior between the chromated and straight salt, data from the two were grouped together on the basis of strength of solution used. Data on 24 poles, 10 treated with 5 per cent solution and 14 treated with 10 per cent solution are given in Table 6. The poles had a top diameter of 2 to 3½ inches at 14 to 21 feet from the butt.

At 9 days after intake there had been little or no discoloration of the foliage. At 19 days after intake all trees showed more or less

[1]Harry A. McKusick, Silivicultурist, Connecticut State Park and Forest Commission.
[2]Richard H. Fenton, Research Forester, Northeastern Forest Experiment Station, Forest Service, U.S.D.A.

browning of the needles in the lower crown. When they were cut up the poles were sampled for quantitative analysis of salt deposit at points 3 feet, 10 feet and in some cases 17 feet from the intake end.

TABLE 6. STEPPING METHOD: MOVEMENT AND DISTRIBUTION OF ZINC CHLORIDE AND CHROMATED ZINC CHLORIDE IN STEPPED TREES.

	5% Solution		10% Solution	
	Hours	*Number of Trees*	*Hours*	*Number of Trees*
Time for intake of solution	34.9	10	23.2	14
	Feet	*Number of Trees*	*Feet*	*Number of Trees*
Linear movement of salt upward				
In 4 days after intake	27.0	7	13.0	14
In 14 days after intake	......	....	18.8	9
	Lbs./ cu.ft.	*Number of Trees*	*Lbs./ cu.ft.*	*Number of Trees*
Dry salt deposit				
Nine days after intake				
At 3 feet from butt	.59	4	......	......
At 10 feet from butt	.41	4	......	......
At 17 feet from butt	.34	2	......	......
Nineteen days after intake				
At 3 feet from butt	.38	6	.70	14
At 10 feet from butt	.35	6	.40	14
At 17 feet from butt	.30	4	.26	5

The trees treated with 10 per cent solution were not sampled until 19 days after intake at which time they showed a non-uniform but quite satisfactory distribution of salt. The retention at the 3-foot, or approximate ground line level, averaged 0.7 pound per cubic foot; at the 17-foot level 0.26 pound. This is a reasonable distribution if the pole is to be used as a unit but not as satisfactory if it is to be cut up into shorter units. Trees treated with 5 per cent solution showed a more satisfactory distribution of salt at the several levels at 9 days after intake than at 19 days. If this means that the 5 per cent solution is being drawn above the point of top severance and lost, it would be better to use a 10 per cent solution even if the rate of travel upward after intake is somewhat slower.

It was concluded from the above experiments that stepping appears to be a feasible method for treating round poles over 12 feet long without expensive equipment, if these poles are to be used as a unit and not cut into shorter lengths. Further investigative work is needed, however, to determine more precisely what solution concentrations and what methods of subsequent handling will result in the most satisfactory final distributions of salt within the stick.

Other points which may be of interest are the following:

Stepping can be effectively carried out only when the average daily temperature is more than 45° F.

A crew of three men can step 20 trees per hour when the diameters breast high range from 3 to 8 inches.

Spot testing of hardwoods with 5 per cent solution indicated good possibilities for a number of diffuse-porous woods but gave very poor results with ring-porous woods.

Capping

Capping, as described by Craighead and Wilford, is a modification of stepping as described above. The tree is felled, the foliage left intact and a tire tube containing the preservative solution is attached to the cut end. The authors have done no work with this method but they are of the opinion that the points discussed under "Stepping Large Trees" would also apply to capping. The time required for intake and subsequent movement would probably be greater because the crown of the tree is not as fully exposed.

Dry Salt Treatment

Angell (1), whose work will be referred to later in more detail, treated a very limited number of posts of red pine, red maple and red oak with dry salt. This was held in place on the end of the post in a short section of tire tube, the post being in a vertical position. The method appeared to have possibilities.

It occurred to the authors that it might be possible to cut and immediately set posts and very soon thereafter apply dry salt to the top in an amount sufficient to provide 1 pound per cubic foot of wood to be treated. The results obtained in treating 150 posts of five species in this manner are presented later under "Distribution and Movement of Salt". It is sufficient to state, at this point, that the method did provide fair treatment to red pine but was almost a complete failure with the other species used. The results did not compare at all favorably with those obtained by the barrel method using 50 per cent solution on the same species. Moreover, the fastening of the tire tube section to the post is more time consuming and requires more painstaking effort than handling the posts into and out of a barrel.

Injection Under Pressure

At about the time Hunt and Wirka published their first paper on the tire tube method, Mr. Eugene McKelvey of Swiss, West Virginia, developed an apparatus for injecting green posts with salt solutions under pressures up to 75 pounds per square inch. No new principles were involved, Boucherie having done essentially the same thing 100 years before. The really important part of McKelvey's device was his "pressure head", which could be quickly attached and removed from the end of a post or pole and which, when pressure was applied, afforded a tight seal between pressure head and timber. The end of the latter could vary appreciably from circular provided the contour was not concave at any point.

The authors had the McKelvey apparatus on loan for limited tests in the early 1940's. At the time the initial investment in one or more pressure heads needed to inject sticks over a range of diameters and the auxiliary pumps and other equipment seemed rather high. Moreover, little was known about the distribution of salt within the stick at the time of injection, its subsequent movement, or what might be expected in service life of timbers treated by any of the sap stream methods. It was obvious from the tests that injection at 75 pounds pressure could be accomplished in fractions of an hour as contrasted to many hours and even days when intake is by the tire tube or barrel methods. In view of the fact that timbers which have been well treated by sap stream methods have a probable service life of 10 years or more, it would seem that injection under pressure might have a very definite place in a small commercial operation. It is doubtful if the necessary capital investment could be justified by an individual operator. The pattern of salt distribution immediately after injection under pressure would probably be different from that obtained with intake by the tire tube or barrel methods. It would, therefore, be necessary to make analyses of penetration and retention throughout the posts to determine the type of handling that would be necessary during seasoning to insure the most satisfactory final distribution of salt.

Distribution and Movement of Salt

It has been indicated at several points in the discussion of the sap stream methods that the distribution of salt, both qualitatively and quantitatively, is not uniform at the end of the intake period and that subsequent longitudinal movement of salt within the stick during seasoning depends upon the method of handling. While longitudinal movement is taking place, there is undoubtedly lateral movement of salt into adjacent cell cavities and into cell walls by diffusion or otherwise but, in the discussion which follows, no attempt has been made to separate the effects of the two types of movement on the final distribution pattern within the stick. The initial distribution and subsequent movement of salt and their bearing on the quality of treatment obtained are discussed in the following paragraphs. In all cases cited the posts were treated soon after they were cut and the bark was left intact. The amount of solution initially introduced was sufficient to provide for 1 pound or more of dry salt per cubic foot of wood treated.

Angell (1) treated posts of several species by the tire tube method using solution concentrations varying from 7½ per cent to 100 per cent (dry salt). The posts were from 4½ to 7 inches in diameter at mid-point by 7 feet in length. Almost immediately after initial input, increment borings were taken from the posts at the points shown in the figures below and subjected to quantitative analysis

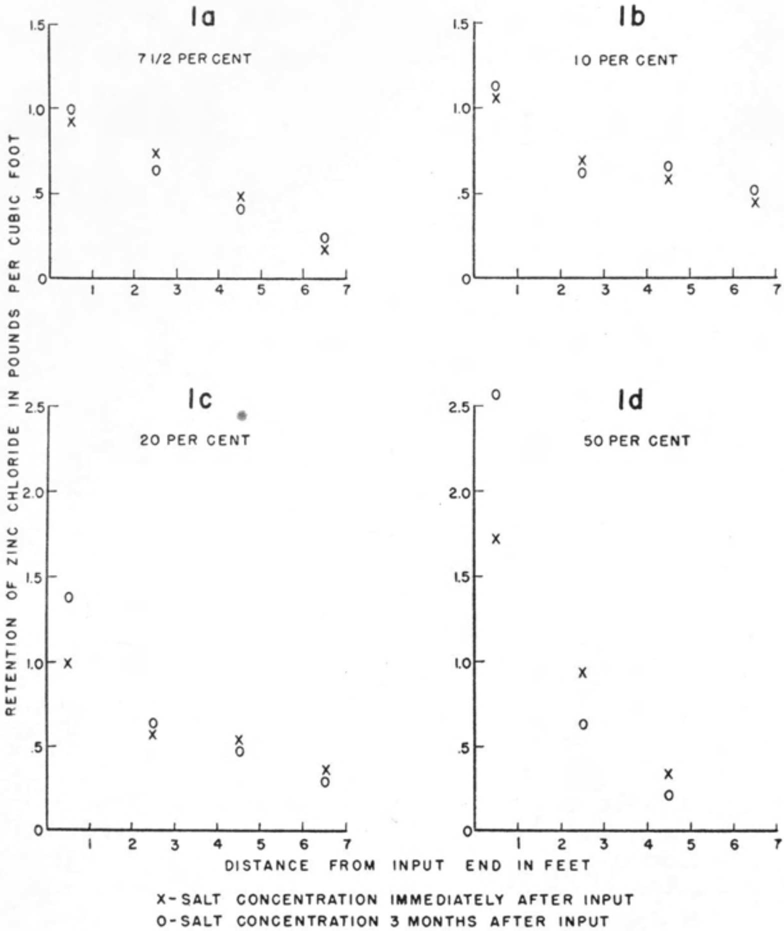

FIGURE 1. Distribution of zinc chloride in red maple posts immediately after, and 3 months after, input by the tire tube method using solution concentrations of 7½, 10, 20 and 50 per cent. All posts seasoned in a vertical position with the input end down.

to determine the distribution of salt over the entire length of the stick. The method used in making the analysis was essentially that described by Bateman (3)[1]. Radial penetration by color test was determined on the same borings.

Figures 1 and 2a show the results of two analyses at intervals of three months on five lots of red maple posts treated with 7½ per cent

[1]In making quantitative analyses for zinc chloride, the authors and their co-workers were faced with the problem of either using a somewhat extensive sampling technique which could be applied to hundreds of samples or employing a more refined technique which could be carried out on relatively few samples. They chose the former but they have, at intervals, also made more precise analyses and have applied correction factors to the data obtained by the cruder method of sampling. The conclusions are that the cruder methods give retentions of salt which are somewhat low but which, relatively, are sufficiently accurate for the comparisons made in this paper.

solution (1a), 10 per cent solution (1b), 20 per cent solution (1c), 50 per cent solution (1d) and dry salt (2a). There were five posts in each lot except for (1d) which had only three and (2a) which had six. Seasoning was in a vertical position with the input end down except for one post shown by a solid line in Figure 2a which was seasoned with the input end up and which the reader is requested to ignore for the moment. These figures show several quite distinctive features. There is in all cases more salt per cubic foot near the butt or input end than at the opposite end immediately after input. This difference becomes more marked as solution concentration increases. There is an increase in salt concentration near the butt over a three months period, this increase becoming quite marked when the higher strength solutions are used. Changes in salt concentration with time are less marked in the upper levels of the post.

Figure 2b shows the salt distribution in two maple posts, one treated with 13½ pounds of 7½ per cent solution and the other with 10 pounds of 10 per cent solution per cubic foot and seasoned in a horizontal position for two years. The distribution patterns within these posts are essentially similar to those in posts treated with the same concentrations and seasoned with the input end down for three months (see Figures 1a and 1b). In contrast to this, the post shown by a solid line in Figure 2a was given the same treatment as others in the same figure but was seasoned in a vertical position with the input end up for six months. At the end of this time, the salt concentration had become nearly equal over the entire length of the post. The effect of position during seasoning will be more fully brought out in a later section.

