Circular No. 683

September 1943 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Effectiveness of Wood Preservatives in Preventing Attack by Termites

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THE FIELD OF WOOD PRESERVATION

Wood has been classed in the present global war as a critical structural material. Much of the wood to be utilized for the construction of the large numbers of necessary barracks and storage depots must be installed in the Tropics. Even in the event of a short war, past experience has shown that structures built to last for only short periods of service must be continued to be used long after the war is over.

Hence, to protect wood from attack by various agencies of destruction, such as insects and decay, a knowledge of wood preservatives is imperative and timely. For, while the initial cost of treated wood may be higher, eventual economy will result through the reduction of early and frequent replacement costs, where the danger of deterioration is great.

The modern use of chemicals to preserve wood and wood products from destructive agencies dates back to early in the eighteenth century in both Europe and North America. The ancients, however, made much earlier attempts to preserve wood by merely rubbing the

[1] The authors appreciate the cooperation of the Forest Products Laboratory of the Forest Service, United States Department of Agriculture, at Madison, Wis.; the Chemical Warfare Service, Edgewood Arsenal, Md., of the War Department; the California Termite Investigations Committee; the Western Union Telegraph Co.; and the American Wood Preservers' Association in furnishing chemicals for testing, making impregnations of wood, and providing timbers and buildings for tests. Several manufacturers of preservative materials have assisted in the tests and have provided extensive material of various types.

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preservative materials, such as essential oils extracted from woods, over the wood that they desired to protect.

Today the more effective commercial treatments of wood are the pressure processes involving expensive, steel, treating cylinders and other equipment in which, before use, wood is impregnated with preservative chemicals.

A dwelling properly constructed of untreated wood in the continental United States will be protected against attack by subterranean termites if built according to the termite-proofing specifications recommended by the United States Department of Agriculture. From the standpoint merely of protection against such termites alone, the cost of the general use of timber pretreated by impregnation with chemical wood preservatives is not warranted by any risk involved. If, however, protection against decay, nonsubterranean termites, borers, and other destructive agencies is deemed necessary, the additional cost may be warranted in some localities for the treatment of certain of the more vulnerable foundation and structural members.

Spraying, with a preservative, of sound structural timber already in place, or even applying the preservative to such timber under strong pressure at borings made at occasional points, is neither necessary nor satisfactory (*5*).[2]

In California, in restricted parts of southern Florida, and in certain tropical countries there will be serious damage by damp-wood and dry-wood termites to the untreated woodwork of properly constructed buildings in some localities. Here again, however, the risk of loss is not sufficient to justify recommendations for the general use of chemically treated timber in the construction of dwellings. Instead, buildings should be properly screened with noncorroding metal screens, preferably with 20 meshes to the inch, and the woodwork should be well painted with several coats of a heavy paint, enamel, varnish, or lacquer. Often the close-grained heartwood of termite-resistant woods may be desirable for certain vulnerable structural parts.

The heartwood only of foundation-grade redwood of the Pacific coast and all-heart, tidewater red baldcypress are commercially available termite-resistant woods. Very pitchy ("lightwood") longleaf pine is a termite-resistant wood obtainable locally in the Gulf States.

For the protection of wooden poles, bridge timbers, derricks, mine props, etc., in certain sections of the United States, chemical impregnations for protection against termites are necessary. Also, in the case of large, permanent buildings it may be highly desirable to employ, for certain vulnerable structural parts, timber chemically impregnated before use, particularly in certain localities in the Tropics, where severe damage to buildings by both subterranean and dry-wood termites occurs.

Chemical impregnation of such woodwork as the more vulnerable sills, joists, and subfloors near the foundation will not protect the remainder of the building or its contents from termites. Only the treated timber itself will be protected, and this will constitute no "shield of treated wood." Subterranean termites can and do construct earthlike shelter tubes (fig. 1) over the treated wood to reach untreated material.

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[2] Italic figures in parentheses refer to Literature Cited, p. 24.

FIGURE 1.—Earthlike shelter tube constructed by subterranean termites over a heavily creosoted pine support of the test building (fig. 4) on Barro Colorado Island, Canal Zone.

Wood-pulp or fiber products, such as insulation boards, particularly those to be exported to the Tropics, need to have toxic materials added during the process of manufacture to protect them from attack by termites.

DESCRIPTION OF WOOD PRESERVATIVES

Hunt and Garratt (*6*) group wood preservatives into the following three general classes:

(*a*) preservative oils, or mixtures of oils, that are of low volatility and only slightly soluble in water; (*b*) inorganic salts and similar materials that are used in water solution; and (*c*) toxic chemicals that are dissolved in some colorless and usually volatile solvent other than water.

The common commercial preservative oils include the creosotes of various derivations and anthracene oils, or carbolineums, and solutions of creosote in petroleum or tar. They are especially adapted for the pretreatment of timber to be used in contact with the ground, but also may be used for protection above ground.

The water-soluble salts employed as wood preservatives are zinc chloride, chromated zinc chloride, sodium fluoride, mercuric chloride, and copper sulfate. Several proprietary preservatives also are in more or less common use. These are for use as "white," or clean, pretreatments and are usually for use above ground and for wood that is to be finished or painted after treatment. When used in considerable concentrations, however—higher than commercially practicable—these water-soluble salts give fair protection to treated timber used in the ground.

Certain nearly colorless, toxic chemicals, insoluble in water but soluble in light petroleum oils, are now in demand for the nonpressure immersion treatment. Some of these preservatives are approved by the National Door Manufacturers' Association and are recommended for window sash, frames, and doors, and other materials which must not warp during the process of treatment. They are specially suitable for finished articles and can be used without fear of causing swelling or shrinkage. They dry rapidly, the wood is left clean, and after treatment it can be finished or painted. There must be a certain minimum period of immersion if the treatment is to be effective.

A wood preservative must be toxic to all wood-destroying organisms and must penetrate satisfactorily so that a good quantity may be absorbed. Preservatives must not be injurious to wood or metal and, for practical use, must be plentiful and cheap enough to be used in the quantities needed for protection.

There is at the present time no shortage of any of the preservatives recommended under Federal specifications for wood preservatives (*12*). Descriptions and a detailed discussion of the availability of the more common preservatives are given in other publications [3] [4] (*6*).

Many wood preservatives are sold under various trade names, one and the same preservative often being given different names by different manufacturers or distributors. Often these proprietary materials include well-known toxics that have been slightly changed or used in different combinations. The advertising matter issued for some of these preservatives often contains extravagant claims as to their properties and effectiveness. Any mixture that is proprietary and secret in composition will have value only in proportion as its ingredients are effective. Necessarily such mixtures are subject to change of formula and, therefore, lack the dependability of the commercial materials recommended under Federal specifications. These recommended preservatives have been tested, and service records have indicated their effectiveness.

