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Preservative Moisture-Repellent Treatments *for* Wooden Packing Boxes

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Three-minute dips protected boxes for a short time against wetting and 3 to 5 years against decay; soil poisons were needed to stop termites. Pressure treatments protected against both.

Fig. 1.—Test exposure piles. (Cover) Fully exposed pile of M22 boxes on poisoned soil, Mississippi. (Above) M22 boxes exposed in jungle, Panama.

THE WOODS COMMONLY USED for shipping crates and boxes have no appreciable natural resistance to fungi and insects. Consequently, containers exposed to the elements are usually attacked by biological deteriorating agents. These agents include decay fungi that destroy wood, and staining and molding fungi that cause little loss in strength but can obscure stencil markings.

For fungus decay it is necessary, of course, for the wood to be wet (above 20 per cent moisture content) but not water-soaked, and for temperatures to be between 50 and 100° F. Termites do not require wet wood for attack, but merely an unobstructed passage from their nest to the wood.

Military Exposures May Be Severe

Wooden boxes and crates for most civilian use are seldom fully exposed long enough to suffer serious fungus decay. Even for military use during peace-time, containers are stored mostly in buildings and consequently are not seriously attacked. In war, however, it is often necessary to store large amounts of ammunition, supplies, and equipment in containers fully exposed to the elements. Heavy fungus deterioration of wooden containers so stored occurred in the South Pacific and continental United States during and just after World War II; often, wooden ammunition boxes were rendered useless after one year. Before ammunition igloos were sufficiently ventilated and waterproofed, wooden boxes stored in them decayed rapidly in both the southern and northern states.

The heartwood of some tree species is naturally decay-resistant, but high costs and limited supplies preclude its general use in box manufacture. A number of common preservatives, when impregnated into wood, will give longtime protection, but usually there is doubt that enough units of a given type of container will be exposed to an extent that would warrant the general use of pressure treatments. Also, poor paintability of wood pressure-treated with some oils and the need for reseasoning boxes impregnated with water solutions would be factors against the use of some pressure treatments.

Dip Treatments

A 3-minute dip or a vacuum treatment with light petroleum solutions of such preservatives as pentachlorophenol has been widely used in the sash and door industry for a number of years. There is little exact data on the protection afforded, but the general impression is favorable. During the past 15 years, considerable experimental evidence has been accumulated on the effectiveness of surface applications of preservatives by brushing, dipping, or soaking for short periods. In soil-burial tests, surface applications ex-

[1] This study was conducted in cooperation with Pitman-Dunn Laboratories, Frankford Arsenal, Army Ordnance Corps. The tropical exposure site was furnished by the Naval Research Laboratory, U. S. Navy.

[2] A short summary of this report was presented at Session V, Wood Preservation, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

[3] Aid in planning, executing, and interpreting these studies was given by L. Teitell, Pitman-Dunn Laboratories and by R. M. Lindgren and T. C. Scheffer, U. S. Forest Products Laboratory.

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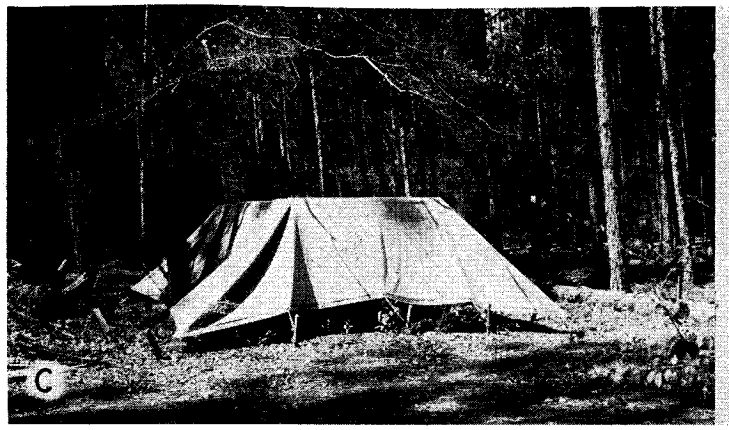

Fig. 1c.—Pile of M22 boxes covered with a tarpaulin, Mississippi.

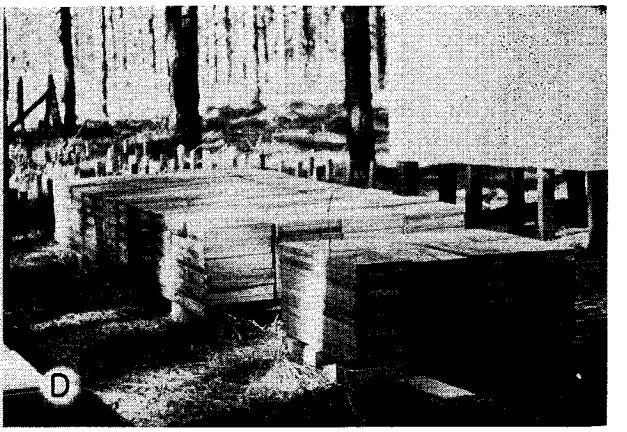

Fig. 1d.—Simulated boxes exposed on creosoted sills, Mississippi.

tended service life only a little (1),[4] but in southern Mississippi (6) 3-minute dips materially increased the life of steps, porch floors, and step rails; 15-minute or longer soaks gave longtime protection to wood that was off the ground but still exposed to rain seepage. The data were sufficiently promising to warrent large-scale tests on the effectiveness of dips and short-period soaks in preventing deterioration of ammunition boxes.

MATERIALS AND METHODS

Test Units

The main test units, including all exposed in Panama and Wisconsin, were 3,000 M22 small-arms ammunition shipping boxes (cover) secured from new warehouse stock at Frankford Arsenal. At the time of treatment, the boxes were thoroughly dry, that is, at about 12 per cent moisture content, and relatively free of fungus stains, molds, and decay. Most wood in the boxes was eastern white pine but some was aspen, yellow-poplar, northern spruce, balsam, and hard pine. The boxes were kept in dry, indoor storage until they were treated, except for some in which moisture content at the time of treatment was under test.

At Gulfport, Mississippi, a number of supplementary tests were made with "simulated box" test units (Fig. 1D). These consisted of two pieces of nominal 1 by 8 lumber, 12 inches long, nailed to peripheral cleats about 1.5 inches wide. A 3/8-inch hole was bored in each face board to allow ready entry of water. In effect, the unit was a box with an interior void nominally 1 by 5 by 9 inches. These units permitted better matching of wood among test categories than did the more variable boxes. All the wood in these simulated boxes was free of obvious fungus infections, but in some tests wood was conditioned to various moisture contents or infected with fungi prior to treatment. Most of these boxes were made of the sapwood of southern yellow pine, but several other species were included.

Forty-eight M22 boxes were made at Gulfport from southern yellow pine sapwood, and divided into 4 groups: Untreated; dipped for 3 minutes in 5 per cent pentachlorophenol; dipped for 3 minutes in 5 per cent pentacholophenol plus a water repellent; and dipped for 3 minutes in 0.3 per cent copper 8-quinolinolate. No hardware was used on these boxes. Southern yellow pine was included because it is used in many types of ammunition boxes, is absorptive, and has low decay resistance.

One hundred wire-bound crates, largely of rotary-cut veneer of southern hardwoods, were dip-treated for exposure at Gulfport.

Treating Solutions

Following is a list of the fungicides and insecticides, solvents, and water repellents that were used.

Toxicants: *Borax.* Technical grade, finely granulated; used to fortify some water solutions.

Benzene hexachloride. Lindex WE–125, a concentrate containing 12.5 per cent gamma isomer.

Copper ammonium fluoride. A complex containing 5.1 per cent metallic copper, dissolved in water; concentration as per cent of the complex.

Copper 3-phenyl salicylate. Crystals dissolved in butanol (15 per cent) and aromatic mineral spirits (85 per cent).

Copper 8-quinolinolate. Cunilate 2174, a 10 per cent concentrate diluted with aliphatic mineral spirits.

Copper naphthenate. Nuodex Cu–8, a concentrate containing 8 per cent metallic copper diluted with aliphatic mineral spirits.

Copper pentachlorophenate. Technical grade crystals dissolved in methyl cellosolve (20 per cent) and diluted with aliphatic mineral spirits (80 per cent).

Orthophenylphenol. Crystals (Dowicide 1) dissolved in aliphatic mineral spirits. Concentrations expressed as per cent Dowicide 1. In cold weather, solubility was increased by using a small amount of aromatic mineral spirits.

Pentachlorophenol. Crystals (Dowicide 7) dissolved in aromatic mineral spriirits and diluted with an equal amount of aliphatic mineral spirits (Concentrations expressed as per cent Dowicide 7); 8 per cent Hecolyn (methyl ester of hydrogenated rosin) was added to prevent blooming.

Phenyl mercuric oleate. IN–2555, a 10 per cent concentrate diluted with aliphatic mineral spirits.

Rosin amine D acetate. A 30 per cent concentrate diluted with water.

Rosin amine D pentachlorophenate. Technical grade, dissolved in aliphatic mineral spirits.

Sodium pentachlorophenate. Concentrations expressed as per cent Dowicide G in water.

Sodium tetrachlorophenate. Concentrations expressed as per cent Dowicide F in water.

Tetrachlorophenol. Concentrations expressed as per cent Dowicide 6; dissolved in aliphatic mineral spirits.

Zinc naphthenate. Nuodex Zn–8, a concentrate containing 8 per cent metallic zinc diluted with aliphatic mineral spirits.

Supplementary tests included several of the most widely-used commercial solutions of chlorinated phenols, and some water-borne salts were used for pressure treatment of some M22 boxes as listed under "Treatment."

Solvents: *Aliphatic mineral spirits.* Kyso, sold by Standard Oil Company of Kentucky.

Aromatic mineral spirits. SS–91, a petroleum mineral spirits with high aromatic content, sold by Southern Solvents, New Orleans.

[4] Numbers in parentheses refer to the Literature Cited at the end of this report.

Butanol. Sold by Commercial Solvents Corporation.

Methyl cellosolve. Sold by Carbide and Carbon Chemicals Company.

Water Repellents: Two of the proprietary products already contained water repellents. In most oil solutions, the water repellent consisted of 8 per cent Hercolyn (methyl ester of hydrogenated rosin) and 2 per cent paraffin wax (AMP 125° F.). The repellent for water solutions was 4 per cent paraffin wax added as 8 per cent Ceremul A, a 50 per cent wax emulsion sold by Socony Vacuum Oil Co. A few other repellents were tried in one or two tests and will be described later.

Concentrations: The concentrations and combinations of chemicals in the main test are given in Table 1. In general, the chemicals were used at three concentrations:

1) That ordinarily used for wood preservation or, for new chemicals, that which, from other uses and known properties, appeared to be suitable.

2) One-half the concentration used in 1), in the hope that quicker determination of the relative effectiveness of different chemicals might be secured; and

3) Twice the concentration used in 1), because it was thought that higher than usual concentration might be needed to protect boxes under the severe conditions in large piles exposed outdoors.

Treating

The M22 boxes were treated between April and July 1952. For dip treating, the box covers were wedged open ½ inch. For the main test, the treating procedure was: 1) weigh boxes, 2) dip for 3 minutes, 3) drain for 4 minutes, 4) reweigh, 5) open-pile under cover for 3 to 5 days for evaporation of solvent, and 6) solid-pile until exposed in the field. The 3-minute immersion period was chosen because it is commonly used in the sash and door industry; much of the absorption in short-period soaks occurs during the first minute, and a 3-minute dip can be fitted into production-line methods. For one supplementary test, immersions were for 5 and 10 seconds, and 1, 2, 3, and 10 minutes, in six different solutions.

To determine the effect of paint on protection and the effect of the main treatments on paintability and paint durability, some boxes were given 2 spray coats inside and outside with enamel (TT-E-485b, Type II, olive drab). Painting was delayed for at least 7 days after treatment to permit evaporation of the solvents.

The Forest Products Laboratory, Madison, Wisconsin, pressure-treated 221 boxes, primarily as reference ma-

Table 1.—AVERAGE RETENTIONS OF PRESERVATIVE, IN POUNDS OF SOLUTION PER CUBIC FOOT

Treatment	Panama		Mississippi						Wisconsin	
			With tarpaulin cover		Uncovered piles					
					Painted boxes		Unpainted boxes			
	WR	No WR	WR	No WR	WR	No WR	WR	No WR	WR	No WR
Oil Solutions, 3-Minute Dips										
Benzene hexachloride (0.5% gamma)	----	0.9	----	----	----	----	----	----	----	----
Copper naphthenate										
0.5% Cu	----	----	----	----	----	----	1.0	----	----	----
1.0% Cu	1.2	----	1.5	----	1.2	----	1.2	1.2	1.1	----
2.0% Cu	1.1	----	----	----	----	----	.9	1.1	----	----
Copper pentachlorophenate										
2.5%	----	----	----	----	----	----	1.4	----	----	----
5.0%	1.4	----	----	----	----	----	1.2	1.2	1.2	
Copper 3-phenyl salicylate										
1.25%	----	----	----	----	----	----	1.2	----	----	----
2.5%	1.2	----	1.1	----	1.0	----	1.1	1.1	1.1	----
5.0%	1.1	----	----	----	----	----	1.2	1.1	----	----
Copper 8-quinolinolate										
0.15%	----	----	----	----	----	----	.9	----	----	----
0.3%	1.0	----	1.1	----	1.1	----	1.1	1.0	1.0	----
0.6%	1.0	----	----	----	----	----	1.2	1.0	----	----
0.3% plus 0.5% gamma benzene hexachloride	----	.9	----	----	----	----	----	.9	----	----
Mineral spirits (aliphatic) 100%	1.0	----	1.0	1.0	1.0	0.9	1.0	.9	1.0	----
Orthophenylphenol										
2.5%	----	----	----	----	----	----	.9	----	----	----
5.0%	1.2	----	1.1	----	1.0	----	1.1	1.0	1.1	----
10.0%	1.2	----	----	----	----	----	1.0	1.1	----	----
Pentachlorophenol										
2.5%	----	----	----	----	----	----	1.2	----	----	----
5.0%	1.1	----	1.1	----	1.1	----	1.1	1.2	1.1	----
10.0%	1.2	----	----	----	----	----	1.3	1.3	----	----
5.0% plus 0.5% gamma benzene hexachloride	----	1.2	----	----	----	----	----	1.1	----	----
Phenyl mercuric oleate										
0.15%	----	----	----	----	----	----	1.0	----	----	----
0.3%	.9	----	1.0	----	1.0	----	.9	.9	1.0	----
0.6%	1.0	----	----	----	----	----	.9	.9	----	----
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent										
25.0%	.9	----	----	----	----	----	1.0	----	----	----
37.5%	1.0	----	----	----	1.1	----	1.0	----	1.1	----
Rosin amine D pentachlorophenate										
2.75%	----	----	----	----	----	----	1.0	----	----	----
5.5%	1.0	----	1.1	----	.7	----	1.0	1.1	1.0	----
11.0%	1.0	----	----	----	----	----	1.0	1.0	----	----
Tetrachlorophenol										
2.5%	----	----	----	----	----	----	1.1	----	----	----
5.0%	1.0	----	----	----	----	----	1.0	1.1	1.0	----
10.0%	1.1	----	----	----	----	----	1.1	1.2	----	----
Zinc alkyl sulphonate										
2.8%	----	----	----	----	----	----	1.0	----	----	----
5.7%	1.1	----	----	----	1.1	----	1.0	----	1.2	----
Zinc naphthenate										
0.5% Zn	----	----	----	----	----	----	1.0	----	----	----
1.0% Zn	1.0	----	1.0	----	1.0	----	1.0	1.0	1.0	----
2.0% Zn	1.3	----	----	----	----	----	1.1	1.0	----	----
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride										
5.0%	----	----	----	----	----	----	----	1.6	----	----
10.0%	1.6	1.6	----	1.6	----	1.7	1.3	1.6	----	1.7
20.0%	----	1.6	----	----	----	----	----	1.6	----	----
Product continaing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol										
2.5%	----	----	----	----	----	----	----	1.8	----	----
7.5%	----	2.1	----	----	----	----	----	2.1	----	----
Rosin amine D acetate										
2.5%	----	----	----	----	----	----	----	1.7	----	----
5.0%	----	1.9	----	----	----	1.7	----	1.7	----	1.9
10.0%	----	1.8	----	----	----	----	----	1.8	----	----
Sodium pentachlorophenate										
2.85%	----	----	----	----	----	----	----	1.8	----	----
5.7%	----	1.7	----	----	----	1.7	1.7	1.9	----	1.8
11.4%	----	1.8	----	----	----	----	----	1.7	----	----
2.0% plus borax 3.0%	1.6	1.8	----	1.8	----	1.8	1.6	1.9	----	1.7
4.0% plus borax 4.0%	----	1.8	----	----	----	----	----	2.0	----	----
Sodium tetrachlorophenate										
2.85%	----	----	----	----	----	----	1.7	----	----	----
5.7%	1.8	1.9	----	----	----	1.8	1.7	1.7	----	1.9
Water repellent										
4% solids	----	----	----	----	----	----	1.5	----	----	----
Oil Solution, Pressure Treatment										
Pentachlorophenol, 5%	5.8	5.6	----	----	----	5.2	5.5	5.8	----	5.2
Water Solutions, Pressure Treatments										
Copperized chromated zinc chloride	----	.81[1]	----	.80[1]	----	----	----	.70[1]	----	.78[1]
Tanalith	----	.34[1]	----	.37[1]	----	----	----	.29[1]	----	.34[1]
Celcure	----	.51[1]	----	.39[1]	----	----	----	.52[1]	----	.50[1]

[1] Expressed as pounds of dry salt.