Angell's data for distribution immediately after input and 3 months thereafter for 7½ and 10 per cent solutions (Figures 1a and 1b) and for the two posts treated with the 7½ and 10 per cent solutions and seasoned horizontally for two years (Figure 2b) are in apparent conflict with the statement on page 18. This statement, based on many observations covering a period of several years, indicates that under a wide variety of conditions, the best treatment of maple will result from using solutions of 7½ per cent strength. The data presented in Figures 1a, 1b and 2b show a better quantitative distribution with 10 per cent solution than with 7½ per cent solution. A careful inspection of Angell's data on radial penetration shows that it was much deeper and more uniform at 6½ feet for 7½ per cent solution than for 10 per cent. The difference in quality of treatment is more apparent than real and indicates the danger of placing too much reliance on either penetration or retention without taking the complementary factor into account.

Figure 2c shows the pattern of salt concentration in red pine when treated with solutions of different strength, with analyses made soon after initial input. There were five posts in each lot. It will be noted that pine shows essentially the same initial salt distribution characteristics as maple.

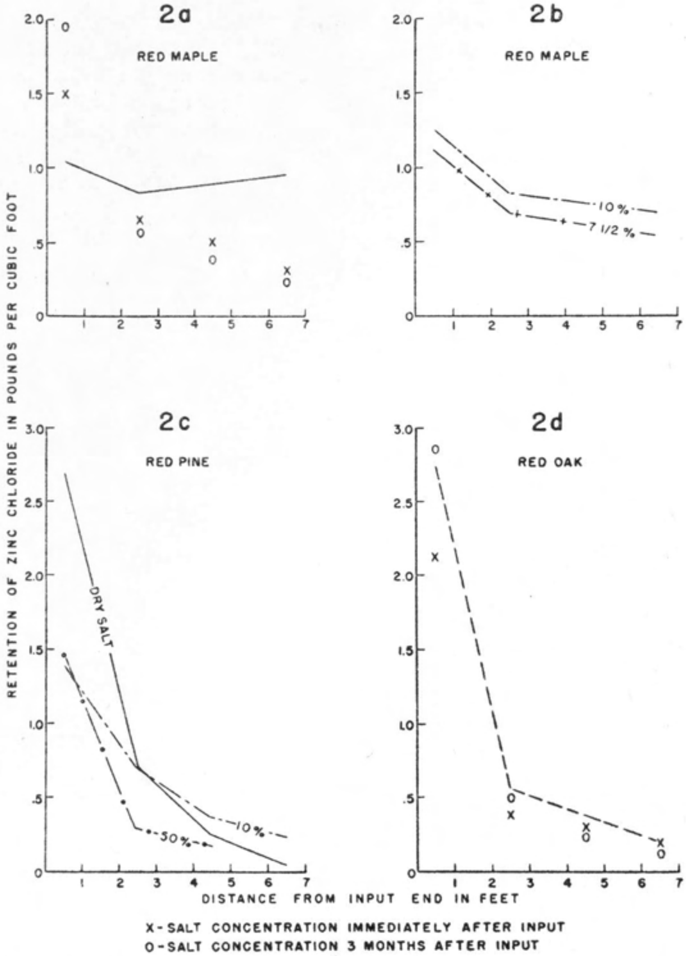

FIGURE 2. Distribution of zinc chloride in posts of red maple, red pine and red oak with input by the tire tube method.

(2a) Red maple. Input of dry salt. Distribution immediately after input, and 3 months later, with seasoning in a vertical position with input end down, shown by symbols X and O. Solid line for 1 post with input of dry salt but with salt distribution determined after 6 months seasoning with the input end up.

(2b) Red maple. Input of 7½ and 10 per cent solutions. Distribution of salt after seasoning 2 years in a horizontal position.

(2c) Red pine. Input of 10 and 50 per cent solutions and dry salt. Distribution of salt soon after input.

(2d) Red oak. Input of dry salt. Distribution of salt immediately after input, and 3 months later, with seasoning in a vertical position with input end down, shown by symbols X and O. Dash line for 1 post with input of dry salt but with salt distribution determined after 6 months seasoning in a horizontal position.

Figure 2d shows the salt distribution pattern for two red oak posts treated with 1 pound of dry salt with analyses immediately after treatment and three months later. Seasoning was in a vertical position with the input end down. Oak likewise shows a salt distribution pattern which is essentially similar to that of maple under the same conditions of treatment and handling. See Figure 2a. Superimposed on Figure 2d is the graph (dash line) showing the salt distribution in a red oak post six months after treatment, the post having been in a horizontal position. There has evidently been very little movement of salt within the post during seasoning in this position.

In connection with his analyses of the posts for salt deposit, Angell also made radial penetration tests immediately after intake at 2½ and 6½ feet from the butt or input end. The 2½-foot point was taken as an assumed ground line. With very few exceptions, all species and all treatments showed penetrations at the 2½-foot point of ½ inch or more and in a high percentage of cases penetrations were between 1 and 2 inches. As might be inferred from what has been said about salt concentration, radial penetrations at 6½ feet from the butt were usually less than ½ inch and, furthermore, were extremely erratic at this level, except for posts treated with 7½ per cent solution. The latter showed good and uniform penetration at 6½ feet.

Angell also made measurements of the total drip and calculations of the amount of salt in the drip as a percentage of total salt input from maple posts treated in October and in January. Solution concentrations used were 7½ per cent and 10 per cent. For both, the amount of drip collected from October-treated posts was always less than the amount injected and the salt content of the drip was generally under 10 per cent of the salt input. Posts treated in January, on the other hand, showed collected drip in an amount greater than the solution input with a salt content ranging from 13 per cent to 37 per cent of that injected. Two maple posts treated in May exhibited conditions quite similar to those treated in October. Angell attributed the differences cited to differences in the moisture content of the wood at the time of the treatment.

Shortly after Angell completed his work, Olson (17) carried out another series of experiments which were designed in part to supplement Angell's findings. Since Angell had demonstrated that the distribution of salt was definitely not uniform immediately after input under a wide variety of conditions, Olson determined salt concentration in his posts at intervals of 3 and 8 months after input and paid particular attention to the effect of the position of the posts during the seasoning period. He confined his work entirely to red maple and used only two salt concentrations, 10 and 50 per cent. His posts averaged 6 to 8 inches in diameter at the small end, somewhat larger than Angell's, and were 7 feet long. Input of solution was by the tire tube and barrel methods but only the results of the former will be reviewed in this paper.

His plan of experiments with the tire tube method involved 60 posts divided equally among six lots which were handled as follows:

Lot No.	Solution Strength Used, per cent	Solution Injected at	Seasoned in a Vertical Position with
1	10	Butt	Butt end up
2	10	Butt	Butt end down
3	50	Butt	Butt end up
4	50	Butt	Butt end down
5	10	Top	Top end up
6	50	Top	Top end up

Determinations of penetration and salt deposit after 3 and 8 months seasoning were made on increment borings at 1½, 3½, 5 and 6½ feet from the intake end. Analysis for zinc chloride followed the method described by Bateman (3) and later modified by Carter *et al.* (6). Since the determinations after three months of seasoning did not cover the entire series, information on them will not be included except to state that they indicated that most of the redistribution of salt subsequent to input takes place within the first three months. Data from experiments conducted by the authors show that in midsummer a major part of the re-distribution of salt during seasoning may take place in much less than three months.

The results of Olson's determinations of salt deposit after 8 months of seasoning are shown graphically in Figure 3. Referring first to Figure 3a, it will be noted that the salt distribution pattern of posts butt-treated with 10 per cent solution and seasoned with the input end down for 8 months is not materially different from Angell's posts similarly treated and handled but seasoned for only 3 months (Figure 1b). Posts treated with a 10 per cent solution (Figure 3b) and seasoned for 8 months with the input end up exhibit a very different and much more even distribution of salt. The response to position during seasoning is also evident when a 50 per cent solution is used. Figure 3c shows the pattern after 8 months when seasoning is with the input end down; Figure 3d, the pattern after seasoning with the input end up. The effect of reversal during seasoning is very marked for both solution concentrations.

Figures 3e and 3f compare the salt deposit in two lots of posts, with input of 10 per cent and 50 per cent strength, respectively, through the top ends, seasoning in both cases being with the input end up. If 3b and 3d are compared with 3e and 3f, respectively, it will be noted that, conditions during seasoning being the same, the final distribution patterns are essentially the same regardless of whether input is through the large or small end or whether 10 per cent or 50 per cent solution is used.

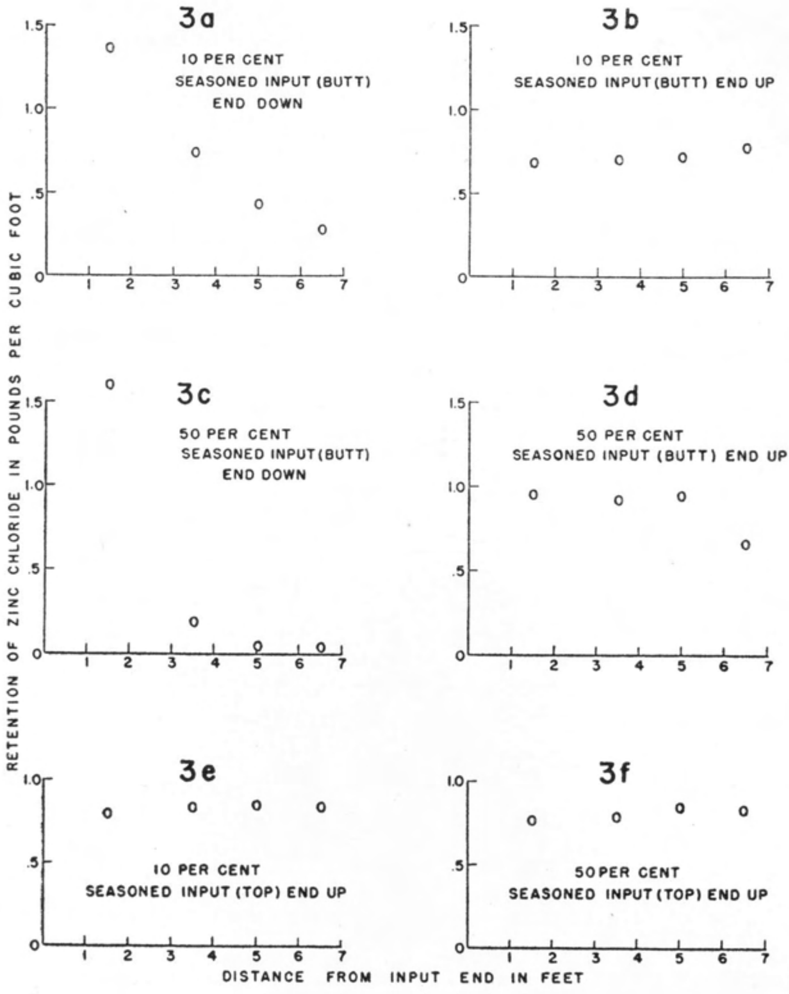

FIGURE 3. Salt distribution in red maple posts eight months after input by the tire tube method with 10 and 50 per cent solutions at both the butt and top ends. Seasoning in a vertical position.

Radial penetration 8 months after input was deep and quite uniform throughout the length of the posts in all cases where they were seasoned with the input end up. Here, retention was at a uniformly high level also (Figures 3b, 3d, 3e and 3f). Penetration was also quite good at the upper levels for the posts shown in Figure 3a even though the salt concentration at these levels was quite low. Penetration at the upper levels of the posts in Figure 3c was shallow and erratic. This was to be expected from the retention at these levels.

In order to supplement the work done by Angell and Olson, the authors have made quantitative and qualitative determinations of salt distribution in some 600 posts. The results of these will be described in the following paragraphs. All quantitative determinations were made by spectrograph.