METHODS OF PRESERVING WOOD

The Forest Products Laboratory of the United States Department of Agriculture has issued reports [5] giving specific descriptions of the various methods of applying wood preservatives. The amount of protection given by a good wood preservative depends largely on the absorption and penetration obtained.

The effective service that can be expected from wood after such superficial methods of treatment as brushing or dipping cannot be compared with the permanency obtained by the standard methods of impregnation. In commercial enterprises the type of treatment must necessarily be determined by the cost and the length of service required.

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[3] UNITED STATES DEPARTMENT OF AGRICULTURE. WOOD PRESERVATIVES. U. S. Forest Serv., Forest Prod. Lab., 12 pp. 1942. Revised. (Processed.)

[4] HUNT, G. M., BAECHLER, R. H., and BLEW, J. O., Jr. PRESERVATIVES, PRIORITIES, AND PROCESSES. U. S. Forest Serv., Forest Prod. Lab. 19 pp. 1942. (Processed.)

[5] U. S. DEPARTMENT OF AGRICULTURE. METHODS OF APPLYING WOOD PRESERVATIVES. U. S. Forest Serv., Forest Prod. Lab., 20 pp., illus. 1940. Revised. (Processed.)

Nonpressure Processes

Preservatives may be applied by brushing or spraying, charring and spraying, dipping, steeping, diffusion in the sap stream, and the hot-and-cold-bath or open-tank method. Steeping, diffusion, and the hot-and-cold-bath treatment, when properly applied, can give satisfactory protection. All these treatments may be applied on a small scale without the use of the expensive equipment required in the pressure processes. The most effective of these nonpressure processes is the open-tank, or hot-and-cold bath, which is also often used on a commercial scale.

Pressure Processes

Pressure treatments can be applied only on a commercial scale with the use of special equipment. The full-cell process is used where the retention of a maximum quantity of preservatives is desired, and for this method 16 pounds or more of the preservative per cubic foot of wood to be treated is forced into the timbers in large steel cylinders by means of a partial vacuum followed by pressure.

The empty-cell process is used for obtaining deep penetration but limited retention of the preservative, a considerable quantity of the preservative being forced out of the wood and recovered. This gives a cleaner treatment with greater certainty of good penetration.

SERVICE TESTS FOR TIMBER

While preliminary data as to the effectiveness of wood preservatives may be obtained in a short time in the laboratory, conclusive data can be obtained only by placing the wood under the same conditions as those to which it will be exposed in actual use. To place the wood in the ground exposes it to the most severe condition of use—a condition too severe for wood treated only for use above ground. However, data on the relative effectiveness of preservatives intended for use above ground can also be obtained in the quickest possible manner by putting the treated woods in the ground and allowing for the fact that they will give much longer service when used above ground where there is no leaching.

In 1912 the former Bureau of Entomology began tests at Falls Church, Va. (*9*), of the relative effectiveness of the various methods of chemical preservation of wood, as well as of different chemical preservatives used chiefly for protecting wood from termites. The toxicity to termites of the chemicals added during the manufacture of wood pulp or fiber products to prevent attack and the proportions needed have also been tested. In the tests of preservatives for timber to be used in contact with the ground, sapwood stakes of southern yellow pine, 2 by 4 inches and 2 feet long, were placed in holes 3 feet apart and 1 foot deep, the holes being dug with a spade and filled in with 1 foot of the stake remaining above ground. In the early work, from 8 to 12 stakes were used for testing each chemical treatment.

In 1924 the tests begun in 1912 in Virginia were expanded by larger scale tests, under tropical conditions, on Barro Colorado Island, Canal Zone. The tests were made with (1) small stakes (fig. 2)—a minimum of 10 per treatment—impregnated with many different chemical wood preservatives, (2) sections of impregnated telephone poles (fig. 3), and (3) buildings constructed entirely of chemically

FIGURE 2.—Method of testing chemically impregnated stakes in the ground on Barro Colorado Island, Canal Zone. The tests were first established there in 1924.

impregnated timber (fig. 4), including interior finish, and containing impregnated furniture. In 1928 the experimental work was again expanded in cooperation with the Forest Products Laboratory and an "international termite exposure test" (7) was set up in several

FIGURE 3.—Test of sections of impregnated pine telegraph poles in the ground on Barro Colorado Island, Canal Zone.

tropical countries where termite damage is serious. Since 1931 additions have been made to these international tests only in the Canal Zone. Each year progress reports are made on these tests.

Since 1934, also, there have been cooperative tests in the Gulf States of nearly all commercial chemical wood preservatives. A report (*13*) has recently been made giving the results of a fence-post-service study after 3 years' test in Mississippi.

FIGURE 4.—Rest house on Barro Colorado Island, Canal Zone, constructed in 1926 of timbers impregnated with either coal-tar cresote or zinc chloride.

Most of these tests of wood preservatives have been or are being made in cooperation with the Forest Products Laboratory of the Forest Service, located at Madison, Wis., and the impregnations are made at that laboratory or under the supervision of a staff member. Full information as to the formula of the chemical or mixture and the maximum, minimum, and average absorption of the chemical in the wood are obtained before testing the wood in the ground. All test specimens are labeled with metal tags giving identifying data or symbols. The installation of the treated wood in the ground and the actual testing against termites is done by the Bureau of Entomology and Plant Quarantine, either in the Canal Zone or in the continental United States.

Until the last few years too little attention was given to the design of the experiments or to details of absorption of the chemicals and of installation of the tests. Furthermore, sufficient tests of timber to give ranges both above and below commercial absorptions were not made. Some preservatives were tested only with excessive absorptions, and these must be retested with absorptions that are commercially practicable. Because of these shortcomings in the earlier tests, it is believed unwise to discuss these experiments in detail.

No one test can be safely relied on for definite conclusions; the results must be compared with those obtained from other tests and from service records of timber in actual use.

PROPERTIES, USES, AND RELATIVE EFFECTIVENESS OF WOOD PRESERVATIVES

The preservatives tested and referred to in the international termite exposure test are not all reported on in detail in this circular. Preservatives dealt with in 1934 in a previous publication (*10, pp. 404–417*), however, have now been in service for longer periods, and reports on these are brought up to date. Additional chemicals have also been tested. Results are reported on the newer, more promising commercial preservatives that have been tested for at least 5 years. Quite a few other new and promising wood preservatives are on the market, but as yet their service records are not of sufficient length to enable any exact conclusions to be drawn as to their effectiveness, and they are therefore not discussed.

Length of service of the treated products is one of the most important criteria for determining the effectiveness of wood preservatives and what recommendations should be made.