Table 2.—RATE OF DECAY OF M-22 BOXES EXPOSED IN THE PANAMA CANAL ZONE

Treatment	Average decay rating[1]					Proportion of failure[2]				
	0.5 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.	0.5 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.
						Per cent				
Oil Solutions, 3-Minute Dips										
Benzene hexachloride (0.5% gamma)	2.3	2.6	4.1	4.9	---	0	0	58	100	---
Copper naphthenate										
1% Cu plus WR	.1	.4	1.3	2.4	3.6	0	0	0	23	35
2% Cu plus WR	.0	.0	.4	2.0	2.8	0	0	0	10	20
Copper pentachlorophenate										
5% plus WR	.2	.3	1.5	2.6	3.0	0	0	0	9	9
Copper 3-phenyl salicylate										
2.5% plus WR	.4	.5	2.0	3.8	4.5	0	0	10	50	75
5.0% plus WR	.0	.6	1.9	3.7	4.4	0	0	0	50	83
Copper 8-quinolinolate										
0.3% plus WR	.1	.7	2.3	3.9	4.4	0	0	17	57	77
0.6% plus WR	.1	.6	1.7	3.5	4.5	0	0	0	33	80
0.3% plus 0.5% gamma benzene hexachloride	.5	1.4	2.6	4.4	4.7	0	0	0	70	89
Orthophenylphenol										
5% plus WR	1.0	1.0	2.2	3.5	4.0	0	4	9	35	62
10% plus WR	1.0	1.3	1.9	4.0	4.4	0	0	0	50	78
Pentachlorophenol										
5% plus WR	.4	.4	1.9	2.9	3.6	0	0	5	25	25
10% plus WR	.2	.8	1.8	2.8	4.1	0	0	0	17	57
5% plus 0.5% gamma benzene hexachloride	.6	.9	2.0	3.1	3.7	0	0	0	18	36
Phenyl mercuric oleate										
0.3% plus WR	.1	.9	2.4	4.5	4.6	0	0	5	65	89
0.6% plus WR	.3	1.0	2.0	4.3	5.0	0	0	0	67	100
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent										
25% plus WR	.5	1.4	3.3	4.9	---	0	0	30	100	---
37.5% plus WR	1.1	1.3	3.4	4.9	4.9	0	0	30	90	100
Rosin amine D pentachlorophenate										
5.5% plus WR	.3	.3	1.9	2.9	3.6	0	0	0	18	33
11.0% plus WR	.2	.7	1.8	3.0	3.8	0	0	0	11	50
Tetrachlorophenol										
5% plus WR	.2	1.2	2.9	4.0	4.5	0	0	10	50	90
10% plus WR	.2	.5	1.5	2.5	3.2	0	0	0	9	9
Water repellent only	1.3	2.1	3.3	4.5	4.8	0	0	28	84	91
Zinc alkyl sulphonate										
5.7% plus WR	.6	1.2	2.8	4.6	5.0	0	0	30	70	100
Zinc naphthenate										
1% Zn plus WR	.3	.5	2.6	4.1	4.7	0	0	16	63	88
2% Zn plus WR	.6	1.1	2.3	3.9	4.2	0	0	20	56	78
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride										
10%	.5	1.1	3.3	4.5	4.6	0	0	5	77	88
20%	.2	.6	2.4	4.4	5.0	0	0	0	78	100
10% plus WR	.5	.7	2.0	3.3	4.7	0	0	0	45	88
Product containing sodium salt of dimethyl dithiocarbamic acid and 2-mercapto benzothiazole and pentachlorophenol, 7.5%	.6	1.1	2.6	4.2	4.4	0	0	36	73	78
Rosin amine D acetate										
5%	.4	1.2	3.3	4.5	4.9	0	0	36	82	100
10%	.2	.7	1.3	3.3	4.2	0	0	0	36	56
Sodium pentachlorophenate										
5.7%	.4	.5	2.0	2.9	3.6	0	0	0	9	44
11.4%	.2	.6	1.9	3.0	3.5	0	0	0	9	40
2.0% plus borax, 3%	.5	.5	2.3	3.4	3.7	0	0	18	32	48
4.0% plus borax, 4%	.3	.6	1.7	2.7	3.4	0	0	0	9	22
2.0% plus borax, 3%, plus WR	.3	.7	2.4	3.8	4.3	0	0	10	50	70
Sodium tetrachlorophenate										
5.7%	.2	.6	2.4	3.6	3.8	0	0	0	30	56
5.7% plus WR	.7	.8	2.9	3.9	4.4	0	0	9	55	80
Oil Solutions, Pressure Treatments										
Pentachlorophenol										
5%	.2	.5	1.7	2.0	2.9	0	0	13	19	20
5% plus WR	.2	.4	.7	1.9	2.9	0	0	0	10	15
Water Solutions, Pressure Treatments										
Copperiazed chromated zinc chloride	.0	.1	.2	.7	2.4	0	0	0	0	0
Tanalith	.1	.3	1.3	3.1	3.2	0	0	0	13	13
Celcure	.1	.0	.4	1.6	2.8	0	0	0	11	19
Untreated	1.4	2.1	3.1	4.3	4.8	0	6	25	81	88

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

terial in interpreting results with the dip treatments. Five common commercial solutions were used:

1) Five per cent pentachlorophenol plus 4 per cent Hercolyn in Enjay Solvent #3,

2) Five per cent pentachlorophenol plus 8 per cent Hercolyn and 2 per cent paraffin in Enjay Solvent #3,

3) Celcure (Federal Specification TT-W-546) 1.7 to 1.8 per cent in water,

4) Tanalith (Federal Specification TT-W-573) 0.9 to 1.2 per cent in water,

5) Copperized chromated zinc chloride (dry salts 73 per cent zinc chloride, 20 per cent sodium dichromate, and 7 per cent cupric chloride), 2.7 per cent in water.

The oil solutions were applied by the Rueping process and the water solutions by the full-cell method.

Exposure

The M22 boxes were exposed, starting in the summer and fall of 1952, at 3 geographical locations: Madison, Wisconsin (average rainfall 31 inches, 171-day growing season); Gulfport, Mississippi (average rainfall 60 inches, 276-day growing season); and Fort Sherman, Panama Canal Zone (average rainfall 130 inches, 365-day growing season).

1) At Madison, all boxes were put in three piles (4 by 6 by 4 boxes high) on untreated soil under the partial shade of hardwood trees.

2) At Gulfport, the main test was exposed as four piles under partial hardwood shade. Three piles were 7 by 16 by 4 boxes high (Fig. 1A). Two of these were on untreated soil from which leaf litter had been removed. The third was on soil that, after removal of leaf litter, was sprinkled with 5 per cent DDT in diesel oil at the rate of 1 pint per square foot. The DDT was for the exclusion of termites. The fourth pile, 6 by 6 by 6 boxes, was on similarly treated soil but was covered, while the boxes were dry, with a tarpaulin (Fig. 1C).

3) In Panama, three piles, 6 by 8 by 4 boxes high (Fig. 1B), were placed under jungle cover at the Naval Research Laboratory's Tropical Exposure Site, Fort Sherman. Two of these piles were on untreated soil while the third was on soil treated with 5 per cent DDT in No. 2 fuel oil at the rate of 0.8 quart per square foot. The soil was retreated after 6 months and the border was again retreated after 18 months.

Two other piles (4 by 6 by 4 boxes high) were on a concrete slab under partial shade at Fort Sherman. Cracks and breaks in the concrete within 5 feet of the piles were flooded with DDT in diesel oil. The boxes were placed on 10-oz. canvas that had been saturated with 5 per cent pentachlorophenol in oil, dried, and, after being placed on the concrete, saturated with 5 per cent DDT in diesel oil.

The simulated boxes were all exposed off the ground at Gulfport on specially constructed tables or sills made of treated wood (Fig. 1D). At first the units were solid-piled in tiers of five, but later the tiers were separated ¼ to ½ inch to remove border effects between good and poor treatments.

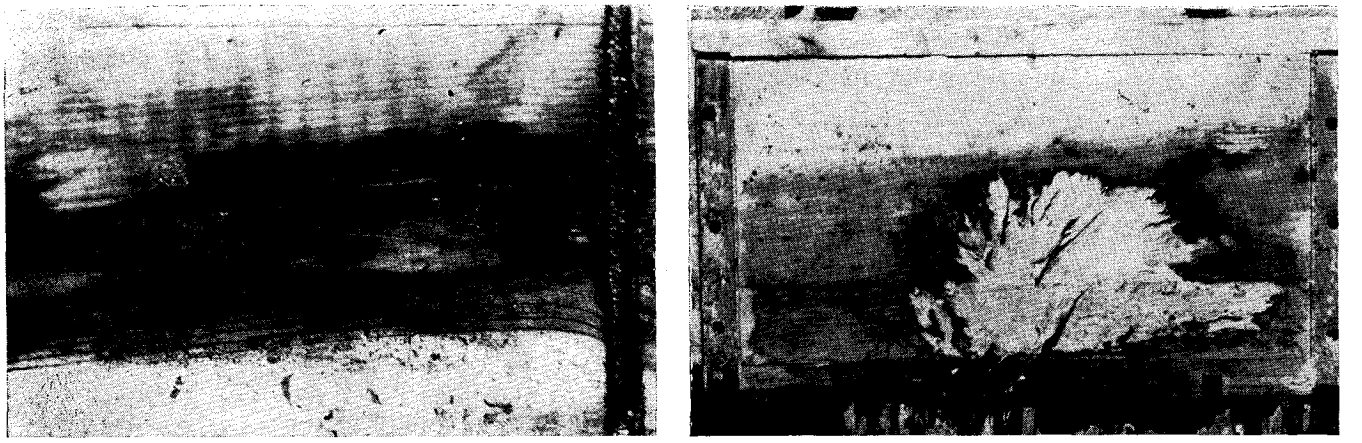

Fig. 2.—(Left) Black, wet rot. This rot, with a shell of softenedwood, was common in many of the treated boxes in Panama. (Right) Mycelial fan of water-conducting rotter *(Poria incrassatal)* growing upside of a dry box under tarpaulin cover. This fungus can rot boxes without rain-wetting, but is rarely encountered.

Absorption of Preservatives

Because of the high variability of the wood among boxes, particularly the percentage of non-penetrable heartwood and the presence of some boards of species that treat with difficulty, or erratically, there were large variations in the absorption of preservatives. With the 3-minute dip the range for individual boxes was 0.2 to 3.3 lb. per cu. ft. for oil solutions and 0.5 to 2.5 lb. per cu. ft. for water solutions. Average absorptions are listed in Table 1. Average pounds of solution absorbed per cubic foot for all comparable treatments were:

	Water solutions	Oil solutions
Straight toxicant	1.8	1.1
Toxicant, plus water repellent	1.6	1.1

Absorptions were significantly greater for the water solutions than for the oil solutions. The addition of water repellents to the oil solutions did not reduce absorptions. In other tests, significant reductions have been reported (6, 8).

Absorptions for different immersion periods are listed in Tables 10 and 11. These data substantiate previous findings (2, 8) that, with dips and short-period soaks, most absorption occurs during the first minute or less.

A large variation in absorption among wood species and between sapwood and heartwood is shown in Table 8.

Previous tests had shown that absorptions and penetrations by dip treatment are reduced as wood moisture content increases (2, 8), and that moisture contents above fiber saturation (about 30 per cent) particularly hinder treatment. Similar effects were found in these tests (Table 12).

The average retentions by pressure-treated boxes are listed in Table 1. Retentions of individual boxes varied from 3.3 to 8.4 lbs. per cu. ft. for 5 per cent pentachlorophenol solution; 3.2 to 9.3 for 5 per cent pentachlorophenol plus water repellent; 0.267 to 0.479 (lb. salt) for Celcure; 0.218 to 0.479 (lb. salt) for Tanalith; and 0.432 to 1.115 (lb. salt) for copperized chromated zinc chloride.

The wire-bound cases of rotary-cut veneer absorbed the preservative solutions readily (Table 7). Further tests with rotary-cut sweetgum veneer (4 by 4-inch squares of kiln-dried ¼-inch veneer) showed the following absorptions (pounds of copper naphthenate solution per cubic foot) with various immersion periods:

	1 sec.	2.5 sec.	5 sec.	10 sec.	1 min.	3 min.
Sapwood	5.8	6.4	7.7	8.6	9.9	9.7
Heartwood	4.5	4.4	4.6	6.0	5.6	5.8

These excessive absorptions by veneer are possibly due to three factors: The relatively large ratio of surface to volume would increase absorption per unit of volume; when rotary-cut veneer is flattened, a multitude of fine checks develop on the formerly concave surface; rapid kiln drying permanently increases absorptiveness (5). In these tests, lateral penetration of the solution into veneer was often complete, whereas sweetgum lumber showed practically no lateral penetration.

Fungus Attack

In both Gulfport and Panama, a number of molds occurred on boxes. These included *Pestalozzia* associated with a white molding, *Aspergillus niger* on copper treatments, *Penicillium, Trichoderma, Tubercularia,* and *Gliocladium.* However, molding and staining sufficiently severe to obliterate stencil markings occurred only on untreated boxes or those given treatments that were ineffective against decay. Molds and stain therefore will not be given further attention in this report.

The most common decay fungi on rain-wetted wood at Gulfport were *Lenzites saepiaria* and *Daedalea berkeleyii* on coniferous woods and *Polyporus versicolor* on hardwoods. Where in contact with soil, coniferous woods were commonly attacked by *Poria radiculosa* and in one pile by the water-conductor *Poria incrassata* (Fig. 2). The latter, unlike most decay fungi, has the ability to wet dry wood ahead of its advance, but fortunately it is of rare occurrence. Thus brown rot predominated on coniferous woods in the Mississippi exposures.

The only identified Basidiomycete that caused decay in Panama was *Odontia bicolor,* which was prevalent among isolations made in 1954 and 1955. In addition, an unidentified decayer with light tan mycelium was particularly destructive in a covered pile that was comparatively dry. A black wet-rot (Fig. 2) was also common in Panama on wood too wet for rapid decay by most wood-destroying Basidiomycetes. An imperfect fungus, *Diplodia natalensis,* was isolated from black wet-rot. In many cases a thin shell of softened wood developed similar to the slow decay caused in saturated wood of cooling towers by such Ascomycetes as *Chaetomium.*

In Wisconsin, the principal type of decay was white rot. No causal fungi were identified.

At none of the test sites was there an apparent difference in species of decay fungi on treated and untreated boxes.

Decay ratings were based on an arbitrary scale of 0 to 5 as follows:

Rating	Decay Class
0	None
1	Suspicious only
2	Small spots only
3	General, but little loss in strength
4	Heavy decay, serious loss in strength
5	Practically destroyed

Table 3.—RATE OF DECAY OF M–22 BOXES EXPOSED WITHOUT TARPAULIN COVER IN SOUTHERN MISSISSIPPI

Treatment	Average decay rating[1]										Proportion of failure[2]									
	With water repellent					Without water repellent					With water repellent					Without water repellent				
	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.
											Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate																				
0.5% Cu	0.5	0.6	0.8	1.5	2.1	---	---	---	---	---	0	0	0	0	8	---	---	---	---	---
1.0% Cu	.2	.4	.5	1.0	2.1	0.0	0.2	0.3	1.0	1.6	0	0	0	8	17	0	0	0	0	8
2.0% Cu	.0	.3	.3	.8	1.1	.2	.2	.3	.8	1.0	0	0	0	0	0	0	0	0	0	0
Copper pentachlorophenate																				
2.5%	.0	.0	.3	1.4	1.9	---	---	---	---	---	0	0	0	0	8	---	---	---	---	---
5.0%	.2	.2	.2	.8	1.9	.2	.3	.3	.6	1.7	0	0	0	0	8	0	0	0	0	0
Copper 3-phenyl salicylate																				
1.25%	.3	.5	.8	2.0	2.8	---	---	---	---	---	0	0	0	8	17	---	---	---	---	---
2.5%	.2	.5	1.1	2.5	3.3	.3	.9	1.8	2.5	3.0	0	0	0	8	42	0	8	17	25	42
5.0%	.2	.7	1.4	2.2	3.1	.2	.3	1.0	2.2	2.7	0	0	0	8	33	0	0	8	8	8
Copper 8-quinolinolate																				
0.15%	.4	.4	1.2	2.4	3.3	---	---	---	---	---	0	8	17	25	25	---	---	---	---	---
0.3%	.4	.7	1.0	1.9	2.8	.2	.6	1.5	2.6	3.3	0	0	0	8	8	0	0	8	17	33
0.6%	.3	.5	1.1	2.7	2.7	.4	.5	1.3	2.8	3.3	0	0	8	8	8	0	8	8	17	25
0.3% plus 0.5% gamma benzne hexachloride	---	---	---	---	---	.5	1.0	2.1	3.5	4.5	---	---	---	---	---	0	0	17	33	75
Mineral spirits (aliphatic)	.4	1.3	1.9	3.0	3.8	.9	1.8	2.3	3.5	4.0	0	0	8	21	46	0	8	8	42	67
Orthophenylphenol																				
2.5%	.8	1.2	2.1	3.3	4.3	---	---	---	---	---	0	8	17	33	75	---	---	---	---	---
5.0%	.8	1.7	3.0	3.6	4.4	.4	1.5	2.5	3.8	4.4	0	17	25	58	75	0	8	8	42	83
10.0%	.4	.5	1.3	2.1	3.3	.4	.5	1.6	2.8	3.6	0	8	8	8	42	0	8	8	17	42
Pentachlorophenol																				
2.5%	.3	.5	1.2	2.0	2.6	---	---	---	---	---	0	0	17	17	17	---	---	---	---	---
5.0%	.2	.3	.6	1.2	2.4	.2	.3	.8	1.8	2.3	0	0	0	0	8	0	0	0	0	8
10.0%	.2	.3	.4	1.3	2.1	.0	.4	.4	1.6	2.2	0	0	0	0	8	0	0	0	0	0
5.0% plus 0.5% gamma benzene hexachloride	---	---	---	---	---	.0	.7	.9	2.2	3.0	---	---	---	---	---	0	0	0	0	8
Phenyl mercuric oleate																				
0.15%	.4	1.1	1.7	2.7	3.3	---	---	---	---	---	0	0	8	8	17	---	---	---	---	---
0.3%	.3	.6	1.5	2.3	2.8	.3	.6	1.3	2.6	3.0	0	8	17	17	25	0	0	0	0	17
0.6%	.2	.4	.7	2.0	2.9	.2	.4	1.1	2.7	2.9	0	0	0	0	17	0	0	0	0	17
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent																				
25.0%	.3	.8	1.3	3.0	4.1	---	---	---	---	---	0	0	8	25	67	---	---	---	---	---
37.5%	.3	.3	.6	1.8	2.9	---	---	---	---	---	0	0	0	0	25	---	---	---	---	---
Rosin amine D pentachlorophenate																				
2.75%	.3	.4	1.3	2.0	2.9	---	---	---	---	---	0	0	0	0	33	---	---	---	---	---
5.5%	.3	.5	.6	1.8	2.6	.3	.3	1.1	1.8	2.5	0	0	0	0	17	0	0	8	8	8
11.0%	.3	.5	.8	1.6	2.0	.2	.3	.5	1.5	2.1	0	0	0	0	8	0	0	8	8	8
Tetrachlorophenol																				
2.5%	.4	.6	1.3	2.3	3.3	---	---	---	---	---	0	0	17	17	25	---	---	---	---	---
5.0%	.2	.6	1.0	1.9	2.8	.5	.5	.8	2.0	2.7	0	0	0	0	17	0	8	17	17	17
10.0%	.0	.4	.9	1.5	2.5	.0	.7	.7	1.5	2.3	0	0	0	0	8	0	0	0	0	0
Zinc alkyl sulphonate																				
2.8%	.3	.9	1.4	2.9	3.5	---	---	---	---	---	0	0	8	17	42	---	---	---	---	---
5.7%	.3	.3	.8	2.0	3.0	---	---	---	---	---	0	0	0	0	33	---	---	---	---	---
Zinc naphthenate																				
0.5% Zn	.3	.5	1.2	2.7	3.5	---	---	---	---	---	0	0	0	17	42	---	---	---	---	---
1.0% Zn	.3	.4	.8	1.7	2.8	.4	.6	1.5	2.4	3.3	0	0	0	0	17	0	8	8	17	42
2.0% Zn	.2	.4	.9	2.0	2.8	.2	.6	.8	2.3	2.8	0	0	0	0	8	0	0	8	8	8
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride																				
5.0%	---	---	---	---	---	.2	.4	1.7	2.8	3.4	---	---	---	---	---	0	0	0	25	42
10.0%	.3	.6	1.7	2.5	2.9	.1	.6	1.3	1.9	2.8	0	0	17	17	17	0	0	8	8	17
20.0%	---	---	---	---	---	.0	.4	.6	1.8	2.9	---	---	---	---	---	0	0	0	0	8
Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol																				
2.5%	---	---	---	---	---	.1	.5	.8	1.3	2.9	---	---	---	---	---	0	0	0	8	17
7.5%	---	---	---	---	---	.0	.3	.9	2.0	3.0	---	---	---	---	---	0	0	0	8	17
Rosin amine D acetate																				
2.5%	---	---	---	---	---	.3	.6	1.1	2.5	3.4	---	---	---	---	---	0	8	8	17	33
5.0%	---	---	---	---	---	.3	.4	.8	1.8	2.9	---	---	---	---	---	0	0	0	0	17
10.0%	---	---	---	---	---	.0	.3	.3	1.9	2.9	---	---	---	---	---	0	0	0	8	33
Sodium pentachlorophenate																				
2.85%	---	---	---	---	---	.4	.6	.8	2.3	2.6	---	---	---	---	---	0	8	8	8	8
5.7%	.2	.3	.5	1.8	2.8	.2	.3	.4	1.5	2.4	0	0	0	0	8	0	0	0	0	8
11.4%	---	---	---	---	---	.1	.3	.4	1.4	1.7	---	---	---	---	---	0	0	0	0	8
2.0% plus borax 3.0%	.0	.2	.3	1.3	2.2	.0	.1	.8	2.3	2.8	0	0	0	0	8	0	0	0	8	17
4.0% plus borax 4.0%	---	---	---	---	---	.0	.2	.7	1.9	2.8	---	---	---	---	---	0	0	0	0	17
Sodium tetrachlorophenate																				
2.85%	.3	.4	1.0	2.0	2.8	---	---	---	---	---	0	8	17	17	17	---	---	---	---	---
5.7%	.3	.4	1.0	1.7	2.5	.0	.3	.7	2.0	2.0	0	0	0	0	17	0	0	0	0	25
Water repellent, 4% solids	.4	1.1	2.1	3.0	3.6	---	---	---	---	---	0	0	8	17	33	---	---	---	---	---
Oil Solution, Pressure Treatment																				
Pentachlorophenol, 5%	.0	.2	.4	.7	1.4	.0	.3	.3	.6	1.7	0	0	0	0	0	0	0	0	0	8
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	---	---	---	---	---	.0	.0	.0	.0	.3	---	---	---	---	---	0	0	0	0	0
Celcure	---	---	---	---	---	.0	.0	.0	.2	.3	---	---	---	---	---	0	0	0	0	0
Tanalith	---	---	---	---	---	.0	.0	.0	.1	.9	---	---	---	---	---	0	0	0	0	0
Untreated																				
	1.8	1.9	2.5	3.4	3.9	---	---	---	---	---	0	2	8	35	61	---	---	---	---	---

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decry classes 4 and 5.