The first tests were made on 28 red pine posts, 12 feet long by 4 to 6 inches in diameter at midpoint, treated by the barrel method with 2 pounds of 50 per cent solution per cubic foot of wood. In half the posts, intake of solution was through the large or butt end; in the remainder, it was through the top or small end. The former were seasoned in a vertical position in air with the butt ends up for 100 days and then set butt end down; the latter were set immediately with the small or intake end up. Sampling was at 3 feet from the butt (approximate ground line position) and at 6 feet and 9 feet from the butt at 45 and 100 days after intake of solution was completed. No determinations were made immediately after intake but from Angell's data on this species, Figure 2c, it may be reasonably assumed that there was very little salt at distances greater than 6 feet from the intake end at this time. The data on penetration and salt deposit at these points is given in Table 7.

TABLE 7. BARREL METHOD: DISTRIBUTION OF ZINC CHLORIDE AFTER 45 AND 100 DAYS OF SEASONING; EFFECT OF INTAKE THROUGH THE LARGE VS. THE SMALL END.

Distance from Butt End, feet	Radial Penetration, inches at				Retention in lbs./cu. ft. at			
	45 Days After Intake		100 Days After Intake		45 Days After Intake		100 Days After Intake	
	Treatment		Treatment		Treatment		Treatment	
	A[1]	B[2]	A	B	A	B	A	B
3	1.9	1.4	2.4	2.0	0.91	0.63	0.91	0.79
6	1.4	1.4	2.1	2.0	0.45	0.60	0.60	0.77
9	1.1	1.7	1.7	2.0	0.36	0.73	0.39	0.77

[1]Treatment A. Intake through butt, seasoned butt end up.
[2]Treatment B. Intake through top, seasoned top end up.

Considering the 3-foot point or critical ground line area, it will be noted that for both treatments radial penetration is not only excellent but increases between 45 and 100 days. Salt deposit is also very good and either remains static or increases during the same period. It seems worth emphasizing that the salt in the "B" treatment has moved 9 feet since intake to reach this level as compared with a movement of only 3 feet in the "A" treatment. Handling by either method appears to have resulted in a good to excellent retention of salt where it is most needed. A possible exception may be the extreme tops of posts treated with intake through the butt. Here the salt deposit and radial penetration might be sufficiently inadequate to require supplemental treatment by "buttering" or other means. It seems worthwhile emphasizing that the posts under consideration were nearly twice as long as the average farm fence posts but even so a good to excellent quantitative distribution of salt throughout the posts was obtained within about 45 days.

Another test of somewhat similar nature was the random sampling of a lot of several hundred red pine posts which had been treated in batches by a private operator using the barrel method. The posts were from 4 to 6 inches in diameter and either 7 or 12 feet long. The solution used was 33 per cent and intake was permitted to take place through the large or butt end until 3 pounds of solution per cubic foot had been taken up. The posts were then reversed in the solution for 2 to 4 hours to insure a positive treatment of the extreme top end. After this, the posts were immediately stored with the butt end up for seasoning.

Qualitative sampling by color test to determine radial penetration was made on increment borings extracted at specified distances from the top end at intervals ranging up to 66 days after intake was completed. Selection for sampling was made wholly on the basis of duration of seasoning and bore no relation to the batches in which posts were grouped for treatment. No quantitative determinations were made.

The results of the sampling are shown in Tables 8 and 9.

Table 8. Barrel Method: Distribution of Zinc Chloride in Red Pine Posts 12 Feet Long after 66 Days of Seasoning.

Post Number	Distance from Top End in Feet		
	1	3	5
	Penetration in Inches		
1	1.7	2.0	2.0
2	1.6	2.3	2.0
3	2.6	2.0	2.3
4	1.2	1.9	2.5
5	1.9	1.8	2.1
6	1.9	1.3	2.1
7	1.0	1.0	1.6
8	2.2	2.1	1.9
9	2.0	1.8	2.1
10	2.1	2.2	2.3
11	1.6	2.0	2.5
12	1.4	1.5	2.1

Table 8 deals with posts 12 feet long which were sampled once at 66 days after intake. Radial penetration at 1, 3 and 5 feet from the top end is good to excellent at all levels and probably reflects a satisfactory retention of salt at these points as well.

Fifty posts, which were part of the large group from which the posts in Table 8 were drawn, were set in a tobacco tent 6 months after seasoning was completed. Their condition after 6 years service is given later under "Service Tests," page 63.

TABLE 9. BARREL METHOD: DISTRIBUTION OF ZINC CHLORIDE IN RED PINE POSTS 7 FEET LONG AFTER 16, 23, 40 AND 66 DAYS.

Post Number	Distance from Top End in Feet: 1	3
	Penetration in Inches	
	Distribution of Zinc Chloride 16 Days After Treatment	
1	1.0	1.1
2	1.5	0.9
3	0.0	1.5
4	0.9	1.8
5	0.0	0.4
6	0.4	1.6
7	1.0	1.1
8	0.3	1.6
9	0.0	1.5
10	1.1	1.3
	Distribution of Zinc Chloride 23 Days After Treatment	
11	1.8	2.0
12	0.8	1.4
13	1.8	1.8
14	1.4	1.4
15	1.5	2.0
16	1.3	1.5
17	1.6	1.7
18	0.0	1.2
	Distribution of Zinc Chloride 40 Days After Treatment	
19	1.8	2.2
20	2.0	2.0
21	1.9	2.0
22	2.0	1.8
23	1.8	2.0
	Distribution of Zinc Chloride 66 Days After Treatment	
24	2.0	1.9
25	1.9	2.1
26	2.1	1.9
27	2.1	2.1
28	2.1	2.3

Table 9 shows the radial penetration at 1 foot and 3 feet from the top of posts 7 feet long sampled at 16, 23, 40 and 66 days after intake. After only 16 days, penetration at 1 foot from the top (6 feet from intake end) tends to be erratic. To a lesser extent, this is also true for the position 3 feet from the top. After 23 days, there is an increase in penetration depth at both levels with less tendency toward erratic behavior. At 40 and 66 days, penetration is excellent and quite uniform at both levels with no advantage indicated for the longer period.

Three other experiments involving 540 posts were also performed by the authors to evaluate the quality of treatment obtained in terms of season of treatment, strength of solution, kind of wood and method of intake. Certain features which are common to all three experiments will be noted first, followed by more detailed description under suitable headings.

All posts were from 4 to 5 inches in diameter at mid-point by 7 feet long. In all cases intake was through the top or small end. One-third of the posts were treated in mid-April, one-third in late May and one-third in mid-October and called spring, summer and fall treatments, respectively. Analyses to determine radial penetration and salt concentration were made at a point 54 inches from the top (approximate ground line) one year after setting. Each analysis was based on the average results from three increment borings taken at equidistant points on the periphery of the post at this level. Data on each treatment item investigated were based on average values from 10 posts.

In each experiment, treatment was evaluated one year later in terms of radial penetration and salt concentration at ground line according to the following criteria:

Penetration

Good: Two-thirds or more of posts with average penetrations of 1 inch or more and none with average penetration of less than ½ inch.

Fair: Two-thirds or more of posts with average penetrations of ½ inch or more.

Poor: More than one-third of posts with average penetrations of less than ½ inch.

Salt Concentration

Good: Two-thirds or more of posts with average retentions of ½ pound or more of salt per cubic foot and none with an average retention of less than ¼ pound.

Fair: Two-thirds or more of posts with average retentions of ¼ pound or more of salt per cubic foot.

Poor: More than one-third of posts with average retentions of less than ¼ pound of salt per cubic foot.

Following are the descriptions and results obtained from the three experiments.

Experiment 1. One hundred and fifty posts were treated in batches of 10 by the barrel method with 50 per cent solution and immediately set in the ground with the intake end up. Kinds of wood were red pine, red maple, aspen, gray birch and American elm. Behavior during treatment and subsequent distribution of salt are given in Table 10 and discussed below:

TABLE 10. BARREL METHOD: EFFECT OF SEASON AND KIND OF WOOD ON QUALITY OF TREATMENT. SOLUTION CONCENTRATION, 50 PER CENT

Species[1]	Season of Treatment	Solution Intake Time, days	Average Radial Penetration, inches	Average Retention, lbs./cu. ft.	Evaluation of Treatment	
					Penetration	Retention
Red Pine	Spring	6	2.0	.85	Good	Good
	Summer	4	2.2	.93	Good	Good
	Fall	5	2.2	1.36	Good	Good
Red Maple	Spring	16	0.9	.23	Fair	Poor
	Summer	1	2.1	.71	Good	Fair
	Fall	5	1.9	.89	Good	Good
Aspen	Spring	23	1.6	.61	Good	Good
	Summer	3	2.0	.69	Good	Fair
	Fall	1	2.1	.84	Good	Good
Gray Birch	Spring	22	0.4	.19	Poor	Poor
	Summer	13	1.1	.48	Poor	Poor
	Fall	14	0.3	.17	Poor	Poor
Elm	Spring	8	0.8	.31	Fair	Poor
	Summer	3	0.4	.18	Poor	Poor
	Fall	8	0.6	.27	Poor	Poor

[1]Data based on 30 posts per species; 10 treated in spring, 10 in summer and 10 in fall; total 150 posts.

Red Pine. Eminently satisfactory and uniform results were obtained at all three seasons. Intake time was short and only a very few posts showed erratic tendencies.

Red Maple. The best and most uniform results were obtained in the fall treatment. Summer treatment was good on the whole but somewhat erratic. Intake took much longer in the spring than at other seasons and both penetration and salt deposit were definitely below acceptable standards.

Aspen. Radial penetration and salt deposit averaged well at all seasons but there was a definite tendency for salt deposit to be erratic in the summer treatment. The results of the spring treatment were good but intake time was much greater than at other seasons.

Gray Birch. Results were generally unsatisfactory in all respects and intake time was prolonged at all seasons, particularly so in the spring. The behavior of this wood is somewhat surprising considering the generally good results obtained with wood of the birches by the tire tube method. The reason is not clear. It has been observed, however, that when red maple is infected with verticillium wilt, those parts of the wood which are diseased become blocked to the passage of solutions. When gray birch reaches the size used for these experiments, the wood frequently has incipient decay and it is conceivable that this has resulted in the conducting passages in this wood becoming blocked also.

American Elm. Results were uniformly poor. Intake time was relatively short but apparently there was little or no subsequent movement of salt. The reason for this is unknown.

Experiment 2. Two hundred and forty posts, equally divided between red pine and red maple, were treated in batches of 10 by the barrel method using solution concentrations of 66⅔ per cent, 50

TABLE 11. BARREL METHOD: EFFECT OF SEASON, KIND OF WOOD AND SOLUTION CONCENTRATION ON QUALITY OF TREATMENT.

Species[1]	Season of Treatment	Treating Solution Concentration, %	Solution Intake Time, days	Average Radial Penetration, inches	Average Retention, lbs./cu.ft.	Evaluation of Treatment	
						Penetration	Retention
Red Pine	Spring	66⅔	3¼	2.2	0.84	Good	Fair
		50	4¼	2.3	0.71	Good	Good
		33⅓	8	2.4	0.90	Good	Good
		25	8	2.3	0.60	Good	Fair
Red Pine	Summer	66⅔	7	2.2	0.88	Good	Good
		50	3½	2.2	0.69	Good	Good
		33⅓	5½	2.2	0.63	Good	Good
		25	4¼	2.2	0.65	Good	Good
Red Pine	Fall	66⅔	11¾	2.5	0.75	Good	Good
		50	4¾	2.5	0.78	Good	Good
		33⅓	2	2.4	0.70	Good	Good
		25	4¾	2.4	0.78	Good	Good
Red Maple	Spring	66⅔	2	1.5	0.26	Fair	Poor
		50	1¾	1.7	0.39	Good	Fair
		33⅓	3¾	1.6	0.32	Fair	Fair
		25	12¾	1.2	0.24	Fair	Poor
Red Maple	Summer	66⅔	12	0.6	0.23	Poor	Poor
		50	¾	1.3	0.39	Fair	Fair
		33⅓	¾	1.9	0.42	Good	Fair
		25	1¼	1.4	0.29	Fair	Poor
Red Maple	Fall	66⅔	12¼	1.8	0.44	Good	Poor
		50	4¾	2.2	0.79	Good	Good
		33⅓	4	1.9	0.51	Good	Fair
		25	4	2.1	0.61	Good	Fair

[1]Data based on 120 posts per species; 40 treated in spring, 40 in summer and 40 in fall; in each season 10 posts were treated with 66-2/3% solution, 10 with 50%, 10 with 33-1/3% and 10 with 25%; total 240 posts.

per cent, 33⅓ per cent and 25 per cent and immediately set with the intake end up.