In this circular wood preservatives have been grouped as (1) preservative oils which make the wood unsuitable for painting; (2) clean, paintable preservatives; and (3) clean, nonswelling preservatives, for millwork, furniture, etc.

Practically all the chemicals and combinations of chemicals used for protecting wood from insect attack are poisonous to human beings, some are inflammable, and some are especially dangerous.

These chemicals, however, can be used without danger if ordinary precautions are taken. Wood freshly impregnated with preservative oils can be ignited easily and the oil on its surface burns freely, producing a dense smoke; this can be overcome by spreading sand or dry cement over the freshly treated wood. Hunt and Garratt (*6*, p. 313) state:

> After the treated timber has seasoned for a few months the more volatile, and hence the more inflammable, fractions of the oil disappear from the surface and there is reason to believe that creosoted wood is then no more easily ignited than sound, untreated timber.

Water-soluble, wood-preservative salts are used in rendering wood fire resistant.

Storage of large amounts of poisonous substances by the layman should be avoided. Persons unfamiliar with the use of these substances should obtain expert advice before attempting to apply them.

Impregnations With Preservative Oils

COAL-TAR CREOSOTE

Coal-tar creosote, a black or brownish oil made by distilling coal tar, has been used as a wood preservative for more than 100 years, especially for timber to be used in contact with the ground. It is a standard preservative for the prevention of decay and of attack by boring insects and marine borers throughout the world. No other chemical has had such extensive use or such long service records, or has been proved to be so effective for timber to be used either in or above the ground.

The odor of creosoted wood is unpleasant to some and may be considered objectionable in dwellings. Foodstuffs that readily absorb odors should not be stored near creosoted wood.

Workmen sometimes object to the use of freshly creosoted lumber because it soils their clothes and sometimes burns the skin of the face and hands, causing an effect similar to sunburn. Such burns result largely because proper precautions are not observed.

As a rule factory-treated lumber is free of accumulated creosote and involves little risk of such burns, particularly when the simple precaution of wearing leather gloves is taken. When considerable quantities of lumber or poles are to be locally treated with improvised equipment and more or less contact of creosote with the skin cannot be avoided, correspondingly greater care should be exercised by the use of proper clothing and gloves to reduce this to a minimum. A formula [6] for ointment which has been found very effective in preventing creosote burns is as follows: Calcium carbonate, 145 grams; pine tar, 95 grams; zinc stearate, 95 grams; and petrolatum, 95 grams. Several prepared creams are also on the market which are suitable for this use.

Creosoted wood is frequently used for sills and foundation timbers of buildings, for floor sleepers, and even for subflooring, without objection by the occupants because of odor. The blackish or brownish color of creosoted wood and the fact that it usually cannot be painted over with good results make it unsatisfactory for finished lumber.

Although there are no patents on coal-tar creosote, the material must meet certain standard specifications and for satisfactory results must be retained in the wood in certain minimum quantities. Under Federal specifications TT–W–571b (*12*) is given a schedule of recommended practice in the preservative treatment of timber of various sizes and species and for use in dry or wet sites. For use on land or in fresh water, for lumber or timber 5 inches or less in thickness, an absorption of 10 pounds per cubic foot is specified. If the treatment is desired for indoor use or special uses where cleanliness and freedom from "bleeding" are specially important, a retention of not less than 6 or more than 8 pounds per cubic foot may be specified.

Where pressure treatments are impracticable, nonpressure methods may be used under these Federal specifications, but they are not equivalent alternatives for pressure treatments. The hot-and-cold bath, or open-tank, treatment is the best of these nonpressure treatments.

In the international termite exposure test almost 43 percent of the pine stakes having an average absorption of 13.2 pounds of coal-tar

[6] Formula recommended by Southern Pacific Hospital, San Francisco, Calif.

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creosote per cubic foot still were in good condition in 1942 after about 12½ years' service. A replication of these tests in the Canal Zone with stakes having an average absorption of 13.6 pounds per cubic foot showed 75 percent in good condition after about 10 years' service.

Sections of southern yellow pine telephone poles, 8 to 9 inches in diameter and 3 feet in length, tested in the ground in the Canal Zone from 1928 to 1941 in cooperation with the Western Union Telegraph Co., showed that an impregnation with coal-tar creosote with an average absorption of 13.0 pounds per cubic foot gave the best service of all the chemicals tested, 100 percent of the sections being sound after a 12½-year test. An impregnation with 5 percent tar acid and petroleum mixture, with an average absorption of 12.4 pounds per cubic foot, left 83 percent of the sections sound after 12½ years.

Another test of coal-tar creosote impregnations made with pine stakes and round posts on Barro Colorado Island from 1929 to 1941, in cooperation with the California Termite Investigations Committee, showed that where the impregnation was at 8 pounds per cubic foot 75 percent of the specimens were sound after 11½ years' service, and where the impregnation was at 12 pounds per cubic foot 100 percent of the specimens were sound.

The frame test building on Barro Colorado Island, which had foundation timbers impregnated with coal-tar creosote at 12 pounds per cubic foot (full cell) and framework treated with the same material at 8 pounds per cubic foot (empty cell), is sound after 14 years' service (*11*). No objection was made to the odor of the creosoted wood by the periodic inhabitants of this rest house. After the wood has dried the creosote odor largely disappears.

Termites have not been known to penetrate through wood properly impregnated with coal-tar creosote. The failures in these service tests were of the treated stakes (containing much heartwood) that had little or no creosote in them, and in which there had been practically no penetration of the chemical into the heartwood. Termites gained entrance through checks in the treated sapwood to the untreated heartwood of the stakes. Proper, even penetration of the preservative and a sufficient amount per cubic foot greatly improve the effectiveness of any treatment.

COAL-TAR CREOSOTE-PETROLEUM SOLUTIONS

To avoid the higher cost of straight coal-tar creosote, petroleum oils in various percentages have been used commercially for more than 30 years as diluents for the creosote. The Federal specifications require not less than 50 percent of coal-tar creosote. For lumber and structural Douglas-fir timber 5 inches or less in diameter and for land or fresh-water use an absorption of 12 pounds per cubic foot is specified.

In the international termite exposure test in the Canal Zone all pine stakes with an average absorption of 14.5 pounds per cubic foot of this 50–50 solution were in good condition after about 10 years' service.

