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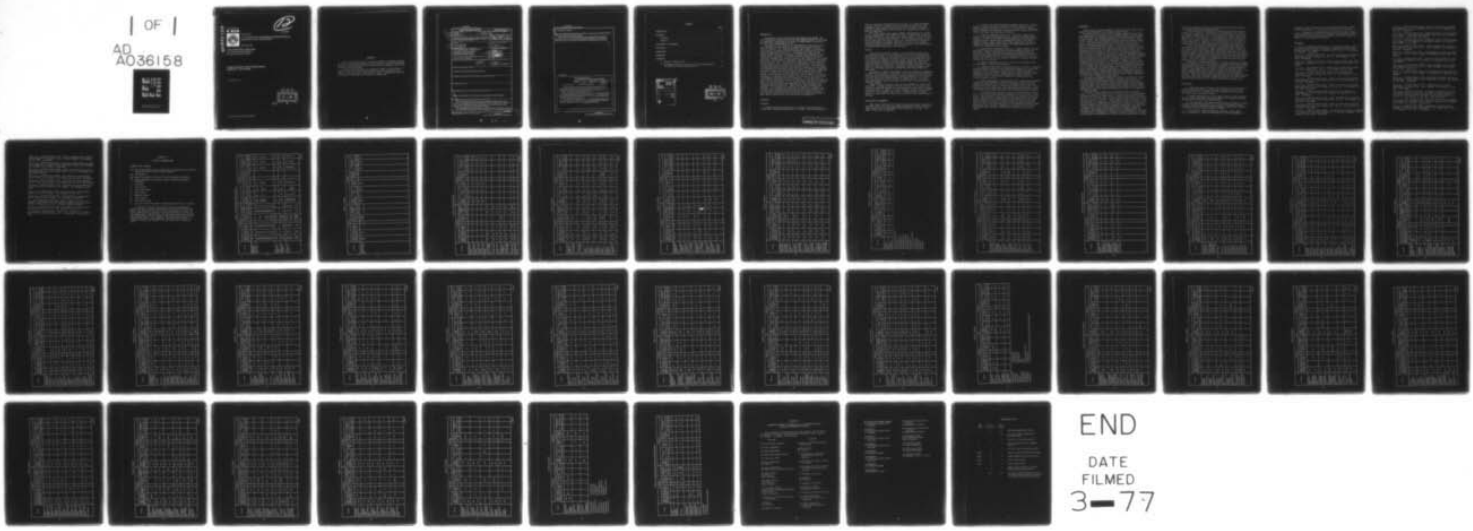

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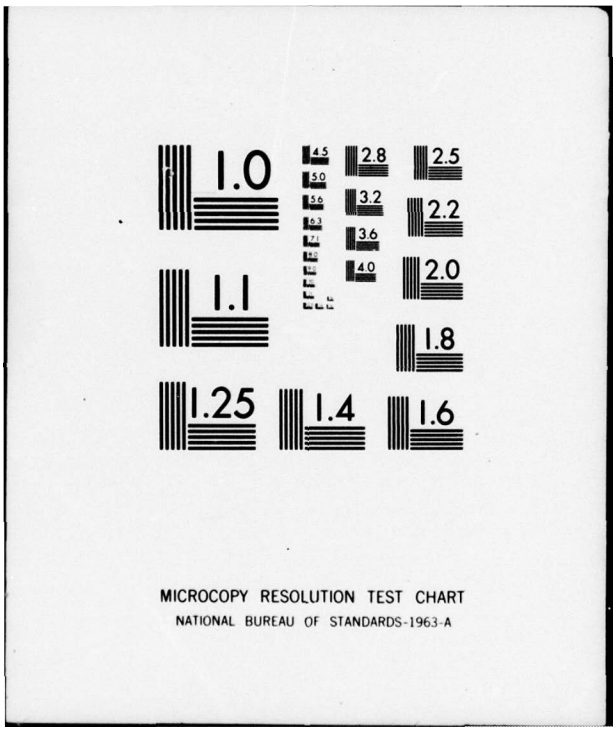
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Technical Report

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December 1976

CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California 93043

HARBOR SCREENING TESTS OF MARINE BORER INHIBITORS – FINAL REPORT

by Thorndyke Roe, Jr.

FOREWORD

This is the thirty-fifth in a series of reports on studies conducted by the Civil Engineering Laboratory to develop more effective methods and materials for the preservation of wooden structures exposed to the attack of marine boring organisms.

It is the tenth and final of a series of reports on the results of harbor exposure of treated and untreated test panels exposed at Port Hueneme, California, and at Pearl Harbor, Hawaii. Some results reported previously are included in this report for comparison.