Behavior during treatment and subsequent distribution of salt are given in Table 11.

Red Pine. As in the previous experiment, red pine again shows up quite well at all seasons and with all solution concentrations. Observable erratic tendencies appear to be confined chiefly to the highest and lowest concentrations. Time for intake is appreciably greater for the 66⅔ per cent solution in summer and fall and for the 25 per cent and 33⅓ per cent solutions during the spring. This is probably of less importance than the apparent tendency for the highest and lowest concentrations to cause erratic salt deposit in spring treatment.

Red Maple. As in the previous experiment, red maple showed better results in the fall treatment than at other seasons regardless of solution concentration. Among the several concentrations used at this season, 50 per cent solution gave consistently good radial penetration and retention. The highest, 66⅔ per cent, required a much longer intake time and salt deposit was erratic. Radial penetration and retention were generally erratic and unsatisfactory in spring and summer treatment. Concentrations of 33⅓ per cent and 50 per cent appeared to give somewhat better results than those higher and lower.

In this experiment total moisture content was determined on discs cut from each post at the time of treatment to determine if there was any relationship between total moisture content and the movement of salt subsequent to intake. As far as could be determined, no relationship existed.

Experiment 3. One hundred and fifty posts were cut, set in the ground and immediately treated by applying dry salt at the rate of 1 pound per cubic foot of wood to the top of the post. The salt was held in place by a short piece of old tire tube. Kinds of wood were red pine, maple, aspen, gray birch and elm.

This method was tried as a possible substitute for the barrel method to reduce the amount of handling and to eliminate all equipment except short sections of old tire tube. The results, which are given in Table 12, are so consistently poor except for red pine that they require little comment. Those for red pine are rated fair to good but are substandard when compared with results obtained by the barrel method.

Miscellaneous

A few rather limited tests were made to determine whether loss of moisture from the top ends of posts, whose butts were immersed in 25 or 50 per cent solution, was primarily responsible for intake. Sticks of red pine and red maple, half with the top ends coated with impervious material and half uncoated, were placed with the butt ends in solution and allowed to stand for periods up to 300 hours. For both kinds of wood, sticks with uncoated tops took up from 16 to 18 per cent more solution in a given time than those with tops coated. It is judged from this that loss of moisture from the top end does hasten intake through the opposite end, but is not the major cause

TABLE 12. DRY SALT TREATMENT: EFFECT OF SEASON AND KIND OF WOOD ON THE QUALITY OF TREATMENT

Species[1]	Season of Treatment	Solution Intake Time, days	Average Radial Penetration, inches	Average Retention, lbs./cu.ft.	Evaluation of Treatment	
					Penetration	Retention
Red Pine	Spring	25	2.0	.52	Good	Fair
	Summer	25	2.3	.62	Good	Good
	Fall	46	2.5	.73	Good	Good
Red Maple	Spring	38	0.9	.22	Fair	Poor
	Summer	42	1.3	.28	Good	Poor
	Fall	103	1.9	.37	Good	Fair
Aspen	Spring	27	1.5	.29	Good	Fair
	Summer	33	1.3	.24	Fair	Poor
	Fall	45	2.2	.60	Good	Fair
Gray Birch	Spring	40	1.7	.53	Good	Fair
	Summer	52	1.1	.28	Fair	Poor
	Fall	101	0.4	.11	Poor	Poor
Elm	Spring	47	0.2	.10	Poor	Poor
	Summer	31	0.2	.11	Poor	Poor
	Fall	36	0.5	.16	Poor	Poor

[1]Data based on 30 posts per species; 10 treated in spring, 10 in summer and 10 in fall; total 150 posts.

of intake. This is probably due to capillary rise in the conducting elements. The tests also demonstrated that, if the intake period is prolonged, it is quite possible to obtain intake of solution in an amount sufficient to provide for excessive retentions.

Resume of the Sap Stream Treatments

After working with the sap stream methods over a period of 15 years, the authors are of the opinion that they can be used to good advantage by the small operator. They are all based on the treatment of freshly cut, unpeeled wood and there is a relatively short time lapse between cutting and actual use. They consequently obviate two of the greatest drawbacks to treatment with oily or oil-soluble preservatives – peeling and seasoning. The equipment and preservative required are easily obtainable and quite inexpensive.

The sap stream methods are not equally applicable to all species. The writers have found them particularly adaptable to coniferous and diffuse porous woods having a thick sapwood. They are not adaptable to ring porous hardwoods which frequently also have a rather thin sapwood layer. The writers realize fully that, on the basis of equal absorption and penetration, a highly soluble preservative such as zinc chloride cannot be expected to provide as long service as creosote or oil soluble pentachlorophenol and the naphthenates. They have found, however, that it is rather difficult to treat diffuse porous woods with the latter materials and get adequate penetration and retention at the critical ground line area without resorting to incising. On the other hand, diffuse porous woods with thick sapwood can be given excellent ground line treatment by sap stream methods. This is a fortunate circumstance since it appreciably broadens the base for giving a good treatment to a wide variety of woods.

The authors believe that the stepping method for small material and the barrel method for posts offer the greatest possibilities. The tire tube method and capping are somewhat slow and tedious to carry out. The stepping of long poles by hanging up the tree, although adaptable only to special situations, appears to be the only feasible method of treating poles over 12 feet long without special equipment.

It will be evident from what has been said that the sap stream methods as a group are adaptable to a wide variety of operating conditions. There are, however, a number of points which must always be observed if they are to result in good service life of the material treated:

Intake by any means results in a distribution of preservative which initially is not uniform, either qualitatively or quantitatively. Really good treatment must provide for handling procedure subsequent to intake that will result in enough zinc chloride (or equivalent salt) at the critical points to protect the timber under all conditions. What constitutes "enough" is open to question but from service records covering up to 15 years the authors are of the opinion that the following should be the minimum retentions after the timber has seasoned to a point where little or no further longitudinal movement of salt may be expected:

(a) Ground line zone from one foot above ground to the butt — ¾ pound per cubic foot.

(b) Top zone from one foot above ground to the top — ¼ pound per cubic foot.

(c) The extreme top end extending several inches below the cut surface — ¾ pound per cubic foot.

The first two goals can be attained by manipulation during or subsequent to intake. The last must be accomplished by reversing in the bath, "buttering" or other means.

Minimum penetration from all outer surfaces should be 1 inch or more.

These minimum specifications and the discussion of qualitative and quantitative determinations of penetration and retention, which follows immediately, are based on the treatment of species with sapwood 1 inch or more in thickness. During intake of solution, the heartwood is not penetrated to any extent. Subsequently there is probably some movement of salt into the heartwood by diffusion which would tend to improve treatment. This has not been considered in this paper which deals only with the movement of salt solutions in the principal conducting elements of the sapwood.

Color tests for depth and uniformity of penetration are very easily made and it is unfortunate that they cannot be used directly as a quantitative measure of salt retention which is difficult and at times impossible to determine by analytical methods. A thorough analysis of a treatment must include both penetration and retention tests at various levels in the post. Analysis of a large body of penetration and retention data indicates, however, that certain relationships between the two types of test can be very useful in an approximate evaluation of a treatment using the color test alone. If the color test shows shallow or erratic penetration at a given level, it is almost certain that retentions will be low and unsatisfactory at that level also. Uniform radial penetrations of three-fourths to full sapwood depth at 2 to 4 feet from the intake end will usually indicate a retention of ½ pound to 1 pound per cubic foot of salt at this point. At distances of 6 to 10 feet from the intake end, a similar penetration may mean a retention of ¼ pound to 1 pound per cubic foot depending on how the post has been handled subsequent to intake. It may be well to point out that the converse of the above statements may not necessarily be true. It sometimes happens that total retention at a given level may seem sufficient but the distribution at that point is so uneven that protection is inadequate. The color test for distribution should never be omitted.

It has been noted on page 30 *et seq.* that, by using various manipulative techniques, it is possible to obtain a fairly even distribution of salt longitudinally through a post. This is not necessarily the best distribution for maximum life in service. If intake is 1 pound of salt per cubic foot for the post as a whole, a more ideal distribution would be at the rate of somewhat more than 1 pound per cubic foot in the critical ground line zone and somewhat less than 1 pound between this zone and the top.

COLD SOAKING

Cold soaking is the simplest method of treating wood that has been peeled and seasoned. The only equipment needed is an open tank of suitable size and shape to permit complete immersion of the wood in an oil solution. Soaking is continued until the wood has taken up from 5 to 10 pounds of solution per cubic foot or until it refuses to take up additional solution. This is usually accomplished in 24 to 72 hours. The preservatives most commonly used are 5 per cent pentachlorophenol or ½ to 1 per cent copper naphthenate in Stoddard solvent, kerosene or fuel oil. For additional details, see Hunt and Garratt (13) and Blew (4). The authors have done only a very small amount of work in the cold soaking of full sized post material. Observations based on results obtained by a private operator indicate the following:

(a) Red and Scotch pine posts, 7 feet long, cold soaked in oil solutions of pentachlorophenol or copper naphthenate for 24 to 48 hours show retentions of 7 to 9 pounds of solution per cubic foot with penetrations at mid-point of 1 to 2 inches.

(b) Under similar conditions, the sapwood of oak posts is very uniformly impregnated but when the sapwood is very thin, penetration is doubtfully adequate.

(c) Maple posts similarly treated show the same characteristics as when treated with creosote by the open tank method, i.e., very heavy absorptions at the ends and very thin and entirely inadequate penetration at mid-point.

PHYTOTOXICITY OF PRESERVATIVES AND SOLVENTS

In connection with the treatment of wood to prevent damage by insects and fungi, experiments and observations were made on the phytotoxicity of certain preservatives and solvents. These are reported in some detail in Station Circular 189 but it seems desirable to review here some of the more important points which deal chiefly with the use of preservatives in close proximity to plants where the circulation of air is retarded.

Creosote on the above-ground parts of tobacco shade tent posts will cause severe injury to tobacco plants near, but not touching, the posts. This may occur for several years after the posts are set. Pentachlorophenol has been used only to a limited extent in treating tobacco posts. Injury similar to that caused by creosote has been reported from some fields and not from others. Extensive use of this preservative on wood used in shade tents seems inadvisable until more is known about its phytotoxicity. No injury has been reported from tent posts treated with zinc meta-arsenite, Wolman salts, copper chromate, zinc chloride or chromated zinc chloride, which have been in use for more than 5 years.

Wood treated with creosote, with pentachlorophenol or copper naphthenate solutions or with the usual solvents for pentachlorophenol or copper naphthenate can cause extreme injury when in close proximity to plants growing under confined conditions, such as in greenhouses and cold frames. Plants may also be severely injured if exposed pentachlorophenol crystals, open containers of preservative solutions or solvents, or freshly treated wood are stored in greenhouses.

As far as can be determined, copper naphthenate without solvent is not injurious to plants but there is no known feasible method of introducing it into wood except in solvents which are toxic to plants.