MONTAN WAX AND COAL-TAR CREOSOTE

Montan wax is a native, waterproof, mineral wax whose source is lignite. It was added to creosote to prevent checking and "bleeding" (exudation of the preservative from the treated wood), but it is not now in general commercial use. Fifty percent of the tupelo stakes and pine saplings heavily impregnated with 50 percent Montan wax and 50 percent creosote were sound after 14½ to 15 years' service in the ground on Barro Colorado Island. The tupelo sap and heartwood stakes had been impregnated with an average of 15.45 pounds per cubic foot; some of the black tupelo sap and heartwood stakes had been impregnated by the empty-cell process with coal-tar creosote, then by the full-cell process with Montan wax, others by using separately each chemical by the full-cell method. The average absorption per cubic foot was 14.94 pounds. Some of the Texas pine saplings had been impregnated by the empty-cell method with coal-tar creosote and then by the full-cell process with Montan wax, others by using separately each chemical by the full-cell process; the average number of pounds per cubic foot absorbed was 9.52.

CREOSOTE WITH ADDITIONS OF ARSENICALS AND DINITROPHENOL

A few small-scale tests of timber left in the ground on Barro Colorado Island for approximately 15½ years showed that the addition of arsenicals [7] rendered the coal-tar creosote more effective in resisting attack by termites. The arsenicals were a 0.71-percent methyl arsenious oxide (21.6 pounds of solution per cubic foot) and 0.77-percent diphenylamine-chlorarsine (26.2 pounds of solution per cubic foot). The impregnations were made by the United States Chemical Warfare Service. The addition of 2½-percent of dinitrophenol (25.3 pounds of solution per cubic foot) also added to the effectiveness of the creosote, but since coal-tar creosote alone is sufficiently toxic, the extra cost which these additions would necessitate is not warranted.

WOOD CREOSOTES, PINE TAR, AND PINE-OIL DERIVATIVES

Wood creosotes [7] are oils obtained in the refining of wood tar, which is produced as a byproduct in the destructive distillation of either pine or hardwoods. Wood creosotes have not been used extensively as wood preservatives in the United States. Their quality is variable, and only a few have been produced to conform to a fixed specification. Hardwood tar is produced in greater volume than is softwood tar. Creosotes manufactured from hardwood tar are decidedly acid in character, which, unless this is corrected, makes them corrosive to iron and steel and hence renders them unsuitable for use in commercial treating equipment. No standard specification for wood-tar creosote has been accepted by any organization of creosote users.

The wood creosotes, pine tar, and pine-oil derivatives that have been tested, either in the continental United States or in the Canal Zone, have failed to give as effective protection against attack by termites as has coal-tar creosote, even when absorptions in impregnated pine stakes have been similar to those in stakes impregnated with coal-tar creosote.

WATER GAS-TAR CREOSOTES

Water gas-tar creosotes [7] are generally less toxic than coal-tar creosotes. They are derived from water-gas tar, which is "the residue

[7] See caution on pp. 8 and 9.

remaining from the carburetion of water gas with petroleum oil" (*6*). These creosotes are not often sold for wood-preserving purposes. There is no standard specification for the use of water-gas tar creosotes alone, although they are mixed to some extent with coal-tar creosotes.

After 10 years' test in the ground in the Canal Zone, 62.5 percent of the pine stakes impregnated with water-gas tar with an absorption of 14.6 pounds per cubic foot were in good condition.

CARBOLINEUMS

Anthracene oils, or carbolineums,[7] are coal-tar distillates of higher specific gravity and boiling point than coal-tar creosotes, but in general their properties and effectiveness as preservatives are similar to those of coal-tar creosote. These oils are usually sold under trade names and are largely used for nonpressure treatments. Anthracene oils are included in Federal specifications for wood preservatives (*12, No. 531*) under nonpressure treatments.

THE BRUCE PRESERVATIVES

The Bruce preservatives consist essentially of approximately 5 percent betanaphthol[7] in an oil solvent. Two preservatives are being produced, one of which (5B) is in a colorless carrier for use where the treated wood is required to be clean, whereas the other (5A) is dark and is in a heavy petroleum diluent. The Bruce preservatives have been used commercially for the treatment of the wooden parts of automobile bodies. The open-tank method of treatment has commonly been used.

In the Canal Zone 25 percent of the pine stakes impregnated with 14.8 pounds of preservative 5A per cubic foot were in good condition after about 10 years' test.

A frame building 18 feet square was completed in August 1931 for test purposes, the house being constructed on Barro Colorado Island in cooperation with the E. L. Bruce Co., of Memphis, Tenn. The house was entirely of southern yellow pine (except the oak flooring) impregnated with Bruce preservatives, an absorption of approximately 3.9 to 5.5 pounds per cubic foot being obtained. One table was also made of timber impregnated with the Bruce preservative. The wooden piers in contact with the ground and supporting the building had been impregnated with Bruce preservative 5A. The siding, red oak flooring, and other woodwork used above ground had been impregnated with Bruce preservative 5B. The exterior of the building has been kept painted on two sides only, the other two sides being left unpainted.

At the last inspection, in August 1940, the treated oak floor had been so severely damaged by both subterranean and dry-wood termites that it needed replacement. The steps and railing, with the exception of three of the treads, have all been replaced on account of termite damage and rot. A large number of termite tubes had been built on the supports of the building, and in May 1938 a termitarium, or termite nest, 15 inches high by 10 inches wide was constructed in the southeast corner of the building against the floor and two sides by one of the subterranean termites *Nasutitermes* (*N.*) *cornigera* (Motsch).

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[7] See caution on pp. 8 and 9.

ARSENICALS IN FUEL OIL

Arsenic [7] in various forms, alone or in combinations, has been used satisfactorily for a number of years as a wood preservative for poles, etc. Arsenic is toxic to termites as long as it remains in the wood.

Heavy impregnations of sap-pine stakes were obtained with three formulas, namely, 1 percent methyl arsenious oxide in fuel oil (14.15 to 27.22 pounds of solution per cubic foot), 0.67 percent methyl arsenious sulfide in fuel oil (15.05 to 26.30 pounds of solution per cubic foot), and 2 grams of arsenious oxide in 2 gallons of acetone in fuel oil 15.50 to 26.00 pounds of solution per cubic foot). These chemicals gave an average of about 10 years' service on Barro Colorado Island. They were supplied by the Chemical Warfare Service, Edgewood Arsenal, Md., but the impregnations were made by the Forest Products Laboratory.

In cooperation with the Chemical Warfare Service, tests of pine blocks impregnated with 1 percent diphenyl-arsenious oxide in paraffin showed that 40 percent of the blocks were sound after 16½ years' test on Barro Colorado Island.

DINITRONAPHTHALENE IN PETROLEUM OIL

Seventy-five percent of the pine stakes impregnated with a 5-percent solution of dinitronaphthalene [7] in petroleum oil, having an average absorption of 14.3 pounds per cubic foot, were in good condition after about 10 years' test in the ground in the Canal Zone. This chemical is not being used on a commercial scale as a wood preservative but appears to be worthy of further study.