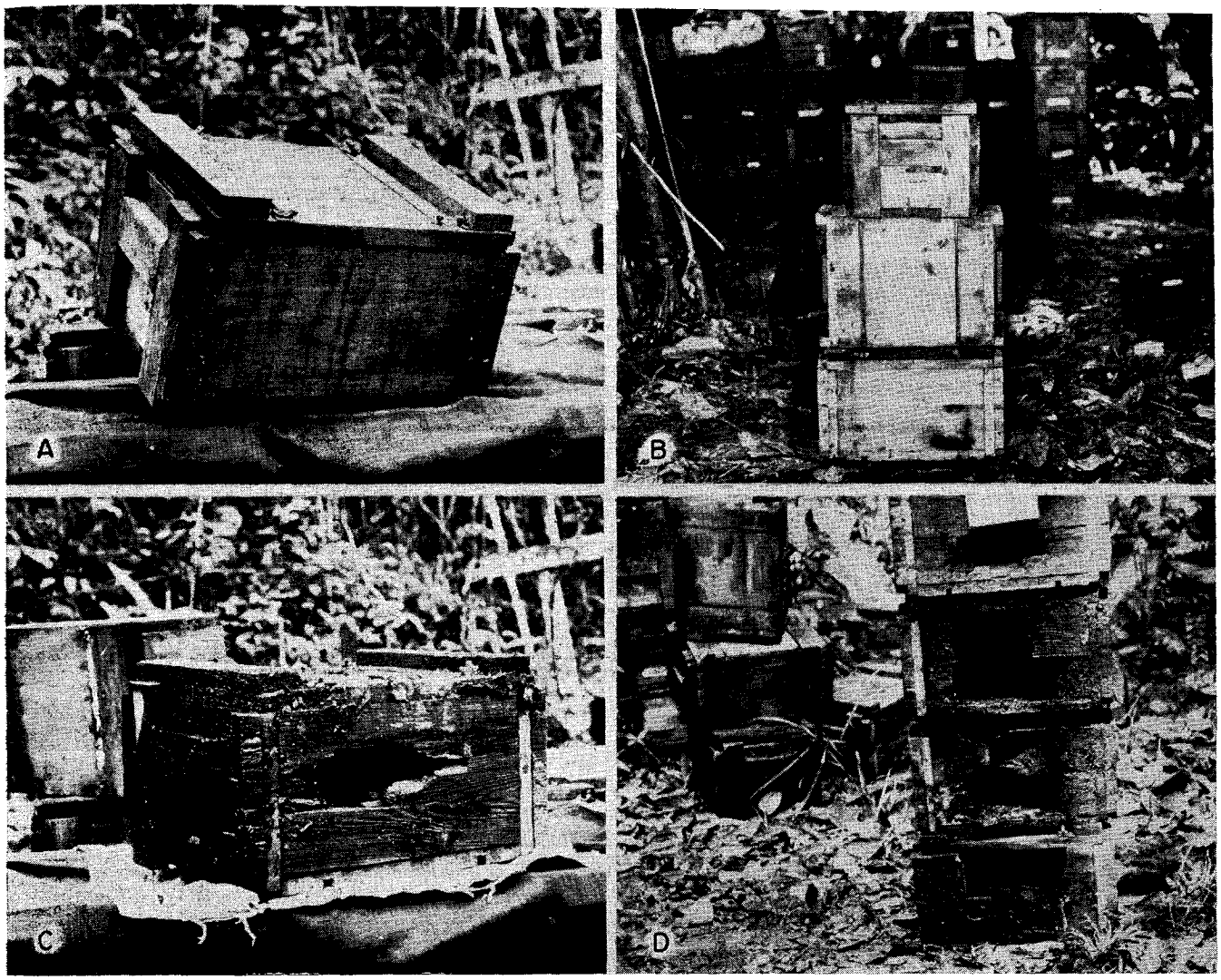

Fig. 3.—Condition of boxes after exposure for 3.5 years in Panama. (A) Box pressure-treated with copperized chromated zinc chloride, showing heavy metal corrosion. Surface is softened, but box is still sound. (B) Boxes given 3-minute dip in copper naphthenate (2 per cent Cu) plus a water repellent. (C) Failure of side of box given 3-minute dip in pentachlorophenol plus water repellent. However, 75 per cent of boxes given this treatment were serviceable after 4.5 years. (D) Failure of all 4 boxes of one treatment in a pile. This is typical of most treatments after 4.5 years.

A decay rating of 1 does not indicate that failure will follow. A rating of 2 indicates that, for the boards involved, failure will eventually occur if only a surface treatment has been used. A rating of 3 indicates well advanced attack, with failure expected soon. Ratings of 4 and 5 indicate that failure has occurred.

In Panama, boxes were tested for strength after 30 months' storage by dropping them, when loaded with 35 pounds of gravel, from a height of 5 feet onto a heavy steel plate. Drops were made successively onto each of the eight box corners. Boxes with a rating of less than 3 for decay or termite attack remained serviceable after 8 drops; those with 3 ratings were badly damaged; those with 4 and 5 ratings were damaged beyond use in 2 to 4 drops. This also applied to strap-corrosion ratings of 4 and 5, as discussed later.

In the Wisconsin exposures, decay was essentially limited to the bottom boards in contact with the soil. In Mississippi and Panama, decay was first noticed, and progressed most rapidly, in the top and bottom boxes of tiers. This was true for treated as well as untreated boxes. A common place for initial decay was under a fallen leaf adhering to the lid of the top box. In storage on untreated soil, decay appeared early on the bottoms of the lower tier of boxes—those in contact with the soil. Treating the soil with DDT in oil delayed bottom decay for 2 years. Bottom decay in Panama was of the black wet-rot type; bottom rot in Mississippi and top rot at both locations were typical Basidiomycete decay. Greatest decay and the common point of failure in boxes between the top and bottom boxes of a tier was the midpoint on the sides of the box.

The condition of boxes after exposure for 3.5 years in Panama is shown in Fig. 3 and after 2 to 4 years in Mississippi in Fig. 4. The amounts of decay occurring in M22 boxes after different storage periods are listed in Tables 2 to 6, inclusive.

Untreated Boxes: If average service life is considered the point at which 60 per cent of the boxes failed, untreated eastern white pine M22 boxes have the following service life when fully exposed to rain-wetting but protected from termites:

Wisconsin—More than 5 years
Mississippi—5.0 years
Panama—3.2 years

Giving the untreated boxes 2 spray coats of paint (TT-E-485b) inside and out reduced the average decay rating after 5.1 years' exposure in Mississippi from 3.9 to 3.2, and the percentage of failures from 61 to 21 (Table 5). Painted boxes were not exposed elsewhere.

Covering a pile of dry boxes in Mississippi prevented decay in untreated boxes during the entire exposure period except at the ground line (Table 4, Fig. 4C). No condensation was ever noted under the tarpaulin.

Wire-bound hardwood veneer boxes had a very short life (2.0 years) when fully exposed in Mississippi (Table 7).

The rate of decay of sapwood and heartwood of 8 wood species commonly used for boxes and crates (Tables 8, 9) showed that none of these species have sufficient natural decay resistance for longtime service when untreated and fully exposed in Mississippi. Eastern white pine heartwood had the slowest decay rate.

Pressure Treatments: Boxes pressure-treated with pentachlorophenol and Tanalith developed small amounts of decay during 5 years of exposure in Wisconsin (Table 6). Those treated with copperized chromated zinc chloride and Celcure remained decay-free. So far, decay has not progressed enough to reveal practical differences between pressure treatments and dips in the Wisconsin exposure.

In Mississippi (Tables 3, 4, and 5), one box pressure-treated with pentachlorophenol failed from decay by *Poria radiculosa*. Except for this the pressure-treated boxes had only minor decay during exposure for 5 years. The pressure treatments were in general more effective than the dip treatments.

In Panama (Table 2), most pressure-treatments did not give better service than the best of the 3-minute dips. Boxes treated with the inorganic salts generally softened at the surface, and by 4.5 years this softening extended to significant depths in many boxes. Boxes treated with copperized chromated zinc chloride were the last to develop this softening and at the end of 4.5 years still had no failures. The heavy rainfall (130 inches) probably caused serious leaching of the

Table 4.—EFFECT OF WATER-TIGHT TARPAULIN COVER ON RATE OF DECAY OF M–22 BOXES EXPOSED IN SOUTHERN MISSISSIPPI

Treatment	Average decay rating[1]										Proportion of failure[2]									
	Uncovered pile					Covered piles[3]					Uncovered pile					Covered piles				
	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.
											Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate (1.0% Cu)+WR	0.2	0.4	0.5	1.0	2.1	0.0	0.0	0.0	0.0	0.6	0	0	0	8	17	0	0	0	0	8
Copper 3-phenyl salicylate, 2.5%+WR	.2	.5	1.1	2.5	3.3	.0	.0	.0	.0	.4	0	0	0	8	42	0	0	0	0	8
Copper 8-quinolinolate, 0.3%+WR	.4	.7	1.0	1.9	2.8	.0	.0	.0	.2	.6	0	0	0	8	8	0	0	0	0	8
Mineral spirits (aliphatic), 100%	.9	1.8	2.3	3.5	4.0	.0	.0	.0	.0	.1	0	8	8	42	67	0	0	0	0	0
Orthophenylphenol, 5%+WR	.8	1.7	3.0	3.6	4.4	.0	.0	.0	.3	.4	0	17	25	58	75	0	0	0	0	8
Pentachlorophenol, 5%+WR	.2	.3	.6	1.2	2.4	.0	.0	.0	.2	.4	0	0	0	0	8	0	0	0	0	8
Phenyl mercuric oleate, 0.3%+WR	.3	.6	1.5	2.3	2.8	.0	.0	.0	.3	.4	0	8	17	17	25	0	0	0	0	8
Rosin amine D pentachlorophenate, 5.5%+WR	.3	.5	.6	1.8	2.6	.0	.0	.0	.0	.6	0	0	0	0	17	0	0	0	0	0
Zinc naphthenate (1% Zn)+WR	.3	.4	.8	1.7	2.8	.0	.0	.0	.0	.5	0	0	0	0	17	0	0	0	0	8
Water repellent (10% solids)	.4	1.3	1.9	3.0	3.8	.0	.0	.0	.1	.4	0	0	8	21	46	0	0	0	0	0
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride, 10%	.1	.6	1.3	1.9	2.8	.0	.1	.1	.0	.3	0	0	8	8	17	0	0	0	0	
Sodium pentachlorophenate, 2%, plus borax, 3%	.0	.1	.8	2.3	2.8	.0	.0	.0	.0	.1	0	0	0	8	17	0	0	0	0	
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	.0	.0	.0	.0	.3	.0	.0	.0	.0	.1	0	0	0	0	0	0	0	0	0	0
Celcure	.0	.0	.0	.2	.3	.0	.0	.0	.0	.3	0	0	0	0	0	0	0	0	0	0
Tanalith	.0	.0	.0	.1	.9	.0	.0	.0	.0	.1	0	0	0	0	0	0	0	0	0	0
Untreated																				
	1.8	1.9	2.5	3.4	3.9	.0	+	.1	.3	.9	0	2	8	35	61	0	0	0	0	4

[1]Ratings on a basis of 0 (none) to 5 (destroyed). "+" indicates less than 0.05.
[2]Percentage of boxes in decay classes 4 and 5.
[3]All decay caused by Poria incrassata on bottom boxes.

Table 5.—EFFECT OF 2 COATS OF PAINT (TT–E–485b), APPLIED AFTER TREATMENT, ON RATE OF DECAY OF M–22 BOXES EXPOSED WITHOUT TARPAULIN COVER IN SOUTH MISSISSIPPI

Treatment	Average decay rating[1]										Proportion of failure[2]									
	Painted					Unpainted					Painted					Unpainted				
	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 ur.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr
											Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate (1.0% Cu) plus WR	0.0	0.0	0.2	0.3	0.6	0.2	0.4	0.5	1.0	2.1	0	0	0	0	0	0	0	0	8	17
Copper 3-phenyl salicylate, 2.5% plus WR	.0	.0	.0	.4	1.5	.2	.5	1.1	2.5	3.3	0	0	0	0	0	0	0	0	8	42
Copper 8-quinolinolate, 0.3% plus WR	.2	.2	.4	.5	1.8	.4	.7	1.0	1.9	2.8	0	0	0	0	8	0	0	0	8	8
Mineral spirits (aliphatic) 100%	.3	.7	1.0	2.1	3.0	.9	1.8	2.3	3.5	4.0	0	0	0	8	33	0	8	8	42	67
Orthophenylphenol, 5.0% plus WR	.0	.3	.9	1.6	2.1	.8	1.7	3.0	3.6	4.4	0	0	0	0	8	0	17	25	58	75
Pentachlorophenol, 5.0% plus WR	.0	.2	.3	.7	1.4	.2	.3	.6	1.2	2.4	0	0	0	0	0	0	0	0	0	8
Phenyl mercuric oleate, 0.3% plus WR	.0	.0	.3	.5	1.3	.3	.6	1.5	2.3	2.8	0	0	0	0	0	0	8	17	17	25
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent, 37.5%	.0	.0	.3	1.2	1.8	.3	.3	.6	1.8	2.9	0	0	0	17	17	0	0	0	0	25
Rosin amine D pentachlorophenate, 5.5% plus WR	.0	.0	.2	.7	1.5	.3	.5	.6	1.8	2.6	0	0	0	0	0	0	0	0	0	17
Zinc alkyl sulphonate, 5.7% plus WR	.3	.6	.9	1.3	2.3	.3	.3	.8	2.0	3.0	0	0	0	0	8	0	0	0	0	33
Zinc naphthenate (1.0% Zn) plus WR	.2	.2	.2	1.2	1.9	.3	.4	.8	1.7	2.8	0	0	0	0	8	0	0	0	0	17
Water repellent (10% solids)	.1	.2	.2	.8	1.8	.4	1.3	1.9	3.0	3.8	0	0	0	0	8	0	0	8	21	46
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride, 10.0%	.0	.0	.0	.3	1.0	.1	.6	1.3	1.9	2.8	0	0	0	0	0	0	0	8	8	17
Rosin amine D acetate, 5.0%	.3	.6	.6	1.0	2.4	.3	.4	.8	1.8	2.9	0	0	0	8	25	0	0	0	0	17
Sodium pentachlorophenate, 5.7%	.0	.0	.0	.3	.6	.2	.3	.4	1.5	2.4	0	0	0	0	0	0	0	0	0	8
Sodium pentachlorophenate, 2.0% plus borax, 3.0%	.0	.0	.0	.4	.7	.0	.1	.8	2.3	2.8	0	0	0	0	0	0	0	0	8	17
Sodium tetrachlorophenate, 5.7%	.0	.3	.3	.6	1.1	.0	.3	.7	2.0	2.8	0	0	0	0	0	0	0	0	0	25
Oil Solution, Pressure Treatment																				
Pentachlorophenol, 5%	.0	.0	.0	.5	.7	.0	.3	.3	.6	1.7	0	0	0	0	0	0	0	0	0	8
Untreated																				
	.2	.7	1.0	1.9	3.2	1.8	1.9	2.5	3.4	3.9	0	0	4	8	21	0	2	8	35	61

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

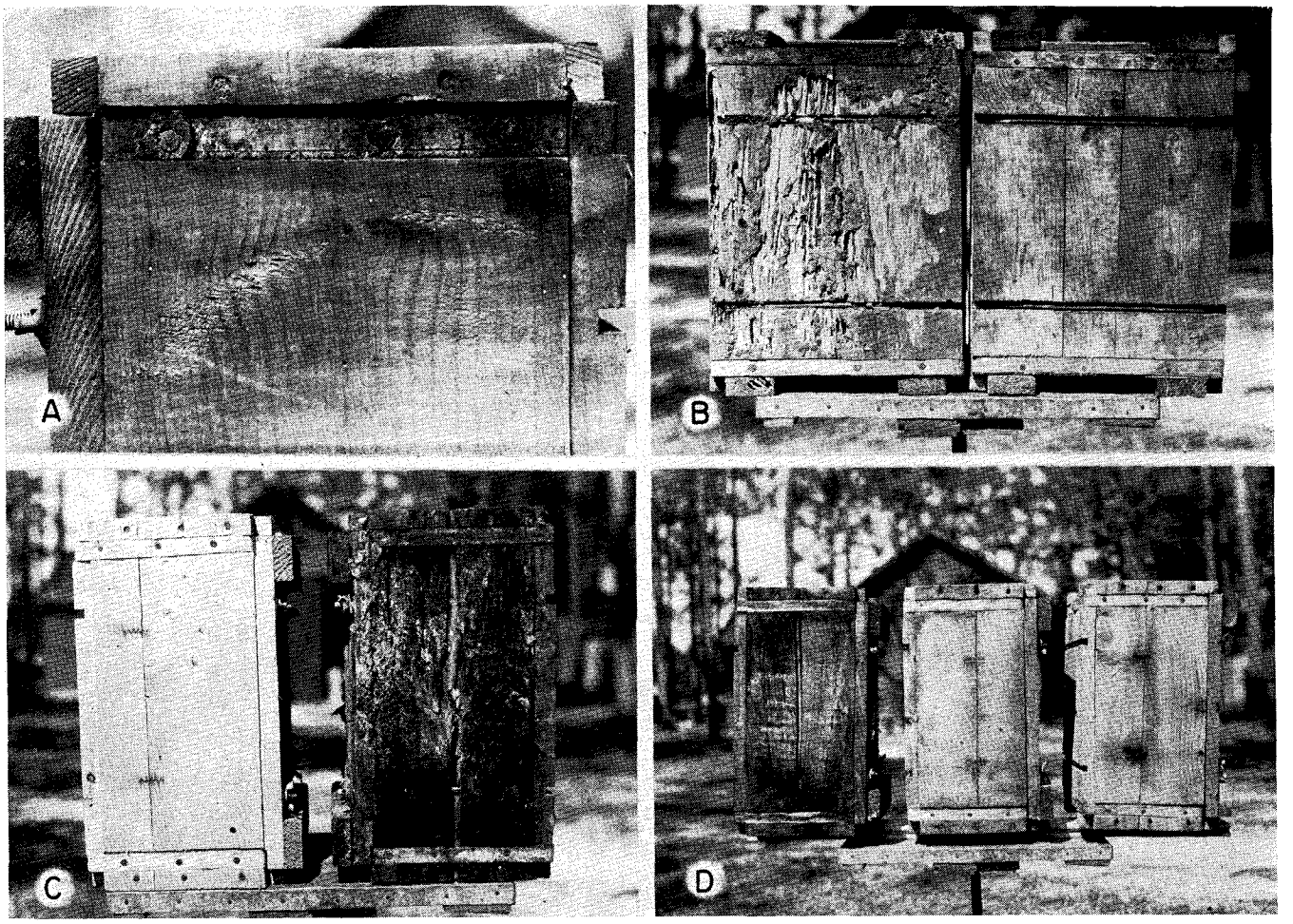

Fig. 4.—Condition of M22 boxes after exposure in Mississippi. (A) Strap failure on box pressure-treated with copperized chromated zinc chloride, 3 years' exposure. (B) Boxes dipped in 5 per cent pentachlorophenol plus water repellent and exposed for 2 years on untreated soil (termite attack) and DDT-treated soil (sound). (C) Untreated boxes after 4 years' exposure under cover (sound) and in exposed pile (decayed). (D) Conditions of boxes in fully exposed pile after 3 years; from left to right: Untreated, and 3-minute dips in 5 per cent pentachlorophenol plus water repellent and copper naphthenate (2 per cent Cu).