MOISTURE CONTENT AND SEASONING

Since the moisture content of wood and the loss of moisture during seasoning are frequently important considerations in preservative treatment, the results of two experiments dealing with these factors are summarized below.

The first experiment deals with the moisture content of unseasoned stem sections of trees determined at weekly or semi-monthly intervals over a period of a year; the second, with the behavior during seasoning of red maple posts which were handled in different ways.

SEASONAL MOISTURE CONTENT

In this work moisture content determinations were made during the period April, 1952 to March, 1953 on unpeeled red maple stem sections 1¼ inches in diameter by 5 inches long and composed entirely of sapwood. The material all came from a low-lying site where the water table was at or near the surface at all times. At each sampling period four stems were cut and from each one or two 5-inch sections were taken within 3 feet of the ground. The samples were dried to constant weight and the total moisture content determined on an oven dry basis.

The results are shown in Table 13.

TABLE 13. MOISTURE CONTENT OF RED MAPLE IN RELATION TO SEASON.

Date	Total Moisture Content, %	Date	Total Moisture Content, %
April 9, 1952	92.1[1]	August 25, 1952	76.2[1]
April 14, 1952	95.9[1]	September 8, 1952	78.6[1]
April 21, 1952	101.8[1]	September 22, 1952	78.4[1]
April 29, 1952	90.4[1]	October 6, 1952	78.8[1]
May 5, 1952	89.4[1]	October 20, 1952	85.6[1]
May 12, 1952	75.7[1]	November 3, 1952	83.9[1]
May 19, 1952	72.5[1]	November 17, 1952	86.4[1]
May 26, 1952	82.0[1]	December 1, 1952	97.9[1]
June 2, 1952	76.3[1]	December 15, 1952	100.5[1]
June 16, 1952	82.9[1]	January 26, 1953	103.7[2]
June 30, 1952	82.4[1]	February 10, 1953	93.6[2]
July 14, 1952	83.4[1]	February 23, 1953	105.5[2]
July 28, 1952	86.3[1]	March 9, 1953	97.5[2]
August 8, 1952	87.7[1]	March 23, 1953	101.9[2]

[1]Average of 8 pieces, two each from 4 different stems.
[2]Average of 4 pieces, one each from 4 different stems.

Two quite well defined periods are evident—a high period extending from about December 1 to about the last of April when total moisture content averages between 90 and 105 per cent and a low period during the balance of the year when it averages between 72 and 89 per cent. It is interesting to note that there is a rather abrupt drop in moisture content about the first week in May. The shift from the low moisture contents of middle to late summer to the winter highs is much more gradual.

It is believed that the data give a reasonably good picture of general seasonal trends in small red maple samples although, under different atmospheric conditions, some variation from the figures given could probably be expected.

SEASONING OF ROUND POSTS

In the course of treating for commercial use with creosote, it developed that a high percentage of peeled red maple posts had to be rejected because of excessive checking during seasoning. In order to determine whether a seasoning procedure could be devised which would reduce checking to reasonable levels, 14 units totaling 700 8-foot posts were subjected to various methods of handling. Each unit consisted of 50 posts, half unpeeled and half peeled. Of the latter, three posts were incised with a homemade incising hammer over their entire length. The 50 posts were then piled for seasoning in one of three ways.

(a) Two by 10 or open cribbed—alternate tiers consisting of 2 posts and 10 posts.

(b) Ten by 10 or close-cribbed—all tiers consisting of 10 posts.

(c) Ranked as in cordwood.

All piling methods were duplicated in the open with no covering over the tops of the piles (see Piles 9 and 17, 11 and 19, and 10 and 18, Table 14). In addition, the 2 x 10 piles were duplicated in the open with brush or board covering over the tops of the piles (see Piles 12 and 20 and 13 and 21, same table) and in the woods with brush covering over the tops of the piles or with no cover (see Piles 14 and 22 and 15 and 23, same table). In each pile certain posts were so placed that they could be removed for periodic weighings. One pile in each pair was allowed to remain intact for 12 to 15 months, the other for 20 to 22 months. The piles were then dismantled and the unpeeled posts debarked. Each post was examined and rejected for checks above a specified size or for the presence of decay. The standards established for rejection on account of checking were relatively high and were as follows:

(a) Checks over ¼ inch wide in the side of the post but not reaching the ends.

(b) Checks over ¼ inch wide at the top end and extending over 6 inches along the side.

(c) Checks over ¼ inch wide at the butt end and extending more than 18 inches along the side.

The results of the inspection are shown in Table 14.

Development of Checks and Decay

Peeled Posts

Best over-all results were obtained in those posts which were peeled and incised. Less than 5 per cent were rejected for checks and less than 3 per cent for decay. Although the number of posts involved (42) was relatively small, it seems obvious that incising not only reduces the amount of checking but also lowers the incidence of decay. However, as has been stated elsewhere, it is doubtful if incising can be performed economically on small, round, low grade products.

Table 14. The Development of Season Checks and Decay in Peeled and Unpeeled Red Maple Posts When Piled by Different Methods and Under Different Types of Cover for Seasoning.

Pile	Method of Piling	Location and Cover	Duration of Seasoning, Months	Number of Posts				Rejected for Checks, %			Rejected for Decay, %		
				Peeled	Peeled and Incised	Unpeeled	Total	Peeled	Peeled and Incised	Unpeeled	Peeled	Peeled and Incised	Unpeeled
9	10 x 10	In Open, No Cover	22	22	3	25	50	41	0	0	41	33	80
17	10 x 10	In Open, No Cover	14	22	3	25	50	14	0	0	0	0	20
11	Ranked	In Open, No Cover	22	22	3	25	50	5	33	0	18	0	100
19	Ranked	In Open, No Cover	15	22	3	25	50	14	0	0	5	0	64
10	2 x 10	In Open, No Cover	22	22	3	25	50	18	0	0	5	0	96
18	2 x 10	In Open, No Cover	15	22	3	25	50	14	0	0	0	0	48
12	2 x 10	In Open, Brush Cover	21	22	3	25	50	27	0	0	0	0	100
20	2 x 10	In Open, Brush Cover	14	22	3	25	50	14	33	0	14	0	56
13	2 x 10	In Open, Board Cover	20	22	3	25	50	27	0	0	0	0	56
21	2 x 10	In Open Board Cover	14	22	3	25	50	27	0	0	5	0	32
14	2 x 10	In Woods, Brush Cover	20	22	3	25	50	9	0	0	0	0	96
22	2 x 10	In Woods, Brush Cover	14	22	3	25	50	23	0	0	5	0	36
15	2 x 10	In Woods, No Cover	20	22	3	25	50	0	0	0	5	0	88
23	2 x 10	In Woods, No Cover	12	22	3	25	50	0	0	0	0	0	16
Total				308	42	350	700						

Nine per cent or more of the posts which were not incised showed check development sufficient for rejection except in those piles which were ranked in the open or open cribbed in the woods without covering. There appears to be little relation between development of checks and duration of seasoning. Incidence of decay in peeled posts was generally light except where the posts were close cribbed or ranked. Also, these were the only two piling conditions under which decay increased with time.

Unpeeled Posts

Unpeeled posts developed no checks of sufficient size to cause rejection. Incidence of decay was excessive under most conditions and there was a definite increase in decay with time. Although the posts were not inspected until 12 months or more had elapsed, it is believed that maple posts should not be left with the bark on for more than about three months in southern New England unless these months occur in mid-winter or unless the posts are immersed in water. During longer periods, decay may attain undesirable levels. Limited observations on other woods indicate that they also start to decay rather quickly if not peeled.

Progress of Seasoning

The progress of seasoning over a period of 14 months in four of the piles in Table 14 are shown in Figures 4 and 5. In each pile five peeled and five unpeeled posts, which were withdrawn for periodic weighings, were similarly located. All of the piles were located in an open exposed area and were uncovered. Those shown in Figure 4 were close-cribbed, 10 x 10; those in Figure 5 were open-cribbed, 2 x 10. One pile in each figure was laid up in June, 1936 and the other in October of the preceding year. For each weighing, the weight is expressed as a percentage of the initial weight.

Considering both figures, it seems evident that the rate of moisture loss is not markedly different in close-cribbed and open-cribbed piles. The evidence from the figures, as well as from the graphs of moisture loss in the other 10 piles in the series, is that the weight of the unpeeled posts relative to the initial weight does not reach as low a level as when the posts are peeled. It is believed that this is due to the fact that unpeeled posts become infected with staining and decay organisms before the wood becomes dry enough to inhibit these organisms and that, once infected, the posts lose water more slowly than peeled posts and stabilize at a higher relative weight. When the posts were finally peeled, the wood beneath the bark was stained and very wet, frequently to depths of an inch or more.

Looking at Figures 4a and 5a for posts cut and piled in June, most of the weight loss occurs within the first two months with the peeled posts decreasing at a faster rate and to a lower weight level than those unpeeled. During the succeeding 12 months there is comparatively little loss in weight in the peeled posts. Subsequent to the initial

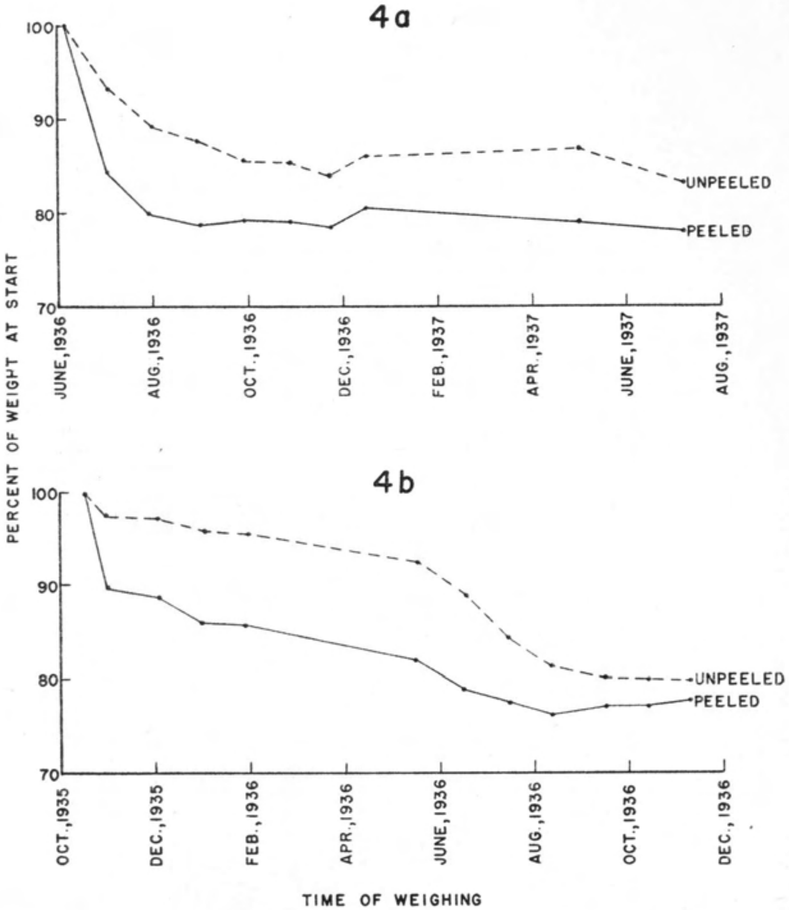

FIGURE 4. Progress of moisture loss in red maple posts cribbed in close (10 x 10) piles of 50 posts each. (4a) Piles laid up in June. (4b) Piles laid up in October.

rapid drop in weight, the unpeeled posts continue to lose moisture slowly until December and again during the months May through July. During the mid-winter months there is little loss in weight in either peeled or unpeeled posts and there may at times be a gain in weight.