PETROLEUM OILS

Petroleum oils, in general, are not toxic to termites. Although waterproofing or sealing in effect, they are not suitable for use alone as wood preservatives. As a rule petroleum oils are used as diluents for creosotes and as solvents for other toxic chemicals.

Tests in the Canal Zone of pine stakes impregnated with these oils, with an average absorption of 14.4 pounds per cubic foot, showed 62.5 percent in good condition after about 10 years. Another test in Louisiana gave excellent results with a petroleum oil, and it is desirable to conduct further tests of them.

Impregnations With Clean, Paintable Preservatives

ZINC CHLORIDE

According to Drefahl (*3*), zinc chloride [7] is the principal water-soluble preservative used in the United States. It is made by the action of hydrochloric acid on zinc. It is inexpensive, uniform in quality, readily available, and is not a patented preservative. Solutions of 2- to 5-percent strength are used in treating wood, and a minimum net retention of 1 pound per cubic foot of treated wood is recommended. Wood impregnated with it is clean, can be painted,

[7] See caution on pp. 8 and 9.

and is slightly reduced in flammability. Like other water-soluble salts, zinc chloride will leach out of treated timber if exposed to soil moisture or rain; hence, this treatment is not recommended for timbers to be used in contact with the ground. In the international termite exposure test, pine stakes impregnated with an average absorption of 1.52 pounds of dry salt per cubic foot and placed in the ground had an average service of only about 38 months. Impregnated wood must be seasoned, preferably by kiln-drying, after treatment to avoid subsequent shrinkage. Superficial methods of applications by brushing, spraying, or dipping are not recommended.

On Barro Colorado Island, in 1926, a frame test building 16 feet square and 10 feet high inside (fig. 4) was constructed of chemically impregnated southern yellow pine timber by the American Wood Preservers' Association in consultation with the Bureau of Entomology. The foundation piers and framework had been impregnated with coal-tar creosote, the absorptions being 12 pounds per cubic foot of wood (full-cell process) and 8 pounds (empty-cell process), respectively. The remainder of the woodwork and furniture (one table and four chairs) had been impregnated with one-half pound of zinc chloride per cubic foot. The insulation, or fiberboard, had been given a light surface coating of chlorinated naphthalene.

Although erected 14 years ago, there has been no attack by termites on the treated wood. There has been considerable termite activity, however, in wood placed underneath the building as "bait" stakes and periodic activity in tubes constructed by termites on the treated supports. Untreated material of wood or other cellulose-containing products stored in this building have been damaged. The fiberboard ceiling treated with chlorinated naphthalene had been damaged by rain leaking through the roof and later had been attacked by termites and small stingless bees. In 1937 this fiberboard was removed and replaced with insulation board treated with chromated zinc chloride with a retention of the dry salt ranging from 0.42 to 2.23 pounds per cubic foot (*11*).

This demonstration building gave an excellent test of the zinc chloride treatment, since the woodwork above ground was treated with only one-half pound of this salt per cubic foot, whereas the normal recommendation would be 1 pound of zinc chloride, which in general would give considerably better results. The treated woodwork has been kept painted a battleship gray.

Zinc chloride is one of the cheapest preservatives, and although for outdoor uses it is less effective than coal-tar creosote or coal-tar creosote-petroleum solutions, nevertheless it has given effective service under conditions that are suitable for timber treated with water-soluble preservatives.

Zinc chloride is recommended in the Federal specifications (*12, No. 576a*) for the treatment of wood that will not be in contact with the ground or water, or where it must be painted. A minimum net retention of 1 pound per cubic foot is specified.

CHROMATED ZINC CHLORIDE

Since about 1934 sodium bichromate has been added to the zinc chloride by one manufacturer to prevent the leaching out of this chemical. The resulting mixture contains approximately 18 percent of sodium bichromate [7] and 82 percent of commercial zinc chloride. Chromated zinc chloride is not a patented preservative, although there is a patent covering a method of preparing it by the addition of acid to the original formula to prevent precipitation of an insoluble residue.

This preservative is intended for use in pressure-process impregnations, and such superficial methods of application as brushing, spraying, or dipping are not recommended. Like zinc chloride, chromated zinc chloride is intended for impregnation of timber to be used above ground and where it will not be wet. As yet it has not been tested long enough for a comparative evaluation to be made of it.

Chromated zinc chloride is now included in the Federal specifications (*12*, *No. 551*) for treatment of timber to be used where it will not be in contact with the ground or water, or where it must be painted. Three-fourths of a pound of dry salt per cubic foot of wood is the absorption specified.

SODIUM FLUORIDE

Sodium fluoride [7] is an important ingredient in several proprietary preservatives, but it has not been used alone to any extent commercially, except in the treatment of factory roof timbers.

In the international termite exposure test, pine stakes impregnated with sodium fluoride with an average absorption of 1.68 pounds of dry salt per cubic foot—a very heavy net retention—had an average length of life in the ground of only about 2½ years.

This chemical has about the same toxicity as zinc chloride but is more expensive. It also has greater toxicity to man. There are no standard specifications for the use of sodium fluoride as a wood preservative. Solution strengths of from one-half to 3 percent are commonly required for absorptions of one-half to three-fourths pound of dry salt per cubic foot.

MERCURIC CHLORIDE

Corrosive sublimate, or mercuric chloride, was not tested in a pressure impregnation treatment. It is one of the oldest wood preservatives in use (*6*). It is a deadly poison,[7] is expensive, and is corrosive to iron and steel and in consequence cannot be used in ordinary treating apparatus. In the United States the use of mercuric chloride has been very limited. A water solution of about 1 percent is used.

COPPER SULFATE

The use of blue vitriol, or copper sulfate,[7] as a wood preservative dates back to 1767 (*8*, *pp. 41–42*). It has not been tested in a pressure impregnation treatment, as the bluish water solutions of copper sulfate attack iron and steel and cannot be used in ordinary treating apparatus. It is more toxic than zinc chloride, but it has never been extensively used alone in the United States. A 1-percent water solution is usually employed. Copper sulfate and other copper compounds have been used in several proprietary preservatives that promise to be effective.

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[7] See caution on pp. 8 and 9.

WOLMAN SALTS

Wolman salts comprise a group of patented preservatives, all essentially fluoride-phenol mixtures,[7] but varying considerably in composition. In the latest developed salt, Tanalith U, arsenic has been added to give treated wood additional protection from termite attack.

Tanalith U is said to consist of—

	Percent
Sodium fluoride	25
Sodium chromate	37½
Di-sodium arsenate (anhydrous)	25
Dinitrophenol	12½

Wolman salt solutions are usually injected into wood by pressure. It is the recommendation of the company selling this preservative that the absorption should be not less than three-tenths of a pound of dry salt per cubic foot of wood. Superficial methods of application, such as brushing, spraying, or dipping, are not recommended.