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The Civil Engineering Laboratory exposed wood panels impregnated with various materials to determine the resistance of these panels to attack by marine borers. This report lists the results of harbor tests of panels which underwent exposure from January 1967 through 1971 at Pearl Harbor and 1976 at Port Hueneme.

When impregnated into wood test panels, creosote and 70-30 creosote/coal-tar solution are about equally effective against *Martesia* and teredinid attack, but the addition of certain

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20. ABSTRACT continued:

organic and organometallic compounds to creosote or creosote/coal-tar solution produces a preservative superior to either solution alone.

Certain creosote-free treatments which contain a combination of one material specifically toxic to *Limnoria* and another material specifically toxic to teredines are superior to creosote or creosote/coal-tar solutions in preventing marine borer attack.

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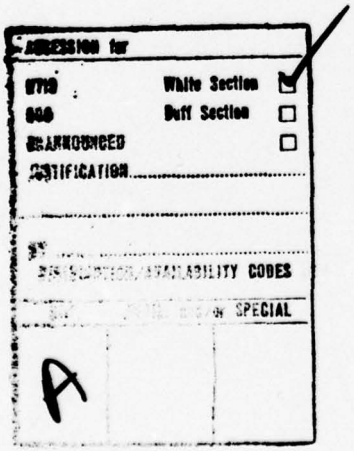
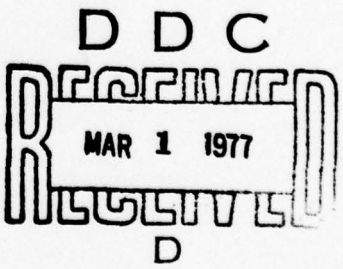
CONTENTS

	Page
INTRODUCTION	1
PROCEDURE	1
Treatment	1
Exposure	2
EVALUATION OF TREATMENTS	2
DISCUSSION	4
CONCLUSIONS	5
REFERENCES	6
APPENDICES	
A — Tables of Exposure Data	9
B — Treatments Superior to Creosote or 70-30 Creosote/Coal-Tar Solution in Preservative Ability	43





INTRODUCTION

With support from the Naval Facilities Engineering Command, the Civil Engineering Laboratory (CEL) has investigated methods and materials for reducing or preventing borer attack on wooden marine structures of the Naval Shore Establishment [1-34].

One phase of this study was the impregnation of wood panels with toxic materials and the exposure of these treated panels to marine borers in harbors. The treating materials were chosen on the basis of their toxicity to marine borers as determined by the Toxicity Testing Procedure developed at CEL [8,11]. The exposure of small treated panels provided a system for rapidly screening large numbers of potentially useful treatments. The panels could be treated by ordinary laboratory equipment and required relatively small quantities of treating materials; a large number of treatments could be exposed in a relatively small dock area. Also, the surface-to-volume ratio of these panels was so high that the rate of leaching of the preservative by the seawater was much higher than it was for round piling sections. This small-panel screening procedure was further accelerated by exposing the more promising treatments in Pearl Harbor where, because of a high water temperature and greater numbers and kinds of borers, attack begins after exposure in a half to a quarter of the time required for initial attack at Port Hueneme. The exposure of full-sized piles would provide a more accurate evaluation of a preservative treatment, but the use of such a method in a preliminary screening would be uneconomical. At the same time, to delay the pile-size tests until all of the panel tests had been completed would also be uneconomical. Pile treatments were, therefore, started as soon as trends were noted that suggested that superior preservative treatments had been uncovered. Three types of pile treatments were employed: (1) treatment with solutions of chemicals in creosote; (2) treatment with creosote-free solutions; and (3) double treatment (that is, first with an aqueous solution followed by an organic solution). Over 200 piles treated with all three types of systems were exposed at Pearl Harbor, Hawaii [16,17,19,23,24,26, and 28 through 34].

PROCEDURE

Treatment

Treating solutions were made up on a volume percentage basis for liquids and a weight percentage basis for solids. With the exception of

coal tar, creosote, creosote/coal-tar solutions, and copper naphthenate solution, only inert solvents were used to make up solutions to 100%. In general, these inert solvents were xylene for nonpolar compounds, water for polar compounds, and cellosolve for combinations of polar and nonpolar compounds.

Sets of ten panels were tagged, weighed, impregnated by the vacuum method, weighed again to determine the amount of preservative retention, and then air-dried to remove any inert solvent present. Details of the procedure are described in Reference 6. Unless otherwise noted, southern yellow pine panels were used in this study. Several sets of pressure-treated ponderosa pine samples submitted by the U.S. Forest Products Laboratory, Madison, Wisconsin, and panels submitted by the Naval Facilities Engineering Command were also evaluated.