Turning to Figures 4b and 5b for posts piled in late October, the peeled posts show a sharp decrease in weight for about a month, a much retarded loss of weight during the winter months and an accelerated loss during the period May to August of the following summer. The unpeeled posts follow essentially the same pattern except that the loss in weight during the month after piling is much less than for peeled posts.

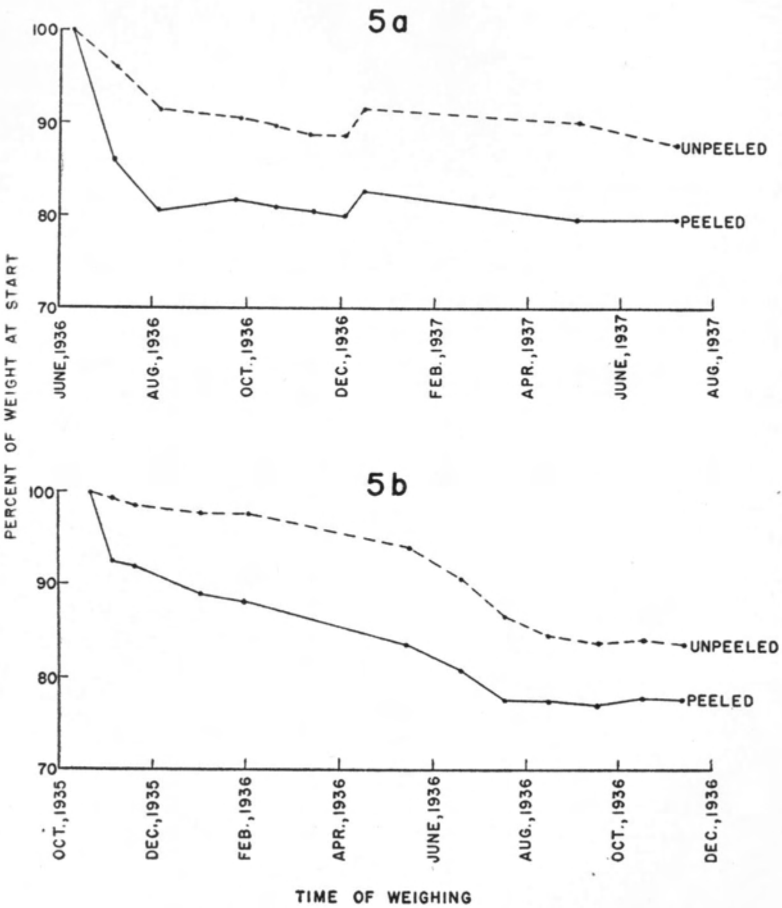

FIGURE 5. Progress of moisture loss in red maple posts cribbed in open (2 x 10) piles of 50 posts each. (5a) Piles laid up in June. (5b) Piles laid up in October.

Although the work just described was carried out under the direction of the senior author, credit for its actual performance is due to Mr. John A. Simon of the Civilian Conservation Corps, Camp Buck, Portland, Connecticut, and to men from that camp who worked under his supervision.

SERVICE TESTS OF TREATED MATERIAL

Service records of some 9,000 treated posts have been kept by the Station for periods up to 15 years. These records have included untreated checks when available. All the posts on which records have been kept are in use to carry cable fencing along highways or to support tobacco shade tents. No posts of the ordinary farm fence type are included. Inspections have usually been at five year intervals and, insofar as it has been possible to do so, record keeping has conformed to procedures established by the U. S. Forest Products Laboratory. However, evaluation of defects in terms of serviceability must necessarily conform to higher standards than if the posts were used for the usual type of farm fencing. This is especially true in highway fencing where human life may be at stake when posts fail. The standards for serviceability of highway posts are given in the next section. Similar standards were not established for tobacco posts but they would also have to be relatively high to guard against heavy monetary loss to both crop and tent covering caused by post failure.

The usual inspection procedure is to dig the soil away from the posts to a depth of 12 inches, to examine the post carefully from the bottom of the hole to the top by probing with a strong thin blade and by tapping with a light hammer. The authors have found that light hammer blows frequently disclose zones of interior decay that are not revealed by the probe. No attempt is made to examine the part of the post below the excavation since experience indicates that, in a very high percentage of cases, deterioration at ground line will be more advanced than at levels more than 12 inches below that point. Posts are identified either by a metal tag or diagrammed field maps or both. Results of the service tests, classified in several categories, are presented below.

HIGHWAY POST SURVEY

In 1940 the Station and the Connecticut State Highway Department began a survey of posts used in guide rail fencing in order to evaluate the service life of posts of different species under different methods of treatment. For the most part, these posts are set on the shoulders of the highway and support two woven steel cables. It was decided at the start that any given preservative or treatment should be represented by 100 or more posts and that inspections should be made at five year intervals. About 7,700 tagged posts have been inspected either two or three times.

Work began in 1940 with the tagging and inspection of over 4,700 posts which had been set between 1933 and 1935 and the tagging without inspection of nearly 3,000 additional posts set in 1939 and 1940. All posts were reinspected in 1945 and again in 1950.

It may be well to note at this point that the posts are scattered over many miles of highway at widely separated locations in Connecticut. With inspections at five-year intervals and with the maintenance of the fences by a large number of highway crews, it has usually not been possible to determine the cause for replacement between inspections. Some posts were undoubtedly replaced because they had become unserviceable through decay but it is also quite certain that some were also replaced because of breakage by snow plows and automobiles. Although these unaccounted losses are regrettable, it is believed that they do not invalidate the conclusions which have been drawn regarding the effectiveness of the several treatments.

Classification of Defects

Highway specifications in Connecticut require that posts for guide rail use be at least 6 inches in diameter at the top end, 7 feet long and be set to a depth of 42 inches. With these specifications in mind, the following criteria were followed in judging the defects in a post.

For the purpose of classifying defects, the posts were divided into two parts:

A. *The Butt*—that part of the post extending from 6 inches above ground to the bottom.

B. *The Top*—that part of the post more than 6 inches above ground.

The condition of butts and tops were then classified as follows:

1. Butt good—no evidence of decay.[1] (Serviceable)
2. Butt partially decayed—decay present but so limited that an effective diameter of 6 inches or more of sound wood still remained at ground line. (Serviceable)
3. Butt decayed—decay present to such an extent that the effective diameter of sound wood at ground line was less than 6 inches. (Unserviceable)
4. Top good—no evidence of decay. (Serviceable)
5. Top partially decayed—decay present but so limited that an effective diameter of 6 inches or more of sound wood still remained at and below the top cable bolt. (Serviceable)
6. Top decayed—decay present to such an extent that the effective diameter of sound wood was less than 6 inches at and below the top cable bolt. (Unserviceable)

The condition of tops and butts of posts, treated by the methods and preservatives described below, are classified in Tables 15, 16 and 17. The percentages under the several headings are based on the number of posts found at the time of inspection, not on the number originally set.

Table 18 classifies the same posts as "serviceable" or "unserviceable" as indicated by the bracketing of these words in the specifications given above. In this case, however, the percentages are based on the number of posts originally set and, consequently, present a better basis for estimating losses from all causes than do the other tables.

Types of Treatment

The types of treatment used in the service tests were as follows:

(a) Treatment under pressure was with Grade I A.W.P.A. coal tar creosote or Wolman salts. Specifications called for retention of 6 pounds per cubic foot of creosote. Specifications for Wolman salts are not available but presumably treatment was standard for this material.

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[1]The term decay, as here used, includes deterioration caused by fungi and insects. Very occasional damage by termites and carpenter ants was found only in brush-treated posts and is not separately classified in this paper.

(b) Open tank treatment to the butts only was made with Grade I A.W.P.A. coal tar creosote for a distance of 4 feet from the butt end, the posts being in an upright position. Hot bath temperatures of 215° F. were maintained for 4 to 6 hours. Some of the posts were subjected to a cold bath of 4 to 16 hours duration; others were not. Some of the poor results in service may have been due to omission of the cold bath but the rapid spread of decay from the untreated tops so complicated the situation that it was impossible to estimate the effectiveness of treatment with and without cold bath. Practically all maple and birch posts were incised from 18 inches below to 6 inches above ground line.

(c) Full length open tank treatment. The posts included are those which were treated as described on page 12 and in Table 4. Maple and birch posts were not incised.

(d) Dip treatment to butts only was accomplished by immersing the lower 4 feet of the posts in hot coke oven tar for 1 minute.

(e) Brush treatment to butts only was either with a high-grade brushing creosote or with a tar known as 8-13.

Results of Treatment

Pressure Treatment—Creosote

The red and southern yellow pine posts, which were framed and bored before treatment, were purchased in a treated condition through commercial channels. They were in almost perfect condition after 10 years of service. The condition of the hardwood posts with essentially the same treatment was much less satisfactory after the same period of service. These posts were purchased by the Highway Department which had them custom treated. They were not roofed and bored until after treatment and there is some evidence that they were not in the best of condition when treated. (See Table 15)

Pressure Treatment—Wolman Salts

These hardwood posts were also bought and custom treated. At the end of 10 years, they were in quite satisfactory condition and in appreciably better condition than posts of the same species which were custom treated with creosote. (See Table 15) An apparent contradiction to this statement is the fact that 95.4 per cent of the butts are listed as partially decayed after 10 years. The type of deterioration indicated here is a softening of the surface of the wood, at or just below ground line, to a depth of not more than ½ inch. This softened wood crumbles readily in the fingers and the transition to sound wood inside the crumbly layer is quite abrupt. This same type of deterioration has also been observed in wood treated with zinc chloride and the authors are of the opinion that it is caused by the chemical rather than by organisms. It will be noted in Table 18, which rates the posts in Tables 15, 16 and 17 as "serviceable" or "unserviceable", that Wolman-treated posts which are designated "butt partially decayed" are classified as serviceable because they have more than the minimum required diameter in good condition.

TABLE 15. SERVICE TESTS OF HIGHWAY POSTS, PRESSURE TREATED WITH CREOSOTE AND WOLMAN SALTS

Species	Number of Posts	Condition: Butt — Good	Butt — Partially Decayed	Butt — Decayed	Top — Good	Top — Partially Decayed	Top — Decayed
		Per Cent			Per Cent		
		Pressure with Creosote[1] *After 5 Years of Service*					
W. Oak	249	98.8	1.2	0.0	100.0	0.0	0.0
R. Oak	520	99.0	1.0	0.0	100.0	0.0	0.0
Maple	68	92.6	5.9	1.5	100.0	0.0	0.0
Birch	42	97.6	2.4	0.0	100.0	0.0	0.0
Red Pine	549	100.0	0.0	0.0	100.0	0.0	0.0
S. Y. Pine	482	100.0	0.0	0.0	100.0	0.0	0.0
Misc.	3	100.0	0.0	0.0	100.0	0.0	0.0
Total	1,913						
Average		99.2	0.7	0.1	100.0	0.0	0.0
		After 10 Years of Service					
W. Oak	245	91.4	5.7	2.9	88.6	11.0	0.4
R. Oak	512	88.9	8.8	2.3	81.1	18.7	0.2
Maple	68	54.4	27.9	17.7	100.0	0.0	0.0
Birch	42	81.0	19.0	0.0	100.0	0.0	0.0
Red Pine	526	100.0	0.0	0.0	100.0	0.0	0.0
S. Y. Pine	472	98.7	0.9	0.4	100.0	0.0	0.0
Misc.	3	0.0	100.0	0.0	100.0	0.0	0.0
Total	1,868						
Average		93.3	4.9	1.8	93.3	6.6	0.1
		Pressure with Wolman Salts[1] *After 5 Years of Service*					
Oak	386	0.0	100.0[2]	0.0	100.0	0.0	0.0
Maple	9	0.0	100.0	0.0	100.0	0.0	0.0
Total	395						
Average		0.0	100.0	0.0	100.0	0.0	0.0
		After 10 Years of Service					
Oak	386	0.0	95.3[2]	4.7	99.5	0.5	0.0
Maple	9	0.0	100.0	0.0	100.0	0.0	0.0
Total	395						
Average		0.0	95.4	4.6	99.5	0.5	0.0

[1]Posts set in 1939-40. Inspected in 1945 and 1950. Tests will be continued.
[2]See text, page 52.