Treatment with these salts leaves the wood odorless, clean, and paintable. As with other water-soluble preservatives, the wood should be thoroughly seasoned after treatment.

Two other older Wolman salt preservatives, Tanalith and Triolith, did not give good results in the international termite exposure test in the ground, since these and other salts are unsuitable for use in wood in contact with the ground. The promoters now recommend an absorption of three-tenths of a pound per cubic foot. Although when these tests were begun in 1928 only one-fourth pound was recommended, the wood in the tests was impregnated with three to five times as much as this. Triolith was said to contain 85 percent of sodium fluoride, 10 percent of dinitrophenol, and 5 percent of potassium bichromate.

In later tests in the Canal Zone, 75 percent of the pine stakes impregnated with Tanalith U with an average absorption of 1.45 pounds per cubic foot were in good condition after about 10 years of service in the ground. These stakes, however, contained practically five times as much preservative as is recommended by the manufacturers.

Tanalith U is now included in the Federal specifications (*12*, *No. 573*) for treatment of timber to be used where it will not be in contact with the ground or water, or where it must be painted. The absorption specified is 0.35 pound of dry salt per cubic foot.

Service records for lumber treated with Wolman salts from 1925 to 1940 have been given by Andrews, Gottschalk, and Johnson (*1*). The treated lumber had been in commercial service in various types of exposure, as in paper mills, dye houses, and bridges.

ZINC META-ARSENITE

Zinc meta-arsenite [7] is prepared by mixing a solution of arsenious acid with a water solution of zinc acetate which contains an excess of acetic acid. It is a patented wood preservative sold under the name ZMA and was in rather wide commercial use from about 1927 to 1937. Since then its use in the treatment of poles, timbers, and, to a lesser extent, ties has declined.

[7] See caution on pp. 8 and 9.

ZMA solution is injected into wood by pressure in a manner similar to that used for zinc chloride. The absorption recommended by the proprietors is about one-fourth pound of dry salt per cubic foot of wood. Superficial methods of application, such as brushing, spraying, or dipping, are not recommended.

Wood treated with ZMA is odorless, clean, and paintable, but should be thoroughly seasoned after treatment to avoid shrinkage.

In the international termite exposure test ZMA-impregnated pine stakes were all attacked or destroyed after 12½ years in the ground. In the Canal Zone the average life was 73 months in the ground. The material was treated with an average of 0.77 pound per cubic foot, and some stakes with 1.17 pounds, whereas 0.25 pound of dry salt was the amount then recommended by the promoters. Now an absorption of 0.30 pound is recommended. Wood impregnated with ZMA is particularly unsuitable for use in acid soils. As reported by Giddings (*4*), however, the sponsors of the treatment state that in one lot of 170,000 poles treated with ZMA less than 1 percent has failed in the course of 12 or 13 years. It was not stated in what localities the poles were in service.

ZMA-treated timber has given good service in the Tropics when used above ground. During the latter part of 1931 a frame building (12 by 16 feet) of southern yellow pine timber impregnated with ZMA (0.27 pound per cubic foot) was constructed on Barro Colorado Island in cooperation with the manufacturer. The furniture was likewise so impregnated, and insulation or fiber wallboard which had been treated with ZMA was installed. The outside of the building was painted green. After 10 years' service this building shows no signs of deterioration or attack by termites. There has been some corrosion of the copper screens owing to the use of chemically treated window frames. This has necessitated their replacement with untreated fir frames.

ZMA is now included in the Federal spcifications (*12*, *No. 581*) for treatment of timber to be used where it will not be in contact with the ground or water, or where it must be painted. The absorption specified is 0.35 pound of dry salt per cubic foot.

CELCURE

Celcure is odorless, and the treated wood is clean and paintable. This patented preservative, composed of copper sulfate, potassium bichromate,[7] and acetic acid, came into commercial use in the United States about 1931. It is applied by pressure treatment and also by a patented method which includes heating with steam and immersing in cold Celcure solution. When substantial absorptions and penetrations have been obtained, good protection may be expected. Although Celcure is also sold for application by brush, spray, or dipping, such treatments give very shallow penetrations, are unlikely to prove satisfactory, and are not recommended.

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[7] See caution on pp. 8 and 9.

Celcure is now included in the Federal specifications (*12, No. 546*) for pressure treatment of timber to be used where it will not be in contact with the ground or water, or where it must be painted. The absorption specified is 0.50 pound of dry salt per cubic foot.

In the international termite exposure test in the Canal Zone, 75.0 to 87.5 percent of the impregnated pine stakes were good after about 10 years' service. In this test the absorptions were excessively high (28.3 to 29.5 pounds of solution per cubic foot).

AC-ZOL

Ac-zol is a patented mixture of copper, zinc, and phenol[7] which has not had extensive commercial use in the United States, hence enough service records are not available for any relative evaluation of it as a wood preservative under conditions found in this country. In the international termite exposure test in the Canal Zone the use of a 6-percent solution in water with an average absorption of 28 pounds of solution per cubic foot left 75 percent of the impregnated pine stakes in good condition after about 10 years' service. A 10-percent solution with an average absorption of 30.9 pounds of solution per cubic foot left none in good condition. Such absorptions are far in excess of those recommended by the manufacturer.

CHLORINATED PHENOLS IN LIGHT PETROLEUM OILS

Five-percent solutions of tetrachlorphenol and pentachlorphenol in light petroleum oils show promise as wood preservatives. They are also being sold in combination with other chemicals under various trade names and are being used commercially. The results of longer service records will be awaited with interest. Solutions of chlorinated phenols are irritating to the skin,[7] and workmen using them should be protected by rubber gloves and aprons or other suitable protection.

In tests of treated wood in the ground in the Canal Zone, 75 percent of the pine stakes impregnated with 4.8- and 5-percent tetrachlorphenol solutions, with an average absorption of 13.8 pounds per cubic foot, are in good condition after about 10 years. Similar tests of pentachlorphenol in the continental United States, with absorption of 0.5 pound straight pentachlorphenol per cubic foot, have shown a similar percentage of sound stakes after at least 5 years' test in the ground.

Treatments With Clean, Nonswelling Preservatives for Millwork and Furniture

A group of preservatives of recent development meet the particular need for a clean treatment that will not swell the wood and that will leave it odorless and paintable. Some of these preservatives have been approved by the National Door Manufacturers' Association for window sash, frames, and doors, and are in commercial use. Other materials, such as furniture, millwork, and cabinet woods, may be similarly treated, ordinarily by dipping in cold solutions with proper periods of immersion, so as to obtain effective treatments.