Table 6.—RATE OF DECAY OF M–22 BOXES EXPOSED IN WISCONSIN, MISSISSIPPI, AND PANAMA

Treatment	Average decay rating[1]												Proportion failure[2]											
	Wisconsin			Mississippi					Panama				Wisconsin			Mississippi					Panama			
	3 yr.	4 yr.	5 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.	3 yr.	4 yr.	5 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.
													Per cent											
Oil Solutions, 3-Minute Dips																								
Copper naphthenate (1% Cu) plus WR	0.3	0.3	0.5	0.2	0.4	0.5	1.0	2.1	0.4	1.3	2.4	3.6	0	0	0	0	0	0	8	17	0	0	23	35
Copper pentachlorophenate, 5% plus WR	.2	.3	.5	.2	.2	.2	.8	1.9	.3	1.5	2.6	3.0	0	0	0	0	0	0	0	8	0	0	9	9
Copper 3-phenyl salicylate, 2.5% plus WR	.4	.6	1.0	.2	.5	1.1	2.5	3.3	.5	2.0	3.8	4.5	0	0	0	0	0	0	8	42	0	10	50	75
Copper 8-quinolinolate, 0.3% plus WR	.5	.4	.8	.4	.7	1.0	1.9	2.8	.7	2.3	3.9	4.4	0	0	0	0	0	0	8	8	0	17	57	77
Orthophenylphenol, 5% plus WR	.6	.5	.7	.8	1.7	3.0	3.6	4.4	1.0	2.2	3.5	4.0	0	0	0	0	17	25	58	75	4	9	35	62
Pentachlorophenol, 5% plus WR	.7	.6	1.0	.2	.3	.6	1.2	2.4	.4	1.9	2.9	3.6	0	0	0	0	0	0	0	8	0	5	25	25
Phenyl mercuric oleate, 0.3% plus WR	.6	.6	1.0	.3	.6	1.5	2.3	2.8	.9	2.4	4.5	4.6	0	0	0	0	8	17	17	25	0	5	65	89
Product containing 23% zinc naphthenate, plus dodecyl amine salt of tetrachlorophenol, 37.5% plus WR	.7	.6	1.3	.3	.3	.6	1.8	2.9	1.3	3.4	4.9	4.9	0	0	8	0	0	0	0	25	0	30	90	100
Rosin amine D pentachlorophenate, 5.5% plus WR	.5	.6	1.0	.3	.5	.6	1.8	2.6	.3	1.9	2.9	3.6	0	0	0	0	0	0	0	17	0	0	18	33
Tetrachlorophenol, 5% plus WR	.4	.4	.8	.2	.6	1.0	1.9	2.8	1.2	2.9	4.0	4.5	0	0	8	0	0	0	0	17	0	10	50	90
Water repellent only	.8	.7	.8	.4	1.3	1.9	3.0	3.8	2.1	3.3	4.5	4.8	0	0	0	0	0	8	21	46	0	28	84	91
Zinc alkyl sulphonate, 5.7% plus WR	.6	.6	.8	.3	.3	.8	2.0	3.0	1.2	2.8	4.6	5.0	0	0	0	0	0	0	0	33	0	30	70	100
Zinc naphthenate (1% Zn) plus WR	.6	.8	.8	.3	.4	.8	1.7	2.8	.5	2.6	4.1	4.7	0	0	0	0	0	0	0	17	0	16	63	88
Water Solutions, 3-Minute Dips																								
Copper ammonium fluoride, 10%	.2	.5	.6	.1	.6	1.3	1.9	2.8	1.1	3.3	4.5	4.6	0	0	0	0	0	8	8	17	0	5	77	88
Rosin amine D acetate, 5%	.3	.6	.8	.3	.4	.8	1.8	2.9	1.2	3.3	4.5	4.9	0	0	0	0	0	0	0	17	0	36	82	100
Sodium pentachlorophenate, 5.7%	.3	.5	.8	.2	.3	.4	1.5	2.4	.5	2.0	2.9	3.6	0	0	0	0	0	0	0	8	0	0	9	44
Sodium pentachlorophenate, 2.0% plus borax, 3%	.4	.4	1.0	.0	.1	.8	2.3	2.8	.5	2.3	3.4	3.7	0	0	0	0	0	0	8	17	0	18	32	48
Sodium tetrachlorophenate, 5.7%	.4	.6	1.0	.0	.3	.7	2.0	2.8	.6	2.4	3.6	3.8	0	0	0	0	0	0	0	25	0	0	30	56
Oil Solution, Pressure Treatment																								
Pentachlorophenol, 5%	.5	.4	.7	.0	.3	.3	.6	1.7	.5	1.7	2.0	2.9	0	0	0	0	0	0	0	8	0	13	19	20
Water Solutions, Pressure Treatments																								
Copperized chromated zinc chloride	.0	.0	.0	.0	.0	.0	.0	.3	.1	.2	.7	2.4	0	0	0	0	0	0	0	0	0	0	0	0
Tanalith	.3	.3	.6	.0	.0	.0	.1	.9	.3	1.3	3.1	3.2	0	0	0	0	0	0	0	0	0	0	13	13
Celcure	.0	.0	.0	.0	.0	.0	.2	.3	.0	.4	1.6	2.8	0	0	0	0	0	0	0	0	0	0	11	19
Untreated																								
	.8	1.5	1.6	1.8	1.9	2.5	3.4	3.9	2.1	3.1	4.3	4.8	0	0	8	0	2	8	35	61	6	25	81	88

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Table 7.—EFFECTIVENESS OF TWO FUNGICIDES IN PREVENTING DECAY IN WIRE-BOUND VENEER CRATES EXPOSED UNDER PARTIAL HARDWOOD SHADE ON DDT-TREATED SOIL IN MISSISSIPPI

Treatment	Solution absorbed[1] lb./cu.ft.	Average decay rating[2] 1.1 yr.	2.0 yr.	3.1 yr.	Proportion of failure[3] 1.1 yr.	2.0 yr.	3.1 yr.
					Per cent		
5% pentachlorophenol+water repellent, 3-minute dip	12.4	0.1	0.4	1.2	0	0	0
5% pentachlorophenol+water repellent, 10-minute soak	5.5	.0	.2	.8	0	0	0
Copper naphthenate (2% Cu), 10-second dip	3.9	.0	.0	.4	0	0	0
Copper naphthenate (2% Cu), 3-minute dip	9.8	.0	.0	.5	0	0	0
Untreated	----	2.7	3.7	4.5	10	60	100

[1]Excluding separators. There was large variation from crate to crate depending mainly on the amount of white-pine heartwood present. In the treated crates there were no ratings above "2", i.e. they are essentially decay free.
[2]Ratings on a basis of 0 (none) to 5 (destroyed).
[3]Percentage of boxes in decay classes 4 and 5.

Table 9.—RELATIVE DECAY RATE OF M-22 BOXES MADE OF EASTERN WHITE PINE AND SOUTHERN YELLOW PINE EXPOSED IN SOUTH MISSISSIPPI

Treatment	Average decay rating[1] Eastern white pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	Southern yellow pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.
Copper 8-quinolinolate, 0.3%	0.2	0.6	1.5	2.6	0.5	1.0	2.8	3.5
Pentachlorophenol, 5%+WR	.2	.3	.6	1.2	.2	.4	.6	1.7
Untreated	1.8	1.9	2.5	3.4	2.0	2.0	4.0	4.3

Treatment	Proportion of failure[2] Eastern white pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	Southern yellow pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.
	Per cent							
Copper 8-quinolinolate, 0.3%	0	0	8	17	0	0	17	17
Pentachlorophenol, 5%+WR	0	0	0	0	0	0	0	8
Untreated	0	2	8	35	0	0	58	58

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Table 10.—EFFECT OF LENGTH OF IMMERSION ON EFFECTIVENESS OF 2 PRESERVATIVES ON SIMULATED BOXES OF SOUTHERN PINE SAPWOOD

Treatment	Solution absorbed lb./cu.ft.	Average decay rating[1] 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Proportion of failure[2] 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.
						Per cent			
5% pentachlorophenol plus WR in mineral spirits									
0.5 min.	1.5	0.0	2.2	2.8	3.3	0	0	0	10
1 min.	1.5	.0	2.2	2.6	3.2	0	0	0	10
3 min.	2.0	.0	.4	2.2	2.7	0	0	0	0
10 min.	2.2	.2	1.7	2.5	3.3	0	0	0	0
4% sodium pentachlorophenate plus 4% borax in water									
0.5 min.	1.5	1.0	2.2	2.6	3.2	0	0	0	20
1 min.	1.7	.0	1.0	2.7	3.3	0	0	0	30
3 min.	2.0	.9	2.1	2.7	3.5	0	0	0	20
10 min.	2.1	.0	1.7	2.4	3.5	0	0	0	30
Untreated	.0	3.2	3.6	4.4	5.0	0	55	90	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

salts in boxes exposed in Panama. With Tanalith, in fact, many of the boxes that failed had slightly higher than average initial retention.

Pressure treatments with 5 per cent pentachlorophenol and 5 per cent pentachlorophenol plus a water repellent likewise did not give a high order of protection in Panama (Table 2). In interpreting these Panama results three factors should be considered: 1) Individual boxes varied in amount of heartwood, which is less easily treated, and thus caused large variations in retentions; 2) some of the wood species (spruce and balsam fir) have sapwood refractory to treatment, and others (as aspen) treat erratically; and 3) heavy blooming occurred, so that actual retentions were lower than indicated. An analysis showed a highly significant correlation (at the 0.1 per cent level) between pentachlorophenol retentions and decay rating in Panama. This is illustrated by the following data for 5 per cent pentachlorophenol:

Decay Class	Absorption of Solution Range	Average
2	3.9–7.6	6.6
3	3.8–8.8	5.7
4 and 5	3.3–3.9	3.6

Three-minute Dips: In Wisconsin, six dip treatments permitted only a few scattered decay spots during 5 years' exposure: Copper naphthenate (1 per cent Cu), 5 per cent copper pentachlorophenate, 5 per cent rosin amine D acetate, 10 per cent copper ammonium fluoride, 5 per cent orthophenylphenol, and 2 per cent sodium pentachlorophenate plus 3 per cent borax. The first three had lower average decay ratings than two of the pressure treatments, but the differences probably are not significant. The other treatments permitted general decay and weakening of the bottom boards in contact with the soil.

At Gulfport (Table 3, Fig. 4D), copper naphthenate (2 per cent Cu), 5 per cent copper pentachlorophenate,

Table 8.—EFFECTIVENESS OF 5 PERCENT PENTACHLOROPHENOL PLUS A WATER REPELLENT ON SIMULATED BOXES MADE OF DIFFERENT WOOD SPECIES

Wood species	Solution absorbed lb./cu. ft.	Average decay rating[1] Treated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Untreated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Proportion of failure[2] Treated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Untreated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.
										Per cent							
Southern yellow pine, sapwood	1.9	0.0	0.9	1.1	1.8	3.1	3.9	4.3	5.0	0	0	0	10	0	80	100	100
Southern yellow pine, mostly heartwood	1.0	.0	.0	.4	1.1	3.2	4.3	5.0	5.0	0	0	0	0	0	80	100	100
Eastern white pine, sap and heartwood	.9	.0	.0	.9	1.7	2.0	3.0	3.5	4.3	0	0	0	0	0	10	30	80
Ponderosa pine, heart and sapwood	2.8	.0	.0	.4	1.7	2.5	4.1	4.7	5.0	0	0	0	0	0	80	100	100
Western hemlock, mostly heartwood	.9	.0	.2	.3	2.2	2.5	4.3	5.0	5.0	0	0	0	0	0	80	100	100
Douglas fir, mostly heartwood	1.0	.0	.1	.1	.4	2.4	3.8	4.2	5.0	0	0	0	0	10	60	80	100
Yellow poplar, sapwood	2.3	.0	.4	1.9	2.6	3.7	4.8	5.0	5.0	0	0	0	0	70	90	100	100
Yellow poplar, mostly heartwood	1.5	.0	.7	1.4	2.3	3.3	4.6	5.0	5.0	0	0	0	0	30	80	100	100
Sap gum (Sweetgum sapwood)	1.7	.0	1.4	2.2	3.0	4.1	5.0	5.0	5.0	0	0	0	0	50	100	100	100
Red gum (Sweetgum heartwood)	1.4	.0	.4	1.5	2.3	3.1	3.5	4.0	5.0	0	0	0	0	20	50	100	100
Tupelo, mostly sapwood	2.9	.0	.0	.7	2.3	3.9	4.8	5.0	5.0	0	0	0	0	80	100	100	100
Misc. northern conifers (from M-22 boxes)	---	.0	.0	.1	1.5	2.3	3.5	4.2	4.8	0	0	0	0	0	10	70	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boves in decay classes 4 and 5.

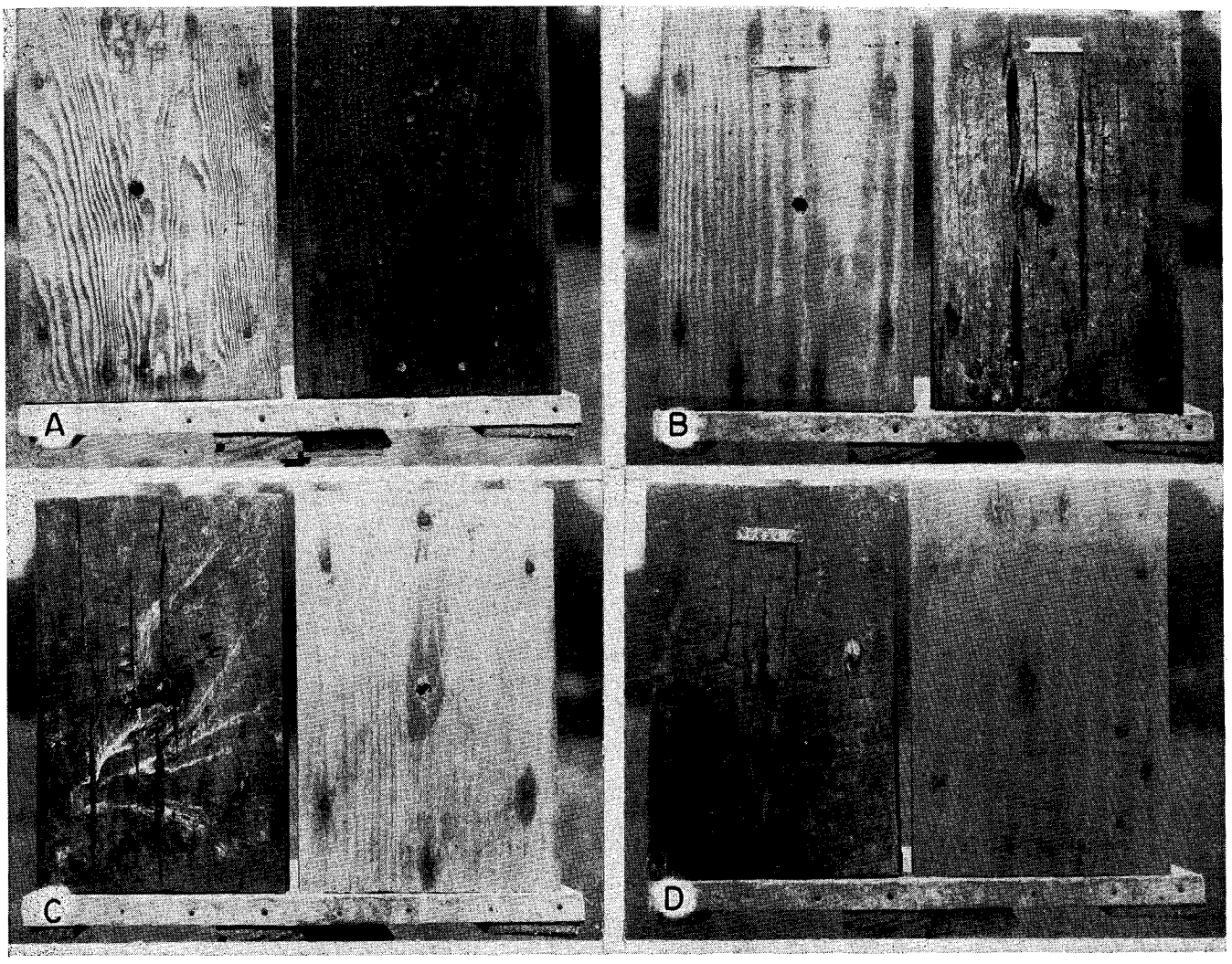

Fig. 5.—Simulated boxes of 4 wood species after exposure for 3.7 years in Mississippi. In each pair, the untreated unit is severely decayed and the one given a 3-minute dip in 5 per cent pentachlorophenol plus a water repellent is sound. (A) Douglas-fir heartwood, (B) southern yellow pine sapwood, (C) western hemlock sapwood and heartwood, and (D) sweetgum sapwood.

and 11.4 per cent sodium pentachlorophenate gave the best protection to boxes in piles fully exposed for 5 years. Copper naphthenate (0.5 and 1 per cent Cu), 5 and 10 per cent pentachlorophenol, 11 per cent rosin amine D pentachlorophenate, 10 per cent tetrachlorophenol, zinc naphthenate (2 per cent Zn), and 5.7 per cent sodium pentachlorophenate also gave good protection. A high percentage of failures occurred with copper 3-phenyl salicylate, copper 8-quinolinolate, orthophenylphenol, zinc alkyl sulphonate, sodium tetrachlorophenate, the product containing zinc naphthenate and dodecyl-amine salt of tetrachlorophenol, and low concentrations of rosin amine D pentachlorophenate, tetrachlorophenol, copper ammonium fluoride, and zinc naphthenate (0.5 and 1 per cent Zn). Other treatments were intermediate in effectiveness.

In Panama (Table 2) only copper naphthenate (2 per cent Cu), 5 per cent copper pentachlorophenate, and 10 per cent tetrachlorophenol gave appreciable control (Figs. 3B, C, D) for 4.5 years.

Five per cent pentachlorophenol plus a water repellent markedly reduced the decay rate of all wood species upon which it was tested (Tables 8, 9, Fig. 5). It was particularly effective on Douglas-fir heartwood. Generally, the treatment was less effective on the hardwood species than on the coniferous woods. McKnight (4) has shown that preservatives in non-swelling solvents (as used in the present tests) are less effective against white rotters than brown rotters. In these tests the coniferous woods were rotted by the brown-rotter *Lenzites saepiaria,* the hardwoods by the white-rotter *Polyporus versicolor.*

With both simulated boxes (Table 10) and M22 boxes (Table 11), varying the immersion period from 5 seconds to 10 minutes had no appreciable effect on rate of decay in Mississippi. In other tests (6) with less severe exposure simulating exterior woodwork of buildings, 15-minute immersions were definitely more effective than 3-minute dips, and the latter were appreciably better than 5-second dips.

Wood treated while green retained little preservative and decayed faster than wood treated when dry, particularly when the toxicant was applied in an oil solution (Table 12). There were only minor differences in decay rate of wood treated when partially seasoned, air-dried, and kiln-dried except when infected with fungi prior to treatment. Partially dried and infected wood treated with the oil solution decayed at a significantly faster rate than uninfected wood treated at the same moisture content. This was not true when the fungicide was in water solution or when infected wood was fully air-dried before treatment.