TABLE 16. SERVICE TESTS OF HIGHWAY POSTS, OPEN TANK TREATED WITH CREOSOTE.

Species	Number of Posts	Condition: Butt: Good (Per Cent)	Butt: Partially Decayed (Per Cent)	Butt: Decayed (Per Cent)	Top: Good (Per Cent)	Top: Partially Decayed (Per Cent)	Top: Decayed (Per Cent)
Open Tank Treatment to Butts Only, Creosote[1]							
After 5 to 7 Years of Service							
W. Oak	400	98.5	1.2	0.3	43.0	47.2	9.8
R. Oak	1264	98.7	0.5	0.8	42.0	48.2	9.8
Maple	1293	98.7	0.9	0.4	67.9	23.2	8.9
Birch	304	100.0	0.0	0.0	70.4	16.8	12.8
Pitch Pine	361	97.8	0.5	1.7	72.0	16.6	11.4
Misc.	11	100.0	0.0	0.0	27.3	45.4	27.3
Total	3633						
Average		98.7	0.7	0.6	56.7	33.4	9.9
After 10 to 12 Years of Service							
W.Oak	384	86.2	4.9	8.9	21.1	49.0	29.9
R. Oak	1188	74.1	15.4	10.5	9.8	37.4	52.8
Maple	1208	66.1	11.7	22.2	24.8	28.0	47.2
Birch	284	70.2	16.3	13.5	18.8	23.0	58.2
Pitch Pine	346	73.7	7.8	18.5	30.9	38.7	30.4
Misc.	10	40.0	20.0	40.0	10.0	10.0	80.0
Total	3420						
Average		72.2	12.7	15.1	19.3	34.2	46.5
After 15 to 17 Years of Service							
W. Oak	329	77.8	15.2	7.0	10.0	53.2	36.8
R. Oak	814	49.8	32.8	17.4	2.8	31.2	66.0
Maple	807	46.1	19.1	34.8	6.2	31.2	62.6
Birch	198	45.5	22.7	31.8	5.1	24.7	70.2
Pitch Pine	297	24.9	18.9	56.2	6.4	36.0	57.6
Misc.	8	12.5	50.0	37.5	0.0	37.5	62.5
Total	2453						
Average		48.8	23.5	27.7	5.5	34.2	60.3
Full Length Open Tank, Creosote[2]							
After 5 Years of Service							
Oak	195	99.5	0.5	0.0	100.0	0.0	0.0
Maple	51	98.0	0.0	2.0	100.0	0.0	0.0
Birch	53	100.0	0.0	0.0	100.0	0.0	0.0
Total	299						
Average		99.3	0.3	0.4	100.0	0.0	0.0

[1]Posts set in 1933-35. Inspected in 1940, 1945 and 1950. Tests terminated in 1950.
[2]Posts set in 1939-40. Inspected in 1945 and 1950. Tests will be continued.

Species	Number of Posts	Condition					
		Butt			Top		
		Good	Partially Decayed	De-cayed	Good	Partially Decayed	De-cayed
		Per Cent			Per Cent		
		After 10 Years of Service					
Oak	194	99.5	0.5	0.0	86.6	13.4	0.0
Maple	43	86.0	4.7	9.3	90.7	9.3	0.0
Birch	52	98.0	0.0	2.0	100.0	0.0	0.0
Total	289						
Average		97.2	1.1	1.7	89.6	10.4	0.0

Open Tank Treatment—Butts Only

The results show quite clearly (Table 16) that decay in the untreated tops is already well advanced within 5 years and by the 15th year has increased to a point where failure in the tops is almost complete. After 15 years, the treated butts were still in fair condition, and while it is not brought out in the table, much of the decay in the butts was inside the treated shell, whence it had progressed from the untreated tops, and not in the treated shell itself.

The upper two feet of most of these posts received a coat of white paint for visibility soon after setting and were repainted at frequent intervals. In some cases, however, no paint was used and it was observed that the tops of unpainted posts were usually in much better condition than when paint had been applied. Decay usually starts in checks at the extreme top end and from there spreads downwards. Apparently the paint coating seals up the sides of the post so that water entering at the extreme top end is not readily lost to the atmosphere and creates very favorable conditions for decay. Frequently the painted tops of posts had a shell of sound wood one quarter inch or less in thickness just under the paint, the remainder of the wood being entirely rotten.

Full Length Open Tank Treatment

Posts with this treatment have been in service only 10 years (Table 16). Although treatment was not all that could be desired, the butts are in very good condition after 10 years and there is very little evidence of decay in the tops.

This and the previous test demonstrate that, in this climate, treatment of the tops of posts of non-durable woods is necessary to insure uniform service of top and butt.

Superficial Treatments

The results obtained with creosote or tar applied by brushing or brief dipping are discussed together since neither afforded satisfactory

TABLE 17. SERVICE TESTS OF HIGHWAY POSTS WITH BUTTS SUPERFICIALLY TREATED BY BRUSHING WITH CREOSOTE OR TAR, OR BY DIPPING IN HOT TAR.

		Condition					
		Butt			Top		
Species	Number of Posts	Good (Per Cent)	Partially Decayed (Per Cent)	Decayed (Per Cent)	Good (Per Cent)	Partially Decayed (Per Cent)	Decayed (Per Cent)
		Butts Brushed with Creosote[1]					
		After 5 to 7 Years of Service					
W. Oak	415	6.0	6.0	88.0	49.4	42.2	8.4
R. Oak	32	3.1	0.0	96.9	37.5	50.0	12.5
Total	447						
Average		5.8	5.6	88.6	48.6	42.7	8.7
W. Cedar	660	43.6	23.5	32.9	93.9	6.1	0.0
		After 10 to 12 Years of Service					
W. Oak	359	0.0	4.2	95.8	7.5	52.4	40.1
R. Oak	31	0.0	6.4	93.6	6.4	45.2	48.4
Total	390						
Average		0.0	4.4	95.6	7.4	51.8	40.8
W. Cedar	647	9.7	38.7	51.6	61.2	36.0	2.8
		After 15 to 17 Years of Service					
W. Oak	193	0.0	6.2	93.8	4.1	45.6	50.3
R. Oak	16	0.0	0.0	100.0	12.5	18.7	68.8
Total	209						
Average		0.0	5.7	94.3	4.8	43.5	51.7
W. Cedar	617	8.8	33.7	57.5	37.0	57.7	5.3
		Butts Brushed with 8-13 Tar[2]					
		After 5 Years of Service					
Oak	78	0.0	12.8	87.2	15.4	79.5	5.1
Pitch Pine	32	3.1	15.6	81.3	18.7	25.0	56.3
Total	110						
Average		0.9	13.6	85.5	16.4	63.6	20.0
		After 10 Years of Service					
Oak	16	0.0	6.2	93.8	18.7	56.3	25.0
Pitch Pine[3]	....	....	....	......	......	......	......

[1]Posts set 1933-35. Inspected in 1940, 1945 and 1950. Tests terminated in 1950.
[2]Posts set 1939-40. Inspected in 1945 and 1950. Tests terminated in 1950.
[3]Posts removed after 5 years.

Species	Number of Posts	Condition					
		Butt			Top		
		Good	Partially Decayed	De-cayed	Good	Partially Decayed	De-cayed
		Per Cent			Per Cent		
		Butts Dipped in Hot Coke-Oven Tar[2]					
		After 5 Years of Service					
W. Oak	82	0.0	45.1	54.9	52.6	47.6	0.0
R. Oak	150	0.0	40.7	59.3	38.0	59.3	2.7
Total	232						
Average		0.0	42.2	57.8	43.1	55.2	1.7
		After 10 Years of Service					
W. Oak	71	0.0	19.7	80.3	1.4	69.0	29.6
R. Oak	79	0.0	7.6	92.4	0.0	39.2	60.8
Total	150						
Average		0.0	13.3	86.7	0.7	53.3	46.0

protection (Table 17). Of the species under consideration, the heartwood of white oak and white cedar have good natural durability. The sapwood of these species is not durable and, when inadequately protected, develops into a soggy, rotting mass surrounding the heartwood. The effect of this condition is obvious since 30 per cent or more of the butts of both species became unserviceable within 5 years, with white oak showing a higher incidence of decay than white cedar. The untreated tops of white cedar were in much better condition at 5, 10 and 15 years than were the tops of white oak. Red oak and pitch pine show a high incidence of decay in the butts within 5 years and in the tops within 10 years.

The condition of these posts bears out a statement previously made that superficial treatments are entirely inadequate for protection of non-durable woods in contact with the soil.

No untreated posts were available for direct comparison with treated posts in the survey. However, the extremely poor condition of superficially treated posts of non-durable woods after a short time is sufficient indication of the probable length of life of such woods when not treated at all.

SURVEY OF TOBACCO POSTS

Posts Butt-treated with Creosote

The posts included in this service test are a part of those that were treated as described on page 6. They were 4 to 5 inches in top diameter and 12 feet long.

TABLE 18. SERVICEABILITY OF HIGHWAY POSTS IN RELATION TO METHOD OF TREATMENT, PRESERVATIVE USED AND KIND OF WOOD.

Species	Original Number of Posts	Condition After 5 to 7 Years Service: Serviceable[1]	Unserviceable[1]	10 to 12 Years Service: Serviceable	Unserviceable	15 to 17 Years Service: Serviceable	Unserviceable
		Per Cent		Per cent		Per cent	
Pressure with Creosote							
W. Oak	249	100.0	0.0	96.7	3.3	......	......
R. Oak	520	100.0	0.0	97.7	2.3	......	......
Maple	68	98.5	1.5	82.4	17.6	......	......
Birch	42	100.0	0.0	100.0	0.0	......	......
Red Pine	549	100.0	0.0	100.0	0.0	......	......
S. Y. Pine	482	100.0	0.0	99.6	0.4	......	......
Misc.	3	100.0	0.0	100.0	0.0	......	......
Total	1913						
Average		99.9	0.1	98.2	1.8	......	......
Pressure with Wolman Salts							
Oak	386	100.0	0.0	95.3	4.7	......	......
Maple	9	100.0	0.0	100.0	0.0	......	......
Total	395						
Average		100.0	0.0	95.4	4.6	......	......
Full Length Open Tank, Creosote							
Oak	195	100.0	0.0	100.0	0.0	......	......
Maple	51	98.0	2.0	90.7	9.3	......	......
Birch	53	100.0	0.0	98.1	1.9	......	......
Total	299						
Average		99.7	0.3	98.3	1.7	......	......
Open Tank Treatment to Butts Only, Creosote							
W. Oak	400	90.0	10.0	67.1	32.9	54.2	45.8
R. Oak	1264	89.6	10.4	43.4	56.6	26.0	74.0
Maple	1293	91.0	9.0	45.7	54.3	24.8	75.2
Birch	304	87.2	12.8	39.1	60.9	20.7	79.3
Pitch Pine	361	88.1	11.9	60.9	39.1	24.2	75.8
Misc.	11	72.7	27.3	27.3	72.7	18.2	81.8
Total	3633						
Average		89.7	10.3	48.2	51.8	28.4	71.6

[1]For definition, see text, page 51.