The chlorinated phenols, alone or in combinations, betanaphthol, and alphanitronaphthalene[7] are some of these toxic preservatives,

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[7] See caution on pp. 8 and 9.

which are usually sold under trade names. They are ordinarily used as 5-percent solutions in volatile solvents or in petroleum oils of the fuel-oil grade. As yet there are not enough service records to warrant dependable conclusions as to the relative effectiveness of these preservatives.

Miscellaneous Treatments

CHLORINATED NAPHTHALENE

Chlorinated naphthalene [7] is a waterproofing toxic wax sold under the trade name "Halowax." It has a marked chlorine odor which is disagreeable to some people. In the international termite exposure test 29.1 percent of the impregnated stakes whose average absorption was 20.1 pounds per cubic foot were in good condition after 12½ years' service in the ground. Of course, such absorptions are much higher than are commercially practicable.

In cooperation with the Western Electric Co., tests were established on Barro Colorado Island in 1924 of 6- by 6- by ½-inch panels of various hardwoods which had been soaked for 15 minutes in molten chlorinated naphthalene at 220° to 240° F. These blocks absorbed 2 to 3 ounces of the wax per board foot. After 5 years' service only 17 percent of the impregnated samples were in good condition. This is quite a different result from that obtained with the heavier impregnations of chlorinated naphthalene just referred to in the international termite exposure test.

Chlorinated naphthalene is an effective preservative treatment for cabinet woods and furniture, as indicated by the results of tests to protect wood against dry-wood termites in South and Central America. It may be difficult to paint over the treated wood.

SUPERFICIAL METHODS OF TREATMENT

The superficial treatments, such as brushing and only brief soaking, do not afford effective, permanent protection. The inner, hidden parts are untreated, and when the outer surface becomes broken the exposed wood is soon destroyed. Some soaking treatments give more than superficial penetration and have legitimate uses where the added life desired does not warrant more costly impregnation treatments, and for use under circumstances where better, more permanent treatments are not available. However, creosotes, carbolineums, coal-tar, and copper or copper-bronze paints [7] brushed on have given an average of 5 to 6 years' life to timbers in contact with the ground in the Canal Zone. Such treatments gave effective protection against attack by dry-wood termites where the painted wood was used above ground. In general, such coated timbers gave much longer service when used above ground than untreated wood. The addition of sand to protective paints is of no value; silica will not protect cellulose products from attack by subterranean termites, which have destroyed both sand and emery papers.

The smelter-waste dusts [7] and pastes containing arsenicals, when used by the diffusion processes, have given varying results, but the pastes appear to be more effective than the dusts in protecting timber against attack by termites, their effectiveness depending upon the

[7] See caution on pp. 8 and 9.

thoroughness of application and the environment in which they are used. An arsenical dust treatment (cold treater dust), however, gave pine stakes in the ground about which it had been placed a life of 76 months in the Canal Zone, where untreated stakes had a life of only 8 months.

Methods of Injecting Metallic Salts Into Trees

Under the Federal specifications of the United States Treasury Department (*12*) certain standard chemicals and methods are approved for preservative treatments of timber. These recommendations, however, need not conflict with other recommendations for simple, cheap tree medication or injections for use at home or on the farm for trees, poles, posts, or rustic work.

The tree-injection method [8] [9] (*2*) consists in impregnating the wood of standing or freshly felled trees with toxic chemicals to preserve it for use after the trees are sectioned. Aqueous solutions of metallic salts are the most effective preservatives. The preservative is well distributed throughout the tree in about 10 days, but the heaviest absorptions are in the lower portion of the tree.

TREATMENTS FOR FIBERBOARDS MADE DURING MANUFACTURE

Large-scale tests of wood-pulp products or fiberboards of various types, into which poisons have been incorporated during the course of manufacture, have been installed in this country (fig. 5) as well as in the Tropics to determine the chemicals most effective in preventing termite attack.

Standard methods of testing the effect of chemicals added to fiberboard during manufacture to determine their effectiveness in preventing attack by termites and decay have gradually been developed since the senior author made his first tests in 1915, as reported by him in 1924 (*9*).

Such treated products contain the toxic chemicals uniformly distributed throughout the board, and the retention of toxic material in terms of percent of the weight of the dry board must be obtained prior to testing the board.

Several effective methods of testing have been developed. In one, stakes of three-ply thickness, 4 inches wide, and of various lengths (fig. 5), are set into the ground. In another, the wallboard is stacked vertically, with an untreated fir board between each two experimentally treated fiberboards, each treatment being tested in a separate fir box without top or bottom. Termites have a good chance to work up from the ground into the fir and thence into the untreated and treated wallboards. The excess water drains off, whereas when a box with a bottom is partly buried in the earth the water does not drain. This method approximates the manner in which wallboard is used under actual service conditions. If the treatment is effective, the termites cannot do more than nibble on the board.

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[8] Craighead, F. C., St. George, R. A., and Wilford, B. H. A METHOD FOR PREVENTING INSECT INJURY TO MATERIAL USED FOR POSTS, POLES, AND RUSTIC CONSTRUCTION. U. S. Bur. Ent. and Plant Quar. E–409, 7 pp., illus. 1937. (Processed.)

[9] Lantz, A. E. AN EFFICIENT METHOD FOR INTRODUCING LIQUID CHEMICALS INTO LIVING TREES. U. S. Bur. Ent. and Plant Quar. E–434, 4 pp., illus. 1938. (Processed.)

Figure 5.—Stakes of poisoned fiberboard in the ground and on the ground under various forms of shelter. Near Saucier, Miss., 1939.

A commercial wallboard company has developed another successful method of testing, namely, to place the stacks of wallboard a short distance off the ground on bricks and then connect the wallboard with the artificially infested ground by means of vertical wicks of untreated wallboard. This prevents the boards from becoming too wet.

A simplification of this method by another company is to place small sections of fiberboard, two together, between bricks placed sideways in a shallow trench and then cover the test boards and the bricks with other bricks (fig. 6). If the tests are made in a region of considerable rainfall, drainage ditches should be dug around the trench.

In all these methods predaceous ants jeopardize the results by killing off the termites, and after inspections all materials should be replaced so as to leave the termite tunnels exposed as little as possible.

A summary of the results of tests of the poisons for protecting fiberboards from attack by termites indicates that the arsenicals have been under test for the longest periods. White arsenic (arsenious acid), zinc meta-arsenite, and certain trade-name arsenicals, at the rate of 0.2 percent for domestic use and 0.6 percent white arsenic for use in the Tropics have protected fiberboards for as long as 5 to 8 years in tests conducted in Louisiana and the Canal Zone. Pentachlorphenol, at the rate of 0.75 to 1 percent of the dry weight of the board, has effectively protected fiberboards in tests in the continental United States and the Canal Zone for several years, a few recent tests having been under way for 5 years. Tests under way at the present time will give more conclusive results than the earlier tests, since the methods have become standardized and quicker, more conclusive results are now being obtained.