The addition of water repellents did not consistently or importantly affect decay rate (Tables 3, 13). This was in contrast to the salutary effects of repellents on siding and other exterior woodwork (6, 7), where they can prevent the capillary movement of rainwater into joints. Under the more severe conditions in a fully exposed

pile of boxes and where water content of the wood gradually builds up, the repellent apparently has little or no effect on decay rate.

Though paint (2 spray coats of TT–E–485b) did not appreciably reduce moisture content, it did retard decay rate (Tables 5, 14). The average decay rating and the percentage of failure of painted M22 boxes after 5.1 years' exposure were significantly lower except where the preservative was rosin amine D acetate (Table 5). Under the more severe exposure of the simulated box tests (Table 14), paint still had a beneficial effect in conjunction with the better preservatives (pentachlorophenol and copper naphthenate), but its effect had largely disappeared at the end of 4.6 years' exposure with copper 8-quinolinolate.

After 4.5 years' exposure, fungicides applied in a No. 2 fuel oil were slightly more effective than the same fungicides applied in mineral spirits (Table 15). The differences, however, were not of a practical degree. In other tests greater differences have been reported (6).

Corrosion of Hardware

Hardware of the M22 box consists of non-galvanized nails; galvanized strapping; and dip-coated U-bolts, wing nuts, and cross bars (Fig. 3). After 38 to 42 months' exposure, each box was rated for corrosion of hardware, on the following scale:

0	None evident
1	Slight amount of white corrosion
2	Moderate amount of white or small amount of red corrosion
3	Considerable corrosion but no danger that straps will fail in ordinary use. Wing nuts still removable by hand
4	Strapping near failure without stress; would probably fail in drop test. Wing nuts not removable by hand
5	Failure without stress

Average corrosion ratings are listed in Tables 16, 17, 18, and 19.

Failure of U-bolts, bars, and wing nuts was limited to boxes treated with copper ammonium fluoride and exposed in Mississippi and Panama. The following treatments, however, put more than 20 per cent of boxes in corrosion class 4, that is, significantly more than the untreated: *In Panama:* copper pentachlorophenate, pentachlorophenol, rosin amine D pentacholophenate, sodium pentacholorphenate (with and without borax),sodium tetrachlorophenate, copperized chromated zinc chloride, and Celcure. *In Mississippi*: The product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol; sodium tetrachlorophenate; copperized chromated zinc chloride; and Celcure. *In Wisconsin*: None.

Because the U-bolts, bars, and wing nuts were removed for pressure treating, serious corrosion of these items on boxes pressure-treated with the inorganic salts was due to salt in the wood, or leached from the wood, and not to direct contact with the treating solutions as occurred in the dip treatment.

Corrosion of the strapping was somewhat affected by adjacent treatments in the piles. Thirty-nine boxes from seven different chemical treatments were rated separately for corrosion of strapping on the side adjacent to boxes treated with copper ammonium fluoride and on the opposite side. In 31 of the 39 comparisons, greater corrosion occurred on the side next to the fluoride treatment, the average increase being 42 per cent. This effect, however, has not caused an otherwise satisfactory treatment to be classed as a failure.

Usually the preservative treatment had no significant effect on strap corrosion, but several treatments seriously increased corrosion and two significantly reduced it.

In Mississippi and Panama, exposures with dangerously high amounts of strap failure (average rating of 3.8 or above in comparison to 2.3 for the untreated) were found on boxes treated with:

Copper ammonium fluoride, all concentrations and conditions.

Copperized chromated zinc chloride, in uncovered piles (Figs. 3 and 4).

Celcure, in uncovered piles.

Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole, and pentachlorophenol at 7.5 per cent concentrations in uncovered piles.

In addition, the following treatments had significant numbers of straps with "4" ratings in Mississippi and Panama: Copper pentachlorophenate plus water repellent, 10 per cent tetrachlorophenol, sodium pentachlorophenate (alone or with borax; particularly severe with water repellent added), and sodium tetrachlorophenate.

In Wisconsin, no treatment caused serious corrosion of U-bolts; the highest average rating was 2.7 for the 3 boxes dipped in copper ammonium fluoride and exposed in contact with the soil. Copper ammonium fluoride (average rating 5.0) and copperized chromated zinc chloride (average rating 4.4) were the only treatments that caused strap failures, but treatments with sodium pentachlorophenate (alone and with borax), sodium tetrachlorophenate, Celcure, and Tanalith resulted in significantly higher corrosion of strapping than occurred on untreated boxes.

Table 11.—EFFECT OF LENGTH OF IMMERSION ON THE EFFECTIVENESS OF 6 PRESERVATIVE SOLUTIONS ON M-22 BOXES MADE OF NORTHERN CONIFEROUS WOODS

Treatment	Solution absorbed lb./cu. ft.	Average decay rating[1] 2.1 yr.	3.3 yr.	3.9 yr.	4.9 yr.
10% copper ammonium fluoride in water					
5 sec.	1.1	0.4	1.1	2.4	3.3
10 sec.	1.2	.4	.7	2.2	3.5
1 min.	1.6	.8	1.0	2.4	3.5
2 min.	1.5	.2	.8	1.8	2.7
3 min.	1.7	.3	.7	2.3	3.8
10 min.	1.9	.7	.8	2.2	3.5
5.7% sodium pentachlorophenate in water					
5 sec.	1.5	.3	1.0	2.7	3.1
10 sec.	1.5	.5	1.3	2.5	3.0
1 min.	1.7	.0	1.7	2.5	2.8
2 min.	1.7	.0	.7	2.0	2.5
3 min.	1.8	.0	.8	2.3	2.6
10 min.	2.3	.2	.8	1.7	3.0
0.3% copper 8-quinolinolate plus water repellent in mineral spirits					
5 sec.	1.0	.5	1.0	2.4	3.0
10 sec.	.9	.5	1.0	2.6	3.3
1 min.	1.3	.5	1.8	2.5	3.3
2 min.	1.1	1.0	.8	2.5	3.3
3 min.	1.1	.5	1.2	2.5	3.3
10 min.	1.3	.3	.8	2.4	3.3
Copper naphthenate (1% Cu) plus water repellent in mineral spirits					
5 sec.	1.0	.0	.0	1.0	2.0
10 sec.	1.0	.0	.3	1.4	2.5
1 min.	1.2	.0	.3	1.2	2.2
2 min.	1.1	.0	.0	1.7	2.3
3 min.	1.1	.0	.0	1.0	2.1
10 min.	1.2	.0	.3	1.2	2.2
5% pentachlorophenol in mineral spirits					
5 sec.	.9	.7	.7	1.8	2.7
10 sec.	.8	.7	1.3	2.3	2.6
1 min.	1.0	.3	1.3	2.3	2.6
2 min.	1.0	.0	.8	2.3	1.5
3 min.	1.2	.0	.7	1.8	2.7
10 min.	1.3	.0	.8	1.3	2.4
5% pentachlorophenol plus water repellent in mineral spirits					
5 sec.	.9	.3	1.2	1.8	2.6
10 sec.	1.0	.0	1.0	2.3	2.8
1 min.	1.0	.0	.7	2.0	2.8
2 min.	1.1	.7	.8	1.8	2.9
3 min.	1.3	.0	.5	2.0	2.8
10 min.	1.5	.0	.7	1.8	2.5

[1]Ratings on a basis of 0 (none) to 5 (destroyed). No failures after 4.9 years' exposure.

Table 12.—EFFECT OF WOOD MOISTURE CONTENT AND FUNGUS INFECTIONS PRIOR TO TREATMENT ON THE RATE OF DECAY OF PINE SAPWOOD SIMULATED BOXES GIVEN 3-MINUTE DIPS IN PRESERVATIVE TREATMENTS

Treatment and wood condition	Moisture content Per cent	Solution absorbed lb./cu. ft.	Average decay rating[1] 1.3 yr.	2.5 yr.	3.2 yr.	4.3 yr.	Proportion of failure[2] 1.3 yr.	2.5 yr.	3.2 yr.	4.3 yr.
							Per cent			
4% sodium pentachlorophenate + 4% borax										
Green, uninfected	110	0.7	0.2	0.5	2.5	3.7	0	0	20	60
Partially dried, uninfected	40[4]	1.5	.0	.2	2.3	3.5	0	0	0	30
Partially dried, infected[3]	40[4]	1.7	.0	.0	2.8	3.8	0	0	0	50
Air dried, uninfected	14	1.9	.1	.6	1.8	3.2	0	0	10	40
Air dried, infected[3]	14	2.1	.0	.7	2.1	3.5	0	0	10	40
Kiln dried, uninfected	9	2.1	.0	.6	1.5	3.0	0	0	0	0
5% pentachlorophenol + water repellent										
Green, uninfected	110	.4	.0	1.2	2.7	3.8	0	0	0	50
Partially dried, uninfected	40[4]	1.6	.0	.7	1.9	3.5	0	0	0	30
Partially dried, infected[3]	40[4]	2.1	1.4	2.6	3.1	3.9	0	0	30	80
Air dried, uninfected	14	2.6	.0	.2	1.0	2.1	0	0	0	0
Air dried, infected[3]	14	2.1	.1	.0	.9	2.4	0	0	0	0
Kiln dried, uninfected	9	2.1	.0	.1	1.0	2.3	0	0	0	0
Untreated										
Green, uninfected	110	---	.0	2.7	3.5	4.4	0	0	70	100
Partially dried, uninfected	40[4]	---	.8	1.8	3.1	4.3	0	0	20	100
Partially dried, infected[3]	40[4]	---	2.9	3.1	4.0	4.9	0	10	90	100
Air dried, uninfected	14	---	.1	3.0	3.6	4.3	0	10	40	100
Air dried, infected[3]	14	---	2.4	2.8	3.9	4.8	0	10	70	100
Kiln dried, uninfected	9	---	2.3	2.7	3.8	4.7	0	0	60	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.
[3]Mainly stain, some mold, and probably incipient decay.
[4]Average moisture content. Surfaces were about 30%; interiors about 65%.

Table 13.—EFFECT OF WATER REPELLENTS APPLIED AS 3-MINUTE DIPS ON THE DECAY RATE OF PINE SAPWOOD IN SIMULATED BOXES

Treatment	Solution absorbed lb./cu. ft.	Average decay rating[1] 1.0 yr.	2.9 yr.	3.6 yr.	4.6 yr.	Proportion of failure[2] 1.9 yr.	2.9 yr.	3.6 yr.	4.6 yr.
							Per cent		
3% orthophenylphenol	2.0	3.1	3.1	3.9	4.8	0	10	50	100
3% orthophenylphenol + water repellent[3]	2.0	2.0	2.7	3.5	5.0	0	10	30	100
5% orthophenylphenol	2.2	1.6	2.2	3.9	4.4	0	10	50	70
5% orthophenylphenol + water repellent[3]	2.0	1.8	3.2	4.3	4.8	0	20	80	100
3% pentachororphenol	2.2	.0	1.3	3.1	3.9	0	0	0	60
3% pentachlorophenol + water repellent[3]	2.1	.2	2.3	3.3	3.4	0	0	0	20
5% pentachlorophenol + water repellent[3]	2.1	.0	.3	2.2	2.4	0	0	0	0
Untreated	---	3.0	4.1	4.8	5.0	0	70	100	100
Water repellent, regular strength[4]	2.0	1.0	1.5	3.4	3.9	0	0	30	60
Water repellent, double strength[5]	2.0	.1	.8	2.8	3.5	0	0	0	10

	Solution absorbed lb./cu. ft.	Average decay rating[1] 2.7 yr.	3.4 yr.	4.4 yr.	Proportion of failure[2] 2.7 yr.	3.4 yr.	4.4 yr.
					Per cent		
5% sodium pentachlorophenate	1.5	2.3	3.1	3.8	0	10	40
5% sodium pentachlorophenate + water repellent[6]	1.5	1.4	2.8	3.7	0	0	30
5% sodium pentachlorophenate + water repellent[7]	1.2	1.2	2.0	3.7	0	0	40
Untreated	---	3.6	4.6	5.0	55	95	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.
[3]8% hydrogenated methyl ester of resin plus 2% paraffin wax was used as a water repellent.
[4]A commercial product that leaves paintable surfaces.
[5]A commercial product that interferes with subsequent painting.
[6]1% silicone (GE silicone SC-50).
[7]4% paraffin wax (8% Ceremul A).

Table 14.—EFFECT OF 2 COATS OF PAINT (TT–E–485b) ON THE EFFECTIVENESS OF 3 PRESERVATIVES IN PREVENTING DECAY IN SIMULATED BOXES OF SOUTHERN PINE SAPWOOD

Treatment	Absorption lb./cu. ft. Painted	Un-painted	Average decay rating[1] Painted 2.8 yr.	3.5 yr.	4.6 yr.	Unpainted 2.8 yr.	3.5 yr.	4.6 yr.	Proportion of failure[2] Painted 2.8 yr.	3.5 yr.	4.6 yr.	Unpainted 2.8 yr.	3.5 yr.	4.6 yr.
									Per cent					
3% pentachlorophenol	2.3	2.1	0.4	1.0	2.6	1.2	2.6	3.0	0	0	0	0	0	0
5% pentachlorophenol	2.2	2.3	.0	.1	1.8	2.0	2.5	2.6	0	0	0	0	0	0
Copper naphthenate, 0.6% Cu	2.1	1.9	.0	.1	1.9	1.9	2.7	3.5	0	0	0	0	40	50
Copper naphthenate, 1% Cu	1.8	1.9	.0	.1	.1	.1	.1	1.5	0	0	0	0	0	0
.18% copper 8-quinolinolate	1.8	1.9	.8	2.1	3.8	2.5	4.1	4.2	0	10	50	0	60	70
.3% copper 8-quinolinolate	2.0	1.8	.4	1.3	3.5	2.3	3.9	4.1	0	0	50	0	40	60
Untreated	---	---	---	---	---	3.3	4.2	5.0	---	---	---	40	67	100
Average (treated)	---	---	.3	.8	2.3	1.7	2.5	3.2	0	0.2	17	0	23	30

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Table 16.—AMOUNT OF METAL CORROSION ON M–22 BOXES EXPOSED FOR 38 MONTHS IN UNCOVERED PILES IN SOUTHERN MISSISSIPPI

Treatment	Proportion of boxes in each corrosion class[1]																			
	U-bolts										Strapping									
	With water repellent					Without water repellent					With water repellent					Without water repellent				
	0–1	2	3	4	5	0–1	2	3	4	5	0–1	2	3	4	5	0–1	2	3	4	5
	Per cent					Per cent					Per cent					Per cent				
Oil Solutions, 3-Minute Dips																				
Copper naphthenate																				
0.5% Cu	67	17	17	0	0	--	--	--	--	--	58	17	25	0	0	--	--	--	--	--
1.0% Cu	75	25	0	0	0	67	33	0	0	0	33	67	0	0	0	50	25	25	0	0
2.0% Cu	83	17	0	0	0	75	25	0	0	0	58	42	0	0	0	33	42	25	0	0
Copper pentachlorophenate																				
2.5%	58	25	8	8	0	--	--	--	--	--	33	33	17	8	8	--	--	--	--	--
5.0%	42	50	8	0	0	0	42	50	8	0	17	33	25	25	0	0	33	33	33	0
Copper 3-phenyl salicylate																				
1.25%	67	33	0	0	0	--	--	--	--	--	8	67	25	0	0	--	--	--	--	--
2.5%	25	75	0	0	0	17	75	8	0	0	25	75	0	0	0	17	75	8	0	0
5.0%	42	50	8	0	0	0	25	67	8	0	17	58	25	0	0	8	50	42	0	0
Copper 8-quinolinolate																				
0.15%	58	33	8	0	0	--	--	--	--	--	8	67	25	0	0	--	--	--	--	--
0.3%	33	58	8	0	0	8	50	42	0	0	17	83	0	0	0	0	75	25	0	0
0.6%	50	50	0	0	0	0	67	25	8	0	17	58	25	0	0	0	67	25	8	0
0.3% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	0	83	17	0	0	--	--	--	--	--	0	83	17	0	0
Mineral spirits (aliphatic)	21	79	0	0	0	33	58	8	0	0	37	64	0	0	0	17	83	0	0	0
Orthophenylphenol																				
2.5%	25	58	17	0	0	--	--	--	--	--	17	50	33	0	0	--	--	--	--	--
5.0%	25	58	17	0	0	0	83	17	0	0	8	42	33	17	0	25	67	8	0	0
10.0%	58	42	0	0	0	8	42	50	0	0	25	58	0	17	0	0	25	75	0	0
Pentachlorophenol																				
2.5%	33	50	17	0	0	--	--	--	--	--	17	67	17	0	0	--	--	--	--	--
5.0%	75	25	0	0	0	30	40	30	0	0	58	42	0	0	0	40	50	10	0	0
10.0%	54	27	18	0	0	42	50	8	0	0	36	36	27	0	0	50	42	8	0	0
5.0% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	8	83	8	0	0	--	--	--	--	--	8	50	42	0	0
Phenyl mercuric oleate																				
0.15%	42	58	0	0	0	--	--	--	--	--	42	50	8	0	0	--	--	--	--	--
0.3%	8	75	17	0	0	17	58	25	0	0	8	50	42	0	0	25	67	8	0	0
0.6%	42	42	17	0	0	8	58	33	0	0	25	67	8	0	0	0	92	0	8	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent																				
25.0%	50	25	25	0	0	--	--	--	--	--	50	25	25	0	0	--	--	--	--	--
37.5%	33	67	0	0	0	--	--	--	--	--	17	83	0	0	0	--	--	--	--	--
Rosin amine D pentachlorophenate																				
2.75%	58	42	0	0	0	--	--	--	--	--	8	92	0	0	0	--	--	--	--	--
5.5%	25	58	17	0	0	25	75	0	0	0	17	67	17	0	0	8	67	25	0	0
11.0%	67	33	0	0	0	8	58	25	8	0	42	58	0	0	0	17	58	17	8	0
Tetrachlorophenol																				
2.5%	33	33	33	0	0	--	--	--	--	--	33	33	33	0	0	--	--	--	--	--
5.0%	42	50	8	0	0	8	25	50	17	0	17	75	8	0	0	58	17	17	8	0
10.0%	42	33	25	0	0	33	42	25	0	0	25	50	25	0	0	0	42	33	25	0
Zinc alkyl sulphonate																				
2.8%	0	75	25	0	0	--	--	--	--	--	0	83	17	0	0	--	--	--	--	--
5.7%	33	58	8	0	0	--	--	--	--	--	8	92	0	0	0	--	--	--	--	--
Zinc naphthenate																				
0.5% Zn	25	75	0	0	0	--	--	--	--	--	33	67	0	0	0	--	--	--	--	--
1.0% Zn	67	33	0	0	0	42	33	25	0	0	50	50	0	0	0	42	50	8	0	0
2.0% Zn	75	25	0	0	0	25	67	8	0	0	17	83	0	0	0	42	42	17	0	0
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride																				
5.0%	--	--	--	--	--	0	0	0	92	8	--	--	--	--	--	0	0	8	58	33
10.0%	0	0	0	42	58	0	0	0	33	67	0	0	0	25	75	0	0	0	8	92
20.0%	--	--	--	--	--	0	0	0	17	83	--	--	--	--	--	0	0	0	8	92
Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol																				
2.5%	--	--	--	--	--	17	42	42	0	0	--	--	--	--	--	0	42	50	0	8
7.5%	--	--	--	--	--	0	17	58	25	0	--	--	--	--	--	0	0	17	8	75
Rosin amine D acetate																				
2.5%	--	--	--	--	--	8	83	8	0	0	--	--	--	--	--	17	67	17	0	0
5.0%	--	--	--	--	--	25	33	42	0	0	--	--	--	--	--	0	75	25	0	0
10.0%	--	--	--	--	--	0	42	58	0	0	--	--	--	--	--	0	33	67	0	0
Sodium pentachlorophenate																				
2.85%	21	42	30	8	0	8	25	58	8	0	--	--	--	--	--	0	42	58	0	0
5.7%	--	--	--	--	--	17	42	42	0	0	0	42	42	8	8	0	17	83	0	0
11.4%	25	67	8	0	0	8	67	25	0	0	--	--	--	--	--	0	75	25	0	0
2.0% plus borax 3.0%	--	--	--	--	--	17	25	50	8	0	50	42	8	0	0	0	58	33	8	0
4.0% plus borax 4.0%	--	--	--	--	--	8	8	75	8	0	--	--	--	--	--	0	33	50	17	0
Sodium tetrachlorophenate																				
2.85%	42	25	25	8	0	--	--	--	--	--	42	17	33	0	8	--	--	--	--	--
5.7%	33	33	8	25	0	8	17	75	0	0	33	25	25	17	0	0	17	42	33	8
Water repellent, 4% solids	8	92	0	0	0	--	--	--	--	--	17	50	33	0	0	--	--	--	--	--
Oil Solution, Pressure Treatment																				
Pentachlorophenol	67	25	8	0	0	8	58	33	0	0	42	58	0	0	0	0	50	50	0	0
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	--	--	--	--	--	0	33	33	33	0	--	--	--	--	--	0	0	0	56	44
Celcure	--	--	--	--	--	0	0	78	22	0	--	--	--	--	--	0	0	22	56	22
Tanalith	--	--	--	--	--	0	56	44	0	0	--	--	--	--	--	0	67	33	0	0
Untreated																				
	15	63	23	0	0	--	--	--	--	--	6	58	35	0	0	--	--	--	--	--

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

Several treatments resulted in significantly less strap corrosion than occurred on the untreated controls. Zinc naphthenate at all concentrations tested and with or without water repellent resulted in significantly less (.6 to .7 as much) corrosion of strapping than occurred on the untreated boxes. Corrosion of U-bolts also was less than on the untreated boxes, but the differences were not so great as with the strapping. Boxes treated with copper naphthenate also usually had less strap corrosion than the controls, but not so consistently as those treated with zinc naphthenate.