Species	Original Number of Posts	Condition After 5 to 7 Years Service: Serviceable (Per cent)	Unserviceable (Per cent)	10 to 12 Years Service: Serviceable (Per cent)	Unserviceable (Per cent)	15 to 17 Years Service: Serviceable (Per cent)	Unserviceable (Per cent)
		Butts Brushed with Creosote					
W. Oak	415	11.3	88.7	3.1	96.9	2.4	97.6
R. Oak	32	3.1	96.9	1.4	98.6	0.0	100.0
Total	447						
Average		10.7	89.3	2.9	97.1	2.1	97.9
W. Cedar	660	67.1	32.9	47.3	52.7	39.7	60.3
		Butts Brushed with 8-13 Tar					
Oak	78	11.5	88.5	2.6	97.4	......	......
Pitch Pine	32	9.4	90.6	0.0	100.0	......	......
Total	110						
Average		10.9	89.1	1.8	98.2	......	......
		Butts Dipped in Hot Coke-Oven Tar					
W. Oak	82	43.9	56.1	15.4	84.6	......	......
R. Oak	150	39.3	60.7	3.7	96.3	......	......
Total	232						
Average		40.9	59.1	8.0	92.0	......	......
Grand Total	7689						

Eleven posts each of pitch pine, red pine, Scotch pine and red maple, together with 10 hardwood posts commercially treated with zinc meta-arsenite were set and wired to support shade tent over 1 acre. Of the first 4 species, 7 posts were treated as hitherto described and 4 were untreated.

At the end of 1 year, all of the untreated posts showed evidence of deterioration at or near ground line and, at the end of 5 years, all had failed at or near ground line and had been replaced.

The treated butts of the posts were all in excellent condition when the tent was dismantled after 6 years of service and at this time the tops of the posts were also in good condition. Two years later the posts were reset at a new location but at a greater depth than the treatment line (36 inches). This, of course, nullified the treatment and posts promptly rotted at the new ground line. They were inspected at the end of 11 years at which time most of the untreated tops had also become unserviceable.

The conclusions from these tests are in essential agreement with those based on similarly treated posts in the highway post survey; the tests also show that untreated non-durable woods begin to deteriorate in less than 2 years and become unserviceable in less than 5 years.

The posts treated with zinc meta-arsenite were in excellent condition throughout after more than 12 years of service.

Posts Treated by the Tire Tube Method

The two service tests which are described below are of especial significance since they can be related to the qualitative evaluations of treatment made immediately after input described on pages 17 *et seq.*

Table 19 shows the condition of spruce and pine posts after 10 and 15 years of service. Table 20 gives the same data for red maple, black birch and gray birch after 8 and 13 years.

It should be emphasized that, in a tobacco tent post, the zone between 6 and 12 inches from the top end is very critical since this is the point where the wires supporting the tent cloth are stapled to the post. Very little decay can be tolerated at this point and any posts with tops designated as decayed or partially decayed are approaching an unserviceable condition. There can also be little deterioration in the ground line zone because wind action on the tent at times subjects the posts to high stresses at this point. For ordinary farm fencing, where requirements are less exacting, nearly all of the posts in Tables 14 and 15 could be classified as serviceable.

It will be noted that after 8 and 10 years respectively, the butts of both the hardwood and softwood posts are all in excellent condition. However, the tops of the softwood posts, which had a relatively poor qualitative distribution of salt immediately after input, showed enough decay after 10 years to make nearly all of them unserviceable. On the other hand, the tops of nearly all of the hardwood posts, in which the qualitative distribution of salt immediately after treatment was comparatively good, were in excellent condition after 8 years.

At the end of 15 years the butts of 80 per cent of the softwood posts are still in excellent condition. The same is true of the hardwoods after 13 years with the exception of maple, in which the percentage of undecayed butts drops to 68. An additional 12 per cent of the maple posts are classified as partially decayed but still serviceable.

The condition of the tops of the softwoods after 15 years was so poor that all were classified as unserviceable. After 13 years the tops of 60 per cent or more of the hardwood posts are still in serviceable condition. The condition of the gray birch posts is rather remarkable considering the extreme susceptibility of this wood to decay.

In all cases decay in the tops occurred within a foot or less of the extreme top end. The condition of these posts, except for the tops of the conifers, is quite satisfactory after 13 to 15 years but it is believed

TABLE 19. SERVICE TESTS OF TOBACCO TENT POSTS OF SPRUCE AND PINE TREATED BY THE TIRE TUBE METHOD.

			Condition											
			Butt						Top					
	Number of	Number of Years in	Good		Partially Decayed		Decayed		Good		Partially Decayed		Decayed	
Species	Posts	Service	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Norway Spruce	5	10	5	100	0	0	0	0	1	20	4	80	0	0
Pine	10	10	10	100	0	0	0	0	2	20	7	70	1	10
Norway Spruce	5	15	4	80	1	20	0	0	0	0	5	100	0	0
Pine	10	15	8	80	0	0	2	20	0	0	9	90	1	10

TABLE 20. SERVICE TESTS OF TOBACCO TENT POSTS OF MAPLE AND BIRCH TREATED BY THE TIRE TUBE METHOD.

			Condition[1]													
			Butt						Top							
			Good		Partially Decayed		Decayed		Good		Partially Decayed		Decayed		Missing	
Species	Number of Posts	Number of Years in Service	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Red Maple	25	8	25	100	0	0	0	0	24	96	1	4	0	0	0	0
Black Birch	10	8	10	100	0	0	0	0	10	100	0	0	0	0	0	0
Gray Birch	10	8	10	100	0	0	0	0	10	100	0	0	0	0	0	0
Red Maple	25	13	17	68	3	12	2	8	21	84	1	4	0	0	3	12
Black Birch	10	13	10	100	0	0	0	0	10	100	0	0	0	0	0	0
Gray Birch	10	13	9	90	0	0	0	0	6	60	2	20	1	10	1	10

[1]Percentages based on number of posts set.

that it would have been appreciably better if the posts had been stood vertically with the intake end up for about 3 months before setting.

Of interest also is the condition of approximately 100 red pine posts 7 feet long which were individually treated by the tire tube method through the butt end with 10 pounds of 10 per cent solution to give a retention of 1 pound of dry salt per cubic foot of wood. The posts were immediately set with the input end down. After 17 years, the butts (lower 4 feet) of these posts are all in excellent condition. The tops (upper 3 feet) are entirely rotted away. These were among the earliest posts treated by the Station in this manner and, while no information on internal distribution of salt is available, it is probable that very little salt ever reached the upper 3 feet of the posts.

Posts Treated by the Barrel Method

After 6 years of service 50 red pine posts, treated as described on page 34 with the results shown in Table 8 were examined. All were in excellent condition throughout.

Statements have been made that treatment by sap stream methods tends to freeze the bark. It may do so for a time, but observations on posts discussed in the preceding paragraphs indicate that after 5 or more years of service most of the bark loosens and peels off the above-ground portions. The bark below ground remains intact and apparently in sound condition and it is believed that it is quite effective in reducing leaching of salt from this part of the post.

The below-ground portions of all posts treated with zinc chloride showed the same type of deterioration which has been described for Wolman salts, i.e., the outer ¼ inch of wood becomes soft and brittle. Beneath this zone the wood is firm and sound.

A study of the distribution and movement of salt subsequent to intake and the results of service tests indicate that the sap stream methods, if properly used, can be expected to provide for a minimum of 10 years of service life with reasonable expectancy of 5 or more additional years.

SUMMARY AND CONCLUSIONS

SUMMARY

During the past 25 years the Station has investigated numerous aspects of the impregnation of wood by methods that can be used by the farm owner to whom commercially treated wood is often not readily available. With minor exceptions, the work has been confined to the treatment of round posts and poles, with the sapwood intact, in lengths up to 30 feet. The principal methods studied were open-tank using coal tar creosote, cold soaking with oil-soluble pentachlorophenol or copper naphthenate, and several sap-stream processes for

treating green, unpeeled posts and poles with zinc chloride, with or without a dichromate added. Movement of salt, subsequent to initial intake of solution by sap-stream methods, was investigated in some detail to determine the best method of handling during seasoning to insure satisfactory distribution of preservative. Some work was also done on the phytotoxicity of oily or oil-soluble preservatives and their solvents, and on the moisture content and seasoning of red maple. The work on round posts has consisted of three phases:

(a) Evaluation of the treatment in terms of absorption and penetration at the time treating was done.

(b) Inspection of experimentally treated posts in actual use to determine service life.

(c) Relating the quality of treatment to service life.

Service inspections have also been made on some 7,000 posts which were treated by several methods but for which no detailed treatment records were available.

CONCLUSIONS

The following conclusions were drawn from the experimental work:

(1) There is virtually no penetration of preservative into the heartwood at the time of treatment with any of the methods used.

(2) Posts or poles of non-durable woods should be given a full-length treatment to afford uniform service life of tops and butts.

(3) Only impregnation treatments afford adequate protection to non-durable woods in contact with the soil.

(4) Woods of different tree species are not equally susceptible to treatment by all methods. However, of the several simple methods available, one or more can be usually relied on to give satisfactory penetration and retention of preservative.

(5) It is almost axiomatic that the hard pines with thick sapwood can be readily treated by any method. In fact, it is sometimes difficult to hold retentions down to reasonable levels.

(6) The open-tank method using creosote will give excellent results with hard pines and oaks. The latter can be given a full sapwood impregnation but, if the sapwood is quite thin, penetration may be doubtfully adequate. Results with such diffuse porous woods as maple, birch and aspen were not satisfactory. Absorption at the ends tends to be excessive; at 3 feet from the ends, or approximate ground line, penetration is usually very thin and erratic. Penetration can be somewhat improved by incising but this is a doubtful procedure, economically. Somewhat contrary to the usual concepts, it was found that frequently as much as 5 pounds of creosote per cubic foot is absorbed during the hot bath. Prolonging the hot bath and omitting the cold bath may be a means of obtaining adequate penetration without excessive absorption in hard pines with thick sapwood.

(7) Somewhat limited observations on cold soaking hard pine, oak, and maple in oil solutions of pentachlorophenol or copper naphthenate indicate that these species react to treatment in much the same manner that they do to open-tank treatment with creosote.

(8) The sap-stream methods, as a group, offer a number of possibilities for the treatment of diffuse porous and coniferous woods with zinc chloride or chromated zinc chloride. They do not provide a satisfactory treatment for ring porous woods. The tire-tube method gives better results with more species than either the barrel method or stepping but fastening of the tubes is rather tedious. The barrel method is suitable for bulk treatment but requires a longer time than either of the other methods. Stepping is the fastest of the methods but can be wasteful of preservative unless controlled.

(9) Immediately after intake of solution by any of the sap-stream methods, distribution of salt within the post is not uniform. Concentration is greatest at the end to which the solution is applied. It decreases toward the opposite end and the final quality of treatment depends on how the posts are handled during seasoning. If they are stacked in a vertical position with the intake end down, salt concentration increases at the intake end; if in a vertical position with the intake end up, there is a tendency for the salt concentration to become equalized throughout the post; if in a horizontal position, there is no change in concentration. Correct position during seasoning is an essential part of the barrel method and can be used to improve the quality of treatment by any sap-stream method.

(10) Creosote, pentachlorophenol and the usual solvents of the latter can cause severe injury to plants growing near them in such structures as tobacco shade tents, greenhouses and cold frames where the circulation of air is retarded. As far as can be determined, copper naphthenate without solvent is not injurious to plants but its solvents can cause injury. No injury to tobacco was observed from shade tent posts treated with water-soluble preservatives.

(11) Round red maple posts are difficult to season. If peeled, large checks develop in the ends and sides; if unpeeled, there is no serious checking but decay sets in quite rapidly. Full length incising will very materially reduce the number of large checks but is expensive. Incising also apparently tends to reduce decay during seasoning.

(12) Service records indicate that if wood, preservative and method of treatment are properly chosen, a service life of at least 10 years can be expected from non-durable woods with a reasonable expectancy of 5 or more additional years.

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