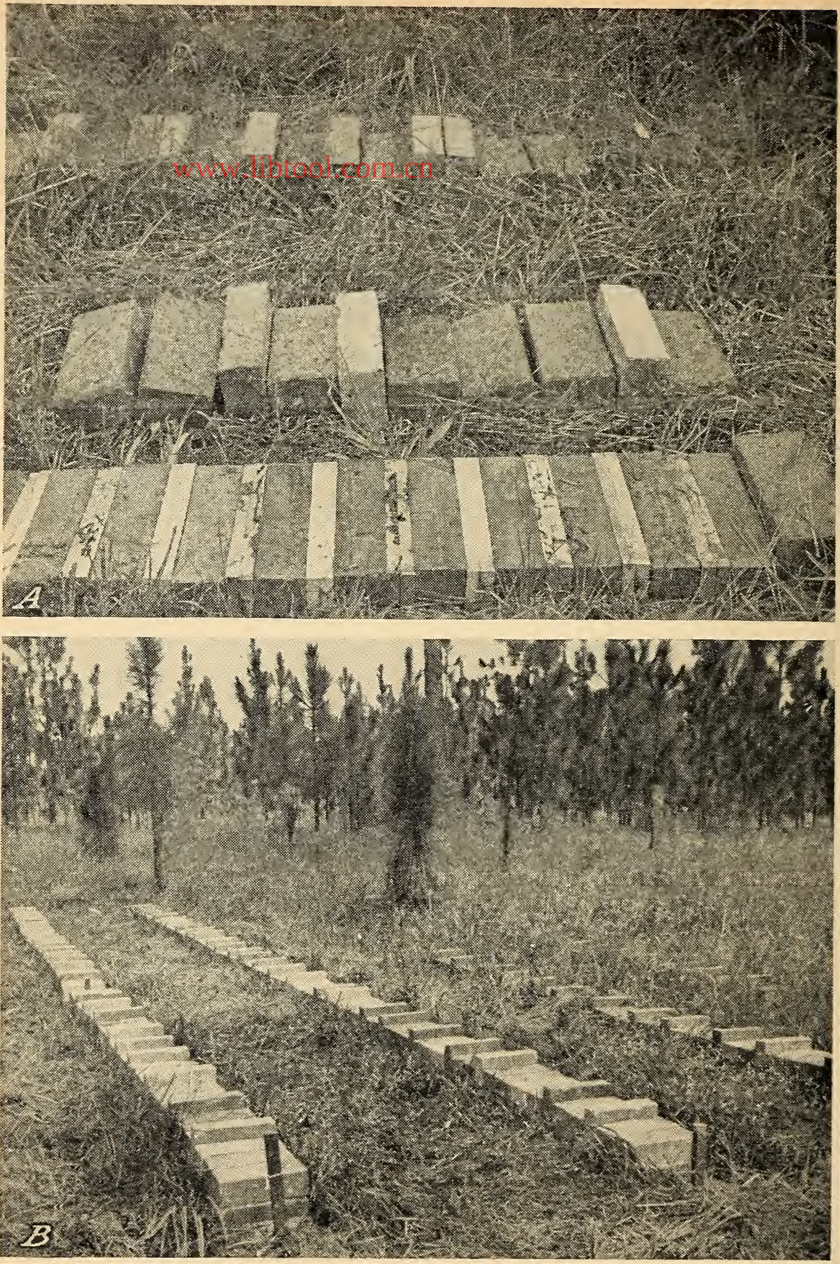

FIGURE 6.—Method of testing poisoned fiberboard in a trench between bricks and covered with bricks: *A*, Fiberboard samples set in between bricks; *B*, the rows of test samples covered by other bricks. Saucier, Miss., 1938.

SUMMARY

There are three general classes of wood preservatives, as described in the following three paragraphs.

Preservative oils, such as creosotes and combinations in petroleum or tar, are especially adapted for the pretreatment of timber to be used in contact with the ground.

Water-soluble salts, such as zinc chloride, chromated zinc chloride, and several proprietary preservatives, are for use as "white," or clean, pretreatments. They are ordinarily utilized above ground, and the wood can be finished or painted after treatment. When used in considerable concentrations (higher than commercially practicable), however, water-soluble salt impregnations give fair service where the treated timber is used in the ground.

Certain toxic chemicals which are nearly colorless, dissolved in light petroleum oils, are adapted for the nonpressure immersion treatment of finished articles. The wood does not swell or shrink, dries rapidly, and is left clean, and after treatment it can be finished or painted.

There are many methods of preserving wood, some being simple, nonpressure processes and others being pressure processes requiring expensive equipment. In commercial enterprises the type of treatment must necessarily be determined by the cost and the length of service required.

With the object of protecting wood against termites, service tests of wood preservatives have been conducted by the Bureau of Entomology and Plant Quarantine since 1912. These tests were begun in this country, extended to the Canal Zone, and later set up in several tropical countries, where they have been made in cooperation with foreign governments.

No one test can be safely relied on for definite conclusions. Results must be compared with those obtained from other tests and from service records of timbers in actual use. Results of tests of some of the commercial preservatives are in agreement with the recommendations in Federal specifications for wood preservatives.

Commercial impregnations with preservative oils, including the chlorinated phenols, are effective where the timbers are to be utilized in contact with the ground.

Water-soluble salt preservatives give effective protection of impregnated timbers to be used above ground.

Even when the most toxic chemicals are used, uniform, well-distributed, and good penetration into the wood is essential for effective preservative impregnations.

In general the open-tank or "natural vacuum" process of impregnation is not so effective as the pressure process of impregnation.

Although superficial treatments, such as brushing, dipping, and temporary soaking, may add life to timber for which impregnation treatments are unavailable, they cannot be considered as effective, permanent treatments for timber to be used in contact with the ground.

Standardized tests in the continental United States and the Canal Zone of poisons for integral treatments of fiberboards to protect them from attack by termites indicate that arsenicals and pentachlorphenol are effective preservatives.

Practically all the chemicals and combinations of chemicals used for protecting wood from insect attack are poisonous to human beings, some are inflammable, and some are especially dangerous. However, these chemicals can be used without danger if ordinary precautions are taken. Water-soluble wood preservative salts are used in rendering wood fire-resistant.

Storage of large quantities of poisonous substances by the layman should be avoided. Persons unfamiliar with the use of these substances should obtain expert advice before attempting to apply them.

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