Metal corrosion was significantly less on boxes in the pile covered with the tarpaulin (Table 18). Here only the hardware on boxes treated with copper ammonium fluoride was seriously corroded, and then to a lesser degree than on uncovered boxes.

The effect of painting on the corrosion rate of strapping is summarized in Table 19. The outer face of the strapping was painted as well as the wood surfaces. This materially reduced the amount of corrosion, as the following averages show:

Treatment	Unpainted	Painted
11 oil treatments with WR	1.8	1.2
4 water treatments without WR (excluding copper ammonium fluoride)	2.7	1.6
Untreated	2.3	1.3

The addition of a water repellent to oil solutions reduced corrosion of both U-bolts and strapping in Mississippi (Table 16). This was true of 17 of 21 comparisons for U-bolts and 16 of 21 comparisons for strapping. The average rating for U-bolts was reduced from 2.0 to 1.5 and strapping from 2.1 to 1.8. With water solutions (excluding copper ammonium fluoride), there were three comparisons. The addition of the water repellent reduced corrosion of U-bolts in each case—the average rating being reduced from 2.5 to 2.0—but had no effect on average corrosion ratings for strapping. In the Panama exposures there were only 2 comparisons with water treatments, and 1 with oil. In all 3 comparisons, the water repellent caused more corrosion of strapping, and in 2 of the 3 more corrosion of U-bolts. Because of the small number of comparisons in Panama, however, there is no assurance that this apparent reversal would apply in general.

Insect Attack

The only insect importantly attacking sound boxes in Mississippi was the subterranean termite *Reticulitermes*. Borers, however, did commonly enter decayed wood. In Panama the greatest damage was by the subterranean termite *Coptotermes niger*, but some damage was caused by the termites *Nasutitermes* and *Heterotermes*. In Panama practically all treatments except the inorganic salts applied by pressure were commonly penetrated by an unidentified borer, but the resulting damage was insignificant.

Termite attack was rated on a scale of 0 to 5:

0	No attack
1	Nibbles, but no penetration
2	Penetration, but limited damage
3	Attack general, but only minor loss in strength
4	Heavy attack; box would fail in drop test
5	Destroyed

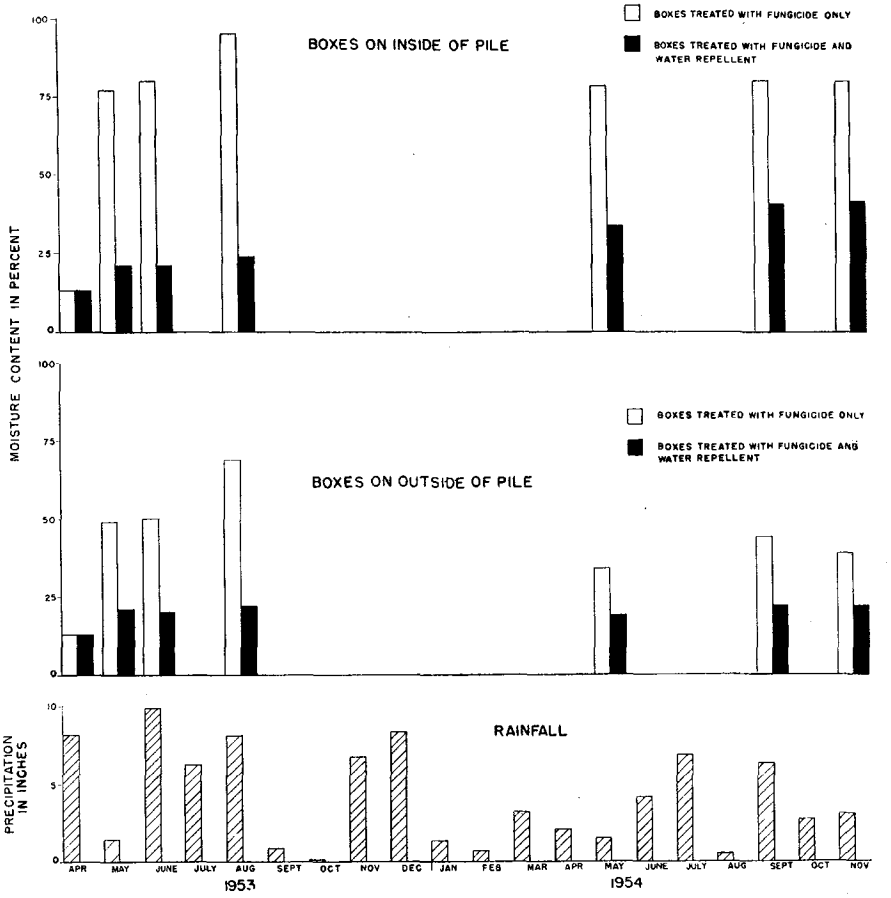

Fig. 6.—The effectiveness of a water repellent applied as a 3-minute dip in preventing wetting of M22 boxes by rainwater. Exposure was in Mississippi. Fungicide was pentachlorophenol.

Table 15.—RELATIVE EFFECTIVENESS OF PRESERVATIVES APPLIED TO SOUTHERN PINE SAPWOOD SIMULATED BOXES IN MINERAL SPIRITS AND A NUMBER 2 FUEL OIL WHEN USED AS A 3-MINUTE DIP

Treatment	Solution absorbed lb./cu.ft.	Average decay rating[1] 1.6 yr.	2.9 yr.	3.4 yr.	4.5 yr.	Proportion of failure[2] 1.6 yr.	2.9 yr.	3.4 yr.	4.5 yr.
						Per cent			
Copper naphthenate, 1% Cu									
Mineral spirits	1.8	0.0	0.1	0.9	2.2	0	0	0	0
Fuel oil	2.1	.0	.3	1.3	1.8	0	0	0	0
0.3% copper 8-quinolinolate									
Mineral spirits	1.6	.0	1.0	2.0	3.4	0	0	0	20
Fuel oil	1.8	.0	1.1	2.5	2.6	0	0	0	0
5% orthophenylphenol									
Mineral spirits	1.9	1.5	1.9	2.7	3.6	0	0	0	50
Fuel oil	2.2	.0	.1	2.2	3.1	0	0	20	20
5% pentachlorophenol									
Mineral spirits	2.0	.0	.0	.9	2.3	0	0	0	0
Fuel oil	1.9	.0	.0	1.2	2.3	0	0	0	0
Untreated	---	2.9	3.3	4.2	5.0	0	40	68	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Termite attack in Mississippi was much slower than decay attack (Tables 20 and 3). Even with the untreated boxes, damage was restricted to the bottom units in contact with the soil. In Mississippi, pressure treatments with Celcure, Tanalith, and copperized chromated zinc chloride prevented termite damage for 5 years. Similar treatment with pentachlorophenol permitted slight attack, but no important damage.

Dip treatments, because they result only in a surface covering of the toxicant, are less effective against termites

Table 17.—AMOUNT OF METAL CORROSION ON M-22 BOXES EXPOSED FOR 42 MONTHS IN UNCOVERED[1] PILES IN THE PANAMA CANAL ZONE

Treatment	Proportion of boxes in each corrosion class[2] — U-bolts — 0–1	2	3	4	5	Strapping — 0–1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Benzene hexachloride, (0.5% gamma)	0	22	78	0	0	0	78	22	0	0
Copper naphthenate, (1% Cu) plus WR	11	78	11	0	0	0	89	11	0	0
Copper naphthenate, (2% Cu) plus WR	44	44	11	0	0	0	78	22	0	0
Copper pentachlorophenate, 5% plus WR	0	0	56	44	0	0	56	11	33	0
Copper 3-phenyl salicylate, 2.5% plus WR	17	33	50	0	0	6	50	44	0	0
Copper 3-phenyl salicylate, 5.0% plus WR	0	33	67	0	0	0	56	44	0	0
Copper 8-quinolinolate, 0.3% plus WR	11	67	22	0	0	0	67	33	0	0
Copper 8-quinolinolate, 0.6% plus WR	0	67	33	0	0	0	67	33	0	0
Copper 8-quinolinolate, 0.3%, plus 0.5% gamma benzene hexachloride	0	0	100	0	0	0	67	33	0	0
Orthophenylphenol, 5% plus WR	0	67	33	0	0	0	33	67	0	0
Orthophenylphenol, 10% plus WR	0	67	22	11	0	0	67	22	11	0
Pentachlorophenol, 5% plus WR	0	25	38	38	0	0	63	38	0	0
Pentachlorophenol, 10% plus WR	0	22	56	22	0	0	11	89	0	0
Pentachlorophenol, 5% plus 0.5% gamma benzene hexachloride	0	22	67	11	0	0	44	56	0	0
Phenyl mercuric oleate, 0.3% plus WR	0	56	44	0	0	0	67	33	0	0
Phenyl mercuric oleate, 0.6% plus WR	0	33	56	11	0	0	22	78	0	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent										
25.0%	0	100	0	0	0	0	78	22	0	0
37.5%	0	89	11	0	0	11	67	22	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	0	11	78	11	0	0	44	56	0	0
Rosin amine D pentachlorophenate, 11.0% plus WR	0	33	44	22	0	0	56	33	11	0
Tetrachlorophenol, 5% plus WR	0	22	67	11	0	11	11	67	11	0
Tetrachlorophenol, 10% plus WR	0	33	56	11	0	0	56	33	11	0
Water repellent only	6	47	47	0	0	6	53	41	0	0
Zinc alkyl sulphonate, 5.7% plus WR	0	33	67	0	0	11	44	44	0	0
Zinc naphthenate, (1% Zn) plus WR	67	33	0	0	0	44	44	11	0	0
Zinc naphthenate, (2% Zn) plus WR	78	22	0	0	0	67	33	0	0	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 10%	0	0	0	100	0	0	0	0	100	0
Copper ammonium fluoride, 20%	0	0	0	75	25	0	0	13	62	25
Copper ammonium fluoride, 10% plus WR	0	0	0	33	67	0	0	0	33	67
Product containing sodium salts of dimethyl dithiocarbamic acid and 2-mercapto benzothiazole, and pentachlorophenol, 7.5%	0	0	89	11	0	0	0	89	11	0
Rosin amine D acetate, 5%	0	44	56	0	0	0	78	22	0	0
Rosin amine D acetate, 10%	0	33	67	0	0	0	78	22	0	0
Sodium pentachlorophenate, 5.7%	0	11	33	56	0	0	33	56	11	0
Sodium pentachlorophenate, 11.4%	0	0	44	56	0	0	11	56	33	0
Sodium pentachlorophenate, 2.0%, plus borax 3%	0	11	78	11	0	0	0	100	0	0
Sodium pentachlorophenate, 4.0%, plus borax 4%	11	11	44	33	0	0	33	67	0	0
Sodium pentachlorophenate, 2.0%, plus borax 3%, plus WR	0	0	22	78	0	0	11	33	56	0
Sodium tetrachlorophenate, 5.7%	0	0	67	33	0	0	0	100	0	0
Sodium tetrachlorophenate, 5.7% plus WR	0	11	0	89	0	0	0	22	78	0
Oil Solutions, Pressure Treatments										
Pentachlorophenol, 5%	0	11	78	11	0	0	56	44	0	0
Pentachlorophenol, 5% plus WR	0	11	78	11	0	0	22	67	11	0
Water Solutions, Pressure Treatments										
Copperized chromated zinc chloride	0	0	0	100	0	0	0	0	33	67
Tanalith	33	33	33	0	0	0	67	33	0	0
Celcure	0	0	17	83	0	0	0	17	83	0
Untreated	0	59	29	12	0	0	53	41	6	0

[1]One of 3 piles was covered after 18 months. The boxes remained moist, but not wet.
[2]Rated on a basis of 0 (none) to 5 (destroyed).

than against decay. Termites attack by chewing away the treated surface. Many may be poisoned before a passageway is eaten into the untreated interior, but many will remain to continue the attack once the treated shell is broken. Among the 3-minute dips, attack was appreciably reduced only by 0.3 per cent copper 8-quinolinolate plus 0.5 per cent gamma benzene hexachloride, 5 per cent pentachlorophenol plus 0.5 per cent gamma benzene hexachloride, and 10 per cent rosin amine D pentachlorophenate. Benzene hexachloride, which is a good insecticide, was added to these two fungicides in the hope that it would increase resistance to termites, but the protection gained was not so great as that afforded by soil treatment.

In Panama, termite attack was very rapid on boxes exposed on untreated soil (Table 21), and attacked boxes were usually destroyed in 6 months. This was much faster than decay action. After the first half year, however, very few failures from termites were recorded, and very little activity was noted except when piles were disturbed in examination. Perhaps high moisture content of the wood reduced termite attack as well as typical decay.

Only the pressure treatments with Tanalith and copperized chromated zinc chloride and a 3-minute dip in 10 per cent orthophenylphenol prevented serious termite attack in Panama for 2.5 years. Eight other treatments, however, showed some effectiveness in that heavy attack was restricted to the bottom boxes in contact with the soil:

Copper naphthenate (2% Cu) plus WR	3-minute dip
Copper pentachlorophenate, 5% plus WR	3-minute dip
Copper 8-quinolinolate, 0.3% plus WR	3-minute dip
Pentachlorophenol, 5% plus 0.5% gamma benzene hexachloride	3-minute dip
Pentachlorophenol, 10% plus WR	3-minute dip
Sodium pentachlorophenate, 4% plus borax, 4%	3-minute dip
Sodium tetrachlorophenate, 5.7%	3-minute dip
Pentachlorophenol plus WR	pressure

Table 18.—EFFECT OF TARPAULIN COVER ON THE AMOUNT OF METAL CORROSION ON M–22 BOXES EXPOSED FOR 38 MONTHS IN SOUTH MISSISSIPPI

Treatment	Proportion of boxes with U-bolts in each corrosion class[1] — Covered pile — 0–1	2	3	4	5	Uncovered piles — 0–1	2	3	4	5	Proportion of boxes with strapping in each corrosion class[1] — Covered pile — 0–1	2	3	4	5	Uncovered piles — 0–1	2	3	4	5
	Per cent																			
Oil Solutions, 3-Minute Dips																				
Copper naphthenate (1% Cu) plus WR	100	0	0	0	0	75	25	0	0	0	100	0	0	0	0	33	67	0	0	0
Copper 3-phenyl salicylate, 2.5% plus WR	100	0	0	0	0	25	75	0	0	0	100	0	0	0	0	25	75	0	0	0
Copper 8-quinolinolate, 0.3% plus WR	100	0	0	0	0	33	58	8	0	0	100	0	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic)100%	50	50	0	0	0	33	58	8	0	0	100	0	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic) 100%, plus WR	100	0	0	0	0	21	79	0	0	0	100	0	0	0	0	37	64	0	0	0
Orthophenylphenol, 5% plus WR	100	0	0	0	0	25	58	17	0	0	100	0	0	0	0	8	42	33	17	0
Pentachlorophenol, 5% plus WR	100	0	0	0	0	75	25	0	0	0	100	0	0	0	0	58	42	0	0	0
Phenyl mercuric oleate, 0.3% plus WR	83	17	0	0	0	8	75	17	0	0	100	0	0	0	0	8	50	42	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	100	0	0	0	0	25	58	17	0	0	100	0	0	0	0	17	67	17	0	0
Zinc naphthenate, (1% Zn) plus WR	100	0	0	0	0	67	33	0	0	0	100	0	0	0	0	50	50	0	0	0
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride, 10%	0	0	92	8	0	0	0	0	33	67	0	0	0	100	0	0	0	0	8	92
Sodium pentachlorophenate, 2%, plus borax, 3.0%	33	67	0	0	0	17	25	50	8	0	75	25	0	0	0	0	58	33	8	0
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	67	33	0	0	0	0	33	33	33	0	11	78	11	0	0	0	0	0	56	44
Tanalith	22	67	11	0	0	0	56	44	0	0	0	89	11	0	0	0	67	33	0	0
Celcure	78	22	0	0	0	0	0	78	22	0	22	78	0	0	0	0	0	22	56	22
Untreated	67	33	0	0	0	15	63	23	0	0	100	0	0	0	0	6	58	35	0	0

[1]Ratings on a basis of 0 (none) to 5 (destroyed).

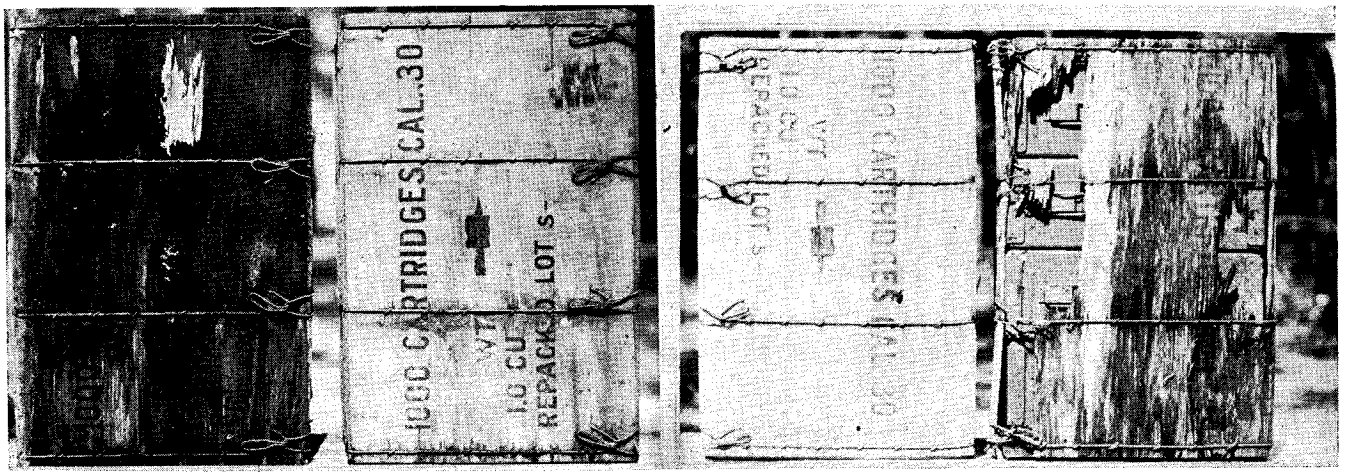

Fig. 7.—Rotary-cut hardwood veneer crates exposed in uncovered piles in Mississippi. (Left) After 1.3 years' exposure: heavy stain and important decay in untreated crate. Crate given a 3-minute dip in 5 per cent pentachlorophenol plus a water repellent is essentially free of stain and decay. (Right) Similar boxes after 3.1 years exposure.

In Wisconsin, no termite attack occurred.

Some boxes exposed in Mississippi had two spray coats of paint (TT-E-485b). Painting reduced termite attack in both treated and untreated boxes (Table 22). Only one painted box failed, as compared with 16 of the comparable unpainted boxes. It is doubtful, however, that painting should be considered an important termite-prevention measure. In Panama, where the voracious *Coptotermes* is common, painting would probably have had little effect.

Two piles in Mississippi and one pile in Panama were on soil that had been poisoned with DDT. Two additional piles in Panama were on a concrete slab that had been similarly poisoned. No termite attack occurred in the Mississippi piles on treated soil for four years. During the fifth year, a few termites entered one corner of the pile, but had not caused any damage. In Panama, *Nasutitermes* bridged into two treated piles through fallen branches and destroyed some boxes. No attack, however, occurred through the treated soil during 4.5 years.

Water Repellency

Test units exposed in Mississippi were weighed periodically to determine how much rain-wetting had occurred. Weights were also secured once in Panama and Wisconsin, but unless otherwise stated, weights are for Mississippi. Fully air-dried boxes weighed 7 to 10 pounds, with an average weight of about 8 pounds. In general, boxes in the 12 to 15 pound range were optimum for decay. Those at 18 to 20 pounds were probably at or near the maximum moisture content for decay, and those below 10 pounds contained too little moisture for decay. It must be remembered that these relationships are average. For example, a box may weigh 10 pounds and still have individual boards sufficiently wet to be decayed.

Table 19.—EFFECT OF 2 COATS OF PAINT (TT-E-485b) ON THE AMOUNT OF CORROSION OF GALVANIZED STRAPPING ON M-22 BOXES TREATED WITH VARIOUS PRESERVATIVES AND EXPOSED WITHOUT COVER FOR 38 MONTHS IN SOUTH MISSISSIPPI

Treatment	Proportion of boxes in each corrosion class[1]									
	Painted					Unpainted				
	0–1	2	3	4	5	1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Copper naphthenate, (1% Cu) plus WR	83	17	0	0	0	33	67	0	0	0
Copper 3-phenyl salicylate, 2.5% plus WR	67	33	0	0	0	25	75	0	0	0
Copper 8-quinolinolate, 0.3% plus WR	50	50	0	0	0	17	83	0	0	0
Mineral spirts (aliphatic) 100%	100	0	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic) 100%, plus WR	96	4	0	0	0	37	64	0	0	0
Orthophenylphenol, 5% plus WR	58	33	8	0	0	8	42	33	17	0
Pentachlorophenol, 5% plus WR	58	42	0	0	0	58	42	0	0	0
Phenyl mercuric oleate, 0.3% plus WR	100	0	0	0	0	8	50	42	0	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent 37.5%	100	0	0	0	0	17	83	0	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	42	58	0	0	0	17	67	17	0	0
Zinc alkyl sulphonate, 5.7% plus WR	50	17	33	0	0	0	83	17	0	0
Zinc naphthenate, (1% Zn) plus WR	92	8	0	0	0	50	50	0	0	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 10%	0	0	0	25	75	0	0	0	8	92
Rosin amine D acetate, 5%	75	25	0	0	0	0	75	25	0	0
Sodium pentachlorophenate, 5.7%	42	58	0	0	0	0	17	83	0	0
Sodium pentachlorophenate, 2.0% plus borax 3.0%	58	25	0	17	0	0	58	33	8	0
Sodium tetrachlorophenate, 5.7%	42	42	8	0	8	0	17	42	33	8
Oil Solution, Pressure Treatment										
Pentachlorophenol, 5%	58	42	0	0	0	0	50	50	0	0
Untreated	79	17	4	0	0	6	58	35	0	0

[1]Ratings on a basis of 0 (none) to 5 (destroyed).

In wet periods, the boxes under cover became moist where in contact with the soil but no traces of condensation were found in this test. The boxes should remain too dry to decay as long as the tarpaulin is water-tight, or except for wetting by the rare water-conducting fungus (Fig. 2B).

A tarpaulin cover (Fig. 1) kept boxes dry during the entire 5-year exposure period, as the following average weights show:

Exposure condition	Average weight per box (lbs.)		
	Oil solutions		Water solutions
	No WR	WR	No WR
Under tarpaulin			
Outside and inside tiers	8.1	8.0	8.1
Fully exposed			
Outside tiers	8.9	8.7	8.8
Inside tiers	13.6	11.8	13.1

Two spray coats of paint (TT–E–485b, Type II) had some effect on moisture content. Boxes treated with copper naphthenate (2 per cent Cu) and 5 per cent pentachlorophenol, when weighed during a dry period in May and a wet period in August 1954, had the following weights:

Treatment	Average weight (lb.) of boxes in inside tiers			
	Dry weather		Wet weather	
	Painted	Unpainted	Painted	Unpainted
With water repellent	9.7	9.5	10.0	9.8
Without water repellent	11.8	12.9	11.8	13.3
Untreated	12.1	14.8	12.3	17.3

Paint reduced wetting, but without the water repellent the reduction was not sufficient to keep the moisture content below the minimum for decay activity. As pointed out earlier, however, the paint did reduce the amount of decay.

Next to the tarpaulin cover, water repellents had the most marked effect on moisture content of boxes. The average effect of all water-repellent treatments at Gulfport is shown in Fig. 6. For this graph, weights were transformed to moisture contents expressed as percentage of oven-dry weight. There is no doubt that the addition of a water repellent reduced water absorption. The effect was very striking for exposures of a few months, but with prolonged storage, water-repellent-treated boxes became and remained sufficiently wet inside test piles to support optimum decay. This water accumulation was particularly evident in Panama where, after 18 months, boxes given water-repellent treatment averaged 18.2 pounds for inside tiers and 14.2 pounds for outside tiers. Many of the boxes weighed 20 pounds and were probably at the maximum moisture content for ordinary types of decay.

The water repellents were effective on all wood species tested (Table 23). Units made of less permeable woods, such as the heartwood of southern pine and Douglas-fir, when treated, showed appreciably slower water build-up than did the more permeable woods. This factor, along with moderate natural decay resistance, probably contributes importantly to the apparently better protection afforded by dip treatments to some wood species.

Repellents applied as 3-minute dips prevented moisture pickup as effectively as when aplied by pressure. The following weights were secured after a wet period (18 months' exposure):

	Average weight (lbs.) of boxes in inside tiers
5% pentachlorophenol plus WR 3-minute dip	9.3
Pressure treatment	9.6
5% pentachlorophenol (no WR)	13.8

In supplementary tests, a 5-second dip was just as effective as a 10-minute soak in imparting water repellency (Tables 24 and 25).

Water repellent WR-7 was effective in overcoming the high absorbency of wood molded with *Trichoderma* (8). Matched boards of southern pine sapwood, some of which were intentionally molded with *Trichoderma,* were given 3-minute dips. The amount of preservative absorbed and average moisture content at different exposure periods are listed in Table 26. The 3-minute dip resulted in excessive ab-

Table 20.—SUBTERRANEAN TERMITE ATTACK ON M-22 BOXES EXPOSED FOR 38 MONTHS ON NON-POISONED SOIL IN SOUTHERN MISSISSIPPI

Treatment	Proportion of boxes in each rating class[1]									
	With water repellent					Without water repellent				
	0–1	2	3	4	5	0–1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Copper naphthenate, 0.5% Cu	75	0	25	0	0	--	--	--	--	--
Copper naphthenate, 1.0% Cu	75	0	25	0	0	88	13	0	0	0
Copper naphthenate, 2.0% Cu	75	25	0	0	0	75	0	25	0	0
Copper pentachlorophenate, 2.5%	88	13	0	0	0	--	--	--	--	--
Copper pentachlorophenate, 5.0%	75	13	13	0	0	88	0	13	0	0
Copper 3-phenyl salicylate, 1.25%	75	0	13	13	0	--	--	--	--	--
Copper 3-phenyl salicylate, 2.5%	75	0	25	0	0	75	0	13	13	0
Copper 3-phenyl salicylate, 5.0%	75	13	13	0	0	75	0	25	0	0
Copper 8-quinolinolate, 0.15%	75	0	25	0	0	--	--	--	--	--
Copper 8-quinolinolate, 0.3%	75	0	0	25	0	75	0	0	25	0
Copper 8-quinolinolate, 0.6%	75	13	0	0	13	75	0	25	0	0
Copper 8-quinolinolate, 0.3% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	88	13	0	0	0
Mineral spirits (aliphatic)	75	0	19	6	0	75	0	13	0	13
Orthophenylphenol, 2.5%	75	0	25	0	0	--	--	--	--	--
Orthophenylphenol, 5.0%	75	0	25	0	0	75	0	13	13	0
Orthophenylphenol, 10.0%	75	0	13	13	0	75	0	25	0	0
Pentachlorophenol, 2.5%	75	0	13	13	0	--	--	--	--	--
Pentachlorophenol, 5.0%	75	0	13	13	0	75	0	25	0	0
Pentachlorophenol, 10.0%	75	0	25	0	0	75	0	25	0	0
Pentachlorophenol, 5.0% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	75	25	0	0	0
Phenyl mercuric oleate, 0.15%	75	0	13	0	13	--	--	--	--	--
Phenyl mercuric oleate, 0.3%	75	0	13	13	0	75	0	0	25	0
Phenyl mercuric oleate, 0.6%	75	13	13	0	0	75	0	13	13	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl amine salt of tetrachlorophenol, and 25.5% water repellent										
25.0%	75	0	13	0	13	--	--	--	--	--
37.5%	75	0	25	0	0	--	--	--	--	--
Rosin amine D pentachlorophenate, 2.75%	75	0	13	13	0	--	--	--	--	--
Rosin amine D pentachlorophenate, 5.5%	75	0	13	13	0	75	0	13	13	0
Rosin amine D pentachlorophenate, 11.0%	75	0	25	0	0	75	0	13	13	0
Tetrachlorophenol, 2.5%	75	13	0	13	0	--	--	--	--	--
Tetrachlorophenol, 5.0%	75	0	25	0	0	75	0	13	13	0
Tetrachlorophenol, 10.0%	75	13	13	0	0	75	0	25	0	0
Zinc alkyl sulphonate, 2.8%	75	0	25	0	0	--	--	--	--	--
Zinc alkyl sulphonate, 5.7%	75	0	0	25	0	--	--	--	--	--
Zinc naphthenate, 0.5% Zn	75	0	25	0	0	--	--	--	--	--
Zinc naphthenate, 1.0% Zn	75	0	0	25	0	75	0	13	13	0
Zinc naphthenate, 2.0% Zn	75	0	13	13	0	75	0	25	0	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 5.0%	--	--	--	--	--	75	0	13	13	0
Copper ammonium fluoride, 10.0%	75	13	13	0	0	75	13	13	0	0
Copper ammonium fluoride, 20.0%	--	--	--	--	--	75	13	13	0	0
Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol										
2.5%	--	--	--	--	--	75	0	13	0	13
7.5%	--	--	--	--	--	75	0	25	0	0
Rosin amine D acetate, 2.5%	--	--	--	--	--	75	0	13	0	13
Rosin amine D acetate, 5.0%	--	--	--	--	--	75	0	13	13	0
Rosin amine D acetate, 10.0%	--	--	--	--	--	88	13	0	0	0
Sodium pentachlororphenate, 2.85%	--	--	--	--	--	75	0	25	0	0
Sodium pentachlorophenate, 5.7%	75	0	19	6	0	75	0	25	0	0
Sodium pentachlorophenate, 11.4%	--	--	--	--	--	75	13	13	0	0
Sodium pentachlorophenate, 2.0% plus borax 3.0%	75	0	25	0	0	75	0	13	13	0
Sodium pentachlorophenate, 4.0% plus borax 4.0%	--	--	--	--	--	75	0	25	0	0
Sodium tetrachlorophenate, 2.85%	75	0	25	0	0	--	--	--	--	--
Sodium tetrachlorophenate, 5.7%	75	0	25	0	0	75	0	13	13	0
Water repellents, 4% solids	75	0	25	0	0	--	--	--	--	--
Oil Solution, Pressure Treatment										
Pentachlorophenol	75	0	25	0	0	88	0	13	0	0
Water Solutions, Pressure Treatments										
Copperized chromated zinc chloride	--	--	--	--	--	100	0	0	0	0
Celcure	--	--	--	--	--	100	0	0	0	0
Tanalith	--	--	--	--	--	100	0	0	0	0
Untreated	--	--	--	--	--	75	0	12	6	6

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

sorption of the preservative by the molded wood. It is not known if absorptions by the molded wood comparable to those by the bright wood would have given good repellency.

Wood dipped in a water repellent without a toxicant had good repellency during early exposure, but lost it after 6 months to 1 year of exposure (Table 27). Presumably, molds developing on the wood increase its absorbency. Wood given a 3-minute dip in a commercial water repellent with high solids content (leaving non-paintable surfaces) maintained its effectiveness for two years, the longest period under test.

Small differences were found between various commercial water-repellent preservatives sold as meeting Federal Specification TT-W-572, but they were not of practical magnitude. None was superior to the WR-7 formula used in the main box test. Twenty per cent linseed oil was somewhat less effective and 12 per cent alkyd resins were very much less effective than WR-7 (Table 28). Four per cent wax in water emulsions was as effective as 2 per cent wax in oil solutions (Table 29). One per cent silicone in water solution was somewhat less effective than the wax emulsion (Table 29).

Miscellaneous Factors Influencing Box Treatments

The over-all deterioration rate in Panama (Table 6) was higher than in Mississippi, but still decay was slower than anticipated. To test the likelihood that the high rainfall maintained wood moisture contents near the maximum for decay, one of the 5 piles in Panama was covered with roll roofing after 18 months of exposure. Further rainwetting was thus prevented, and one year later the wood moisture conetnt was appreciably lower and the percentage of failures was much higher than in the comparable uncovered pile:

	Per cent failed	
	Not covered	Covered
3-minute dips	5	35
Pressure-treated	5	25
Untreated	42	100

The decay in the covered pile was mostly typical brown-cubical rot as caused by many Basidiomycetes rather than the black wet-rot type predominating in the uncovered piles.

No difficulty was experienced in painting any of the treated wood, including that pressure-treated with pentachlorophenol (Tables 5, 14). Similarly, there was no evidence that paint durability was less on the treated than on the untreated units. A few samples given 3-minute dips in sodium pentachlorophenate in water plus 4 per cent emulsified paraffin wax were successfully painted, and the films have remained intact after 3 years' outdoor storage. In all cases, the paint used was TT–E–485b, Type II, olive drab, and was not applied until a week or more after preservative treatment.

Most preservatives were applied at three concentrations: 1) that ordinarily used in wood preservation or thought to be most suitable, 2) half this concentration, and 3) double the first concentration. With the boxes there was, in general, surprisingly little difference in decay rate with different concentrations (Tables 2, 3), and some boxes with double concentration failed sooner than those with lighter treatments. With the better matched simulated-box units, rate of decay was in direct proportion to concentration (Tables 13, 14). With copper naphthenate, concentration seemed to be more critical than with pentachlorophenol (Table 14). Wood treated with copper naphthenate at 0.6 per cent Cu decayed at a significantly faster rate than at 1 per

Table 21.—SUBTERRANEAN TERMITE ATTACK ON M-22 BOXES ON NON-POISONED SOIL IN THE PANAMA CANAL ZONE

Treatment	Proportion of boxes that failed[1] [2]		
	0.5 years	1.5 years	2.5 years
	Per cent		
Oil Solutions, 3-Minute Dips			
Benzene hexachloride (0.5% gamma)	13	13	13
Copper naphthenate, 1% Cu plus WR	25	25	50
Copper naphthenate, 2% Cu plus WR	25	25	25
Copper pentachlorophenate, 5% plus WR	13	13	13
Copper 3-phenyl salicylate, 2.5% plus WR	30	50	50
Copper 3-phenyl salicylate, 5.0% plus WR	25	38	50
Copper 8-quinolinolate, 0.3% plus WR	13	13	13
Copper 8-quinolinolate, 0.6% plus WR	25	63	75
Copper 8-quinolinolate, 0.3% plus 0.5% gamma benzene hexachloride	25	25	25
Orthophenylphenol, 5% plus WR	13	25	38
Orthophenylphenol, 10% plus WR	0	0	0
Pentachlorophenol, 5% plus WR	25	25	25
Pentachlorophenol, 10% plus WR	0	0	13
Pentachlorophenol, 5% plus 0.5% gamma benzene hexachloride	13	13	13
Phenyl mercuric oleate, 0.3% plus WR	25	25	63
Phenyl mercuric oleate, 0.6% plus WR	13	50	63
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent			
25.0%	38	38	38
37.5%	13	25	25
Rosin amine D. pentachlorophenate, 5.5% plus WR	25	25	38
Rosin amine D pentachlorophenate, 11.0% plus WR	25	50	75
Tetrachlorophenol, 5% plus WR	25	25	25
Tetrachlorophenol, 10% plus WR	13	25	25
Water repellent only	46	63	63
Zinc alkyl sulphonate, 5.7% plus WR	25	25	25
Zinc naphthenate, 1% Zn plus WR	25	25	25
Zinc naphthenate, 2% Zn plus WR	25	25	38
Water Solutions, 3-Minute Dips			
Copper ammonium fluoride, 10%	25	25	50
Copper ammonium fluoride, 20%	25	25	38
Copper ammonium fluoride, 10% plus WR	25	25	25
Product containing sodium salts of dimethyl dithiocarbamic acid and 2-mercapto benzothiazole, and pentachlorophenol, 7.5%	25	25	25
Rosin amine D acetate, 5%	13	38	50
Rosin amine D acetate, 10%	25	25	25
Sodium pentachlorophenate, 5.7%	25	25	38
Sodium pentachlorophenate, 11.4%	13	13	13
Sodium pentachlorophenate, 2.0% plus borax 3%	13	25	38
Sodium pentachlorophenate, 4.0% plus borax 4%	13	13	25
Sodium pentachlorophenate, 2.0% plus borax 3% plus WR	25	25	25
Sodium tetrachlorophenate, 5.7%	13	25	25
Sodium tetrachlorophenate, 5.7% plus WR	25	25	25
Oil Solutions, Pressure Treatments			
Pentachlorophenol, 5%	0	0	13
Pentachlorophenol, 5% plus WR	0	13	13
Water Solutions, Pressure Treatments			
Copperized chromated zinc chloride	0	0	0
Tanalith	0	0	0
Celcure	0	0	0
Untreated	56	75	81

[1] Percentage of boxes in rating classes 4 and 5.
[2] High decay ratings prevented accurate termite ratings after 2.5 years' exposure.

cent Cu. Other tests (6) also indicate that copper concentrations of less than 1 per cent in treating solutions are likely to be ineffective when applied as dips or soaks.

During the 3.1 years of exposure, 10-second to 3-minute dips in 5 per cent pentachlorophenol plus a water repellent or copper naphthenate (2 per cent Cu) plus a water repellent have given almost complete protection to wire-bound crates made of rotary-cut veneer (Table 7, Figure 7). This was expected because of the high absorptions secured.

Discussion and Summary

In interpreting results of these tests, it is important to remember that composite piles were used, so that boxes treated with different chemicals were in contact horizontally in the piles. This arrangement led to some border effects in rate of corrosion of galvanized strapping, of water pickup, and of decay. A box treated with a satisfactory preservative often had significant metal corrosion, became wet sooner, and developed more decay on sides in contact with a box that had an unsatisfactory treatment.

Increased wetting and decay, but not metal corrosion, also occurred next to untreated boxes. These border effects tended to minimize differences and to decrease the showing of the better treatments. The uncontrollable variability in wood (amount of heartwood and species) from box to box also makes it unwise to accept small differences among treatments as significant. For the simulated-box tests, wood was carefully selected and matched among treatments, so that smaller differences became significant.

Three-minute dips did not give good protection against subterranean termites. Pressure treatments also failed in this respect when appreciable amounts of wood of poor treatability were present. The data suggest that, in regions where subterranean termites abound, a soil poison should be used prior to box storage: 1) in temperate regions when boxes are dip-treated, or, if appreciable amounts of heartwood are present, pressure-treated, and 2) in tropical regions for boxes regardless of the type of treatment.

In these tests, DDT was used as a soil poison (Fig. 4B), but any of the following treatments should suffice (3): Chlordane (8 lb.), dieldrin (4 lb.), DDT (60 lb.), or BHC (6.4 lb. gamma), each in 100 gallons of No. 2 fuel oil, and applied to the soil after debris and leaf litter are scraped back.

All these solutions should be evenly distributed over the area to be covered by boxes (plus a 4-foot border) at the rate of 2 pints per square foot in the tropics and 1 pint in temperate regions. Satisfactory application can be accomplished with a garden sprinkling can. If the soil is compacted and a slope is present, a light scarification will reduce surface runoff. All the poisons except DDT may be applied as water emulsions also.

Water repellents did not prevent water from accumulating in boxes stored for long periods in close piles where drying between showers was slow. Even during short periods of outdoor storage in areas of high rainfall, such as south Mississippi, water repellents did not prevent swelling to approximately maximum size. Ammunition boxes for outdoor storage must be designed, therefore, as was the M22 box, to be openable when the wood is either air dry or fully expanded. Water repellents were effective, however, in keeping boxes reasonably dry for 3 or 4 months' outdoor storage in Mississippi. During such

Table 22.—EFFECT OF 2 COATS OF PAINT (TT-E-485b) ON TERMITE ATTACK ON M-22 BOXES TREATED WITH VARIOUS PRESERVATIVES AND EXPOSED WITHOUT COVER FOR 38 MONTHS IN SOUTH MISSISSIPPI

Treatment	Proprotion of boxes in each rating class[1]									
	Painted					Unpainted				
	0–1	2	3	4	5	1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Copper naphthenate, (1% Cu) plus WR	88	0	13	0	0	75	0	25	0	0
Copper 3-phenyl salicylate, 2.5% plus WR	88	13	0	0	0	75	0	25	0	0
Copper 8-quinolinolate, 0.3% plus WR	88	0	13	0	0	75	0	0	25	0
Mineral spirits (aliphatic) 100%	75	13	13	0	0	75	0	13	13	0
Mineral spirits (aliphatic) 100%, plus WR	75	13	13	0	0	75	0	19	6	0
Orthophenylphenol, 5% plus WR	75	13	13	0	0	75	0	25	0	0
Pentachlorophenol, 5% plus WR	75	25	0	0	0	75	0	13	13	0
Phenyl mercuric oleate, 0.3% plus WR	63	13	25	0	0	75	0	13	13	0
Product containgin 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent, 37.5%	75	0	25	0	0	75	0	25	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	75	25	0	0	0	75	0	13	13	0
Zinc alkyl sulphonate, 5.7% plus WR	75	0	13	13	0	75	0	0	25	0
Zinc naphthenate, (1% Zn) plus WR	75	13	13	0	0	75	0	0	25	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 10%	88	0	13	0	0	75	13	13	0	0
Rosin amine D acetate, 5%	75	0	25	0	0	75	0	13	13	0
Sodium pentachlorophenate, 5.7%	88	13	0	0	0	75	0	25	0	0
Sodium pentachlorophenate, 2.0% plus borax 3.0%	88	0	13	0	0	75	0	13	13	0
Sodium tetrachlorophenate, 5.7%	88	0	13	0	0	75	0	13	13	0
Oil Solution, Pressure Treatment										
Pentachlorophenol, 5%	100	0	0	0	0	88	0	13	0	0
Untreated	75	6	19	0	0	75	0	12	6	6

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

Table 23.—EFFECTIVENESS OF 5% PENTACHLOROPHENOL PLUS A WATER REPELLENT APPLIED AS A 3-MINUTE DIP IN PREVENTING WATER PICKUP BY SIMULATED BOXES OF DIFFERENT WOOD SPECIES AFTER DIFFERENT PERIODS OF EXPOSURE IN SOUTH MISSISSIPPI

Wood species	Average moisture content									
	Treated								Untreated	
	1 month		2.5 months		12 months		18 months		2.5 months	
	O	I[1]	O	I	O	I	O	I	O	I
	Per cent of oven-dry weight									
Southern pine, sapwood	18	20	21	32	17	37	29	45	80	86
Southern pine, heartwood	16	19	18	25	17	23	18	33	46	69
Ponderosa pine, sapwood and heartwood	21	26	26	38	22	40	26	43	64	90
Eastern white pine, sapwood and heartwood	16	21	25	31	22	39	18	56	--	111
Western hemlock, probably sapwood and heartwood	18	21	26	36	21	36	22	33	51	80
Douglas-fir, mainly heartwood	16	18	17	23	15	25	15	30	39	66
Sweetgum, sapwood (sap gum)	16	19	21	33	19	27	23	27	59	71
Sweetgum, heartwood (red gum)	15	20	16	27	15	26	19	29	39	54
Yellow-poplar, sapwood	17	19	25	24	23	28	25	36	42	80
Yellow-poplar, heartwood	19	19	23	33	18	39	20	37	46	62
Tupelo, probably sapwood and heartwood	15	20	19	33	18	28	20	38	41	61

[1] O and I refer to units in tiers exposed at the outside and inside of the pile, respectively.

Table 24.—EFFECT OF LENGTH OF IMMERSION OF M-22 BOXES IN THREE WATER REPELLENT SOLUTIONS[1] ON WATER PICKUP DURING 2.1 YEARS' EXPOSED IN SOUTHERN MISSISSIPPI

Immersion period[2]	Average weight[3]		
	0.3% copper 8-quinolinolate	5% pentachlorophenol	Copper naphthenate (1% Cu)
	Pounds		
5 seconds	9.9	11.5	7.5
10 seconds	9.8	10.0	8.5
1 minute	9.8	10.4	8.5
2 minutes	9.9	10.4	8.5
3 minutes	9.7	10.0	8.7
10 minutes	10.0	11.5	8.7

[1] The water repellent was WR-7.
[2] See Table 11 for preservative retentions.
[3] Because of differences in exposure conditions, comparisons between chemicals are not valid.

Table 26.—EFFECTIVENESS OF TOXIC WATER REPELLENTS APPLIED AS 3-MINUTE DIPS IN REDUCING ABSORBENCY OF MOLDED AND NON-INFECTED SOUTHERN PINE SAPWOOD AFTER VARIOUS EXPOSURE PERIODS IN SOUTHERN MISSISSIPPI

Wood condition and treatment	Absorption of preservative Grams/unit	Average moisture content 0.5 months	0.75 months	4 months	4.2 months	6 months
		Per cent of oven-dry weight				
Molded wood						
Untreated	0	50	73	61	63	67
5% pentachlorophenol, plus WR-7	170	15	17	16	17	20
Copper naphthenate (2% Cu) plus WR-7	146	15	18	17	19	21
Non-infected wood						
Untreated	0	29	38	28	35	47
5% pentachlorophenol, plus WR-7	32	14	15	17	19	20
Copper naphthenate (2% Cu) plus WR-7	30	15	17	17	20	23

Table 27.—RELATIVE EFFECTIVENESS OF WATER REPELLENTS APPLIED AS 3-MINUTE DIPS WITH AND WITHOUT FUNGICIDES IN PREVENTING MOISTURE PICKUP BY SOUTHERN PINE SAPWOOD SIMULATED BOXES EXPOSED IN SOUTHERN MISSISSIPPI

Treatment	Average moisture content[1] June 1953	Aug. 1953	Dec. 1953	May 1954	April 1955
Test A, exposed Jan. 1953					
5% pentachlorophenol, plus WR-7	20	25	38	26	54
Commercial water repellents alone, average solids, paintable	21	32	58	33	67
Commercial water repellents alone, high solids, non-paintable	19	21	27	21	39
3% pentachlorophenol, without WR	65	82	--	59	--
	July 1954	Sept. 1954	Dec. 1954	April 1955	May 1955
Test B, exposed May 1954					
5% pentachlorophenol, plus WR-7	13	14	16	16	14
5% pentachlorophenol, plus commercial product, normal solids	16	14	17	17	14
Water repellents alone, WR-7	18	16	20	22	18
Water repellents alone, commercial product, normal solids	17	15	18	19	16
5% pentachlorophenol, without WR	36	32	40	43	31

[1]Averages of units on outside and inside of the piles.

periods, the boxes remained too dry to decay, and 15 to 20 per cent (of the loaded weight of approximately 43 pounds) lighter than untreated boxes. Thus they were more easily handled and could be shipped at lower cost.

Because of this effect of water repellents and the generally satisfactory decay protection afforded by copper naphthenate and pentachlorophenol, the most satisfactory treatments were with preservatives covered by Federal Specification TT-W-572. It is suggested that such preservatives be used for most container treatment, whether applied by dips, soaks, or pressure. When protection from periodic wetting is not needed, however, treatment with the water-borne preservatives according to Federal Specification TT-W-571 should be suitable for some type of containers, except possibly for longtime fully exposed storage under tropical conditions.

Since decay was negligible in aboveground boxes after 5 years' exposure in Wisconsin, treatment in regions of similar or drier climate seems unnecessary if boxes to be held for this period can be stored off the ground. A layer of treated wood or strips to keep the bottoms off the ground should afford adequate protection. Should boxes be made of a more decay-susceptible wood than eastern white pine, a 3-minute dip probably would give good protection for more than 5 years, or well beyond the goal set for these studies.

While no dip treatment afforded five years' protection under tropical exposure, three approached it: tetrachlorophenol 10 per cent, copper pentachlorophenate 5 per cent, and copper naphthenate 2 per cent Cu. The first of these had a uniform decay rating of "3" after 4.5 years and probably will fail completely in a short time; the second was too corrosive to metal and had decay ratings of "3" or higher on 73 per cent of the boxes; the last had decay ratings of "2" or less on 60 per cent of the boxes. Consequently, for dip treatment of boxes for tropical exposure, only copper naphthenate (2 per cent Cu) can be recommended at this time, and then only for 3 years' protection.

The test data indicate that, for longtime protection under tropical exposure, pressure treatment with an oil-borne preservative may be necessary. After 4.5 years' exposure in Panama, no box with a retention of at least 4 lbs. of pentachlorophenol per cu. ft. had failed. It should be remembered, however, that shipping boxes are often made from lower grades of lumber that contain more knots and a higher proportion of heartwood than do higher grades. This will interfere with adequate penetration by pressure treatment, and certain boards may not be adequately protected.

Under the intermediate exposure conditions of south Mississippi, several dip treatments gave adequate protection for 5 years. When all factors are considered, the most satisfactory are those covered by Federal Specification TT-W-572, or copper naphthenate and pentachlorophenol. For the period of the test (5 years) there was no marked advantage in the use of pressure treatments. For longer exposures, pressure treatments very likely would be superior.

Several other preservatives gave satisfactory decay control in Mississippi and Panama, but for one reason or another are not recommended at this time: 1) copper pentachlorophenate was difficult to handle and corrosive to metal, 2) rosin amine D pentachlorophenate was slightly too cor-

Table 25.—EFFECT OF LENGTH OF IMMERSION OF SOUTHERN PINE SAPWOOD IN 5% PENTACHLOROPHENOL, PLUS A WATER REPELLENT, ON WATER PICKUP AFTER VARIOUS PERIODS OF EXPOSURE IN AN UNCOVERED PILE IN SOUTHERN MISSISSIPPI

Immersion period	Absorption of treating solution lb./cu. ft.	Average moisture content 1 month	2.2 months	3.7 months	19 months
		Per cent of oven-dry weight			
30 seconds	1.5	28	36	56	54
1 minute	1.5	28	36	53	53
3 minutes	2.0	30	37	52	47
10 minutes	2.2	29	36	52	50

Table 28.—COMPARATIVE EFFECTIVENESS OF DIFFERENT WATER REPELLENTS IN OIL SOLUTIONS OF 5% PENTACHLOROPHENOL APPLIED AS 3-MINUTE DIPS TO SOUTHERN PINE SAPWOOD SIMULATED BOXES EXPOSED FOR VARIOUS PERIODS IN SOUTHERN MISSISSIPPI

Treatment	Average moisture content July 1954 O	I	April 1955 O	I	Oct. 1956 O	I
	Per cent of oven-dry weight					
Test A, established May 1954						
No water repellent	28	37	31	54	--	--
Plus WR-7[1]	13	14	15	17	23	25
Plus 20% linseed oil[2]	24	--	21	--	35	--
Plus 12% alkyd resins[3]	22	--	25	--	50	--
Test B, established Aug. 1954						
Plus WR[4]	14	--	17	--	18	--
Plus alkyd resins[5]	21	--	18	--	30	--
Untreated	39	--	33	--	77	--

[1]8% methyl ester of hydrogenated rosin and 2% paraffin wax.
[2]20% linseed oil and 0.07% cobalt.
[3]12% alkyd resin (TT-R-266, Type I).
[4]Commercial solution, repellent not disclosed.
[5]Commercial preparation labeled "Army 3-186-Type II".

rosive to metal in Panama, 3) sodium pentachlorophenate alone or with borax was too corrosive to metal, and 4) pressure treatments with Celcure and copperized chromated zinc chloride were too corrosive to metal and did not afford water repellency.

Whether or not chemical protection of shipping containers will be economically feasible depends on the saving due to longer service life in comparison to the cost of treatment. Cost can be fairly accurately estimated, but the length of service is intangible because of the uncertainty of storage conditions. Many boxes, especially in peace-time, are stored indoors and it is not possible under many military conditions to predetermine which containers will be subjected to a specific hazard. Also, as needs change, containers may be reshipped to other locations with a different exposure hazard.

With such a relatively high-cost container as the M22 box, the expense of a dip treatment may be justified even if a relatively small percentage of the boxes are subjected to moderate to high decay hazard. With cheaper containers, the advantage of treating is less obvious unless it is definitely known that the treated boxes will be subjected to an appreciable decay hazard. Service life also influences the economics of treatment. Containers for longtime storage or for re-use justify treatment more than those to be used a short time and then discarded.

Under the conditions of these tests, the number of years of uncovered outdoor storage on poisoned soil necessary to produce 5, 10, and 20 per cent failure of M22 boxes were calculated to be:

Treatment	Mississippi			Panama		
	5%	10%	20%	5%	10%	20%
None	2.5	3.0	3.5	1.5	1.75	2.25
3-minute dip[1]	4.5	5.5	6.5	3.0	3.5	4.5
Pressure[2]	6.0	10.0	18.0	5.0	7.0	10.0

[1]In Mississippi, copper naphthenate (1% Cu) or 5% pentrachlorophenol, and in Panama, copper naphthenate (2% Cu), each with a water repellent.
[2]Pentachlorophenol with minimum retentions of 4 lbs. per cu. ft. of 5% solution.

These data indicate that, under the storage conditions encountered, the 3-minute dips would be satisfactory for about 5 years' exposure in the wetter parts of the United States, and 3 years under tropical jungle exposure. For longer exposure, pressure treatments might well be considered.

The tests further indicate that if untreated boxes were stored on treated strips on poisoned soil no treatment would be needed if a watertight tarpaulin or other cover were provided.

With fully exposed, dip-treated boxes, the rate of deterioration can be reduced by painting the boxes after treatment.

Table 29.—RELATIVE EFFECTIVENESS OF WAX EMULSIONS AND SILICONE AS WATER REPELLENTS WHEN ADDED TO WATER SOLUTIONS OF FUNGICIDS AND APPLIED AS 3-MINUTE DIPS TO SOUTHERN PINE SAPWOOD SIMULATED BOXES EXPOSED FOR VARIOUS PERIODS IN SOUTHERN MISSISSIPPI

Treatment	Average moisture content									
	May 1953		Aug. 1953		Dec. 1953		May 1954		Apr. 1955	
	O[3]	I	O	I	O	I	O	I	O	I
	Per cent of oven-dry weight									
Test A, exposed Dec. 1952										
5% pentachlorophenol plus WR (Oil)	20	22	23	26	34	42	25	27	45	62
5% sodium pentachlorophenate plus 4% wax[1]	18	21	19	29	21	54	19	45	42	53
5 sodium pentachlorophenate plus 8% wax[1]	18	21	21	26	--	--	19	41	29	82
Untreated	52	--	74	--	--	--	--	--	--	--
Test B, exposed April 1953										
5% sodium pentachlorophenate	39	36	66	70	61	79	33	57	43	64
5 sodium pentachlorophenate plus 4% wax[1]	18	20	22	30	19	38	16	28	18	55
5% sodium pentachlorophenate plus 1% silicone[2]	18	19	22	28	25	45	17	35	--	--

[1]Wax was a 50% emulsion, Ceremul A.
[2]Silicone SC-50 supplied by General Electric Company.
[3]O and I refer to units in tiers exposed at the outside and side of the piles, respectively.

For either dip or pressure treatment, only fabricated boxes or shooks should be treated. Dip treatment of boxes can be accomplished with automatic machines. Pressure treatment of boxes would probably be prohibitively costly because of the small wood volume that could be treated in a charge, but the treatment of shooks would remove this difficulty. The making of boxes from treated lumber is not recommended because freshly cut surfaces resulting from manufacture would need retreatment.

Wire-bound crates of rotary-cut southern hardwood veneer decay so fast that it is desirable to treat them if outdoor storage beyond a few months in southern United States is contemplated. High absorptions in veneer boxes, as well as in lumber boxes made of fungus-infected lumber (8), can be deleterious. Even with light solvents and normal handling procedures, sufficient oil can remain in the wood to harm box contents. Serious dissolving of asphalt in lining materials, with resultant damage to ammunition, has been observed in actual use. Rotary-cut veneer boxes or boxes made of stained or molded lumber should be treated with care, often with only instantaneous dips, and subjected to particularly favorable drying conditions to allow evaporation of the solvent.

The current tests leave a number of questions unanswered. Chief among these is the problem of metal corrosion by some of the standard water-borne preservatives. Some corrosion can be attributed to the direct contact of strapping with the treating solutions, but in the waterlogged wood of many of the test boxes, active and serious corrosion began some months after treatment. Also, water-borne pressure treatments of higher retentions should be tried under tropical conditions because other tests (1) indicate these would give a much longer service life in Panama. For other types of crates and boxes it will be necessary to determine whether a 3-minute dip will afford as much protection to 8/4 and thicker lumber as it does to 4/4 lumber. Plywood containers were not tested, and it can only be surmised that they would react similarly to lumber boxes, and certainly only if water-resistant glues were used.

Literature Cited

1. Blew, J. O. 1958. Comparison of wood preservatives in stake tests. U. S. Forest Products Lab. Report 1761.
2. Brown, F. L., R. A. Moore, and R. A. Zabel. 1956. Absorption and penetration of oil-soluble wood preservatives applied by dip treatment. N. Y. State College of Forestry Tech. Bul. 79.
3. Johnston, H. R. 1958. Tests with soil poisons for controlling subterranean termites. Pest Control 26 (2): 9.
4. McKnight, J. S. 1957. Some physical factors influencing the effectiveness of preservatives. Forest Prod. J. VII (12): 441.
5. Sutherland, J. H., W. H. Johnston, and O. Maass. 1934. Further investigations of the penetration of liquids into wood. Canadian Jour. Res., 10: 36.
6. Verrall, A. F. 1953. Decay protection in wooden steps and porches through proper design and protective treatments. J. FPRS. III (4): 54.
7. Verrall, A. F. 1953. Factors leading to possible decay in wood siding in the south. U.S.D.A. For. Path. Special Release 39.
8. Verrall, A. F. 1957. Absorption and penetration of preservatives applied to southern pine wood by dips or short-period soaks. U.S.F.S. Southern For. Expt. Sta. Occasional Paper 157.