Exposure

The panels were mounted on Monel or glass-reinforced epoxy racks suspended horizontally in the harbor about 3 feet above the mudline by nylon parachute cords. At Port Hueneme, panels were cleaned and rated at bimonthly or trimonthly intervals. They were removed whenever structural failure was imminent. At Pearl Harbor, panels were cleaned and inspected monthly, removed whenever extensive damage was noted, and returned to CEL for evaluation. The racks and panels were lost at Pearl Harbor in January 1971 because of vandalism. Because of damage to the racks, all remaining panels were removed from Port Hueneme harbor in March 1976.

The extent of *Limnoria* and *Martesia* attack can readily be determined by inspecting the surface of the panel. In its early stages, teredinid attack is very difficult to detect by surface inspection. When this type of attack reaches an advanced stage, the panel loses much of its structural strength and can easily be bent or snapped in two. All panels which were removed from the test were sawed in two to show the amount of teredinid damage.

Damage caused by *Limnoria*, *Martesia*, and teredines is always rated separately. Although individual records were kept for each panel which had been treated and exposed, the data presented in this report represent average data for all panels of a given treatment exposed at the location specified. Data on panels lost are not included in these averages, except for those panels for which time to initial attack occurred before the loss.

EVALUATION OF TREATMENTS

This report deals with all treated and untreated panels reported in Reference 27 and, thus, with all panels removed from exposure because of heavy attack by one or more marine boring organisms or by loss. The tables of data are in Appendix A.

1. Creosote and Creosote/Coal-Tar Solutions (Table A-1): Panels treated to large retentions of creosote or 70-30 creosote/coal-tar solution resisted teredinid attack but not *Limnoria* attack. Some resistance to *Martesia* was indicated. Creosote and 70-30 creosote/coal-tar solution had about equal preservative ability.

2. Inorganic Compounds (Table A-2): In general, copper salts, chelates, and complexes resisted *Limnoria* attack for long periods but failed in a shorter period than creosoted panels because of *Martesia* or teredinid attack. Mercury salts performed similarly. Acid copper chromate (9.05%), copper acetate (5%), copper naphthenate (3% and 6% copper), and solubilized copper oxinate (4% copper) were superior to creosote or creosote/coal-tar solution.

3. Metal-Organic Compounds (Table A-3): Organic mercury compounds were fairly effective against *Limnoria* but not against *Martesia* or teredinids. Organic tin compounds, specifically tributyltin coconut fatty acid salt and tributyltin oxide provide excellent resistance to *Martesia* and teredinid attack, but are attacked by *Limnoria*. In the latter case, however, they are generally superior to creosote and 70-30 creosote/coal-tar solution.

4. Organic Compounds (Table A-4): None of the compounds tested was promising as a preservative material.

5. Combination Treatments Containing Creosote, Coal Tar, or Creosote/Coal-Tar Solution (Table A-5): The preservative ability of creosote and creosote/coal-tar solution was improved by the addition of agents especially toxic to *Limnoria*. Among these were copper arsenate, copper naphthenate, dieldrin, endrin, phenylmercuric oleate, toxaphene, or tributyltin oxide. None of these combination treatments was very effective against *Martesia*.

6. Other Combination Treatments (Table A-6): Combination treatments containing copper naphthenate, solubilized copper oxinate, dieldrin, thiodan, or toxaphene plus a tributyltin compound are more effective preservatives than creosote or 70-30 creosote/coal-tar solution. Panels double-treated with tributyltin oxide and ammonium sulfide also outperformed those treated with creosote or 70-30 creosote/coal-tar solution.

7. Untreated Panels and Solvent-Extracted Untreated Panels (Table A-7): The tropical woods afambeau, greenheart, and *Lignum vitae* failed after a short exposure at Pearl Harbor because of teredinid or *Martesia* attack. They gave much longer service at Port Hueneme, but were about equal to Douglas fir or southern pine treated with creosote or 70-30 creosote/coal-tar solution. *Antidesma pulvinatum* panels sustained a trace of *Limnoria* and teredinid attack at Port Hueneme and slowly eroded away during their exposure. Edmondson [35] reported that this wood sustained a trace of *Limnoria* attack after exposure for 5 years in Hawaii.

DISCUSSION

Trends noted in previous reports of this series were firmly established at the termination of the harbor exposure tests.

An analysis of the service lives of panels treated with creosote and creosote/coal-tar solutions at Port Hueneme harbor and Pearl Harbor shows that they will average 83 months in Hueneme harbor and 33 months in Pearl Harbor, with standard deviations of 31 and 14 months, respectively. Thus, within one standard deviation, panels treated with creosote or with 70-30 creosote/coal-tar solution will last from 52 to 114 months in Hueneme harbor and from 19 to 47 months in Pearl Harbor. Then, any treatment which gives panels a service life greater than 114 months in Hueneme harbor and 47 months in Pearl Harbor should be considered superior to creosote or 70-30 creosote/coal-tar solution; those treatments which give service lives of 52 to 114 months in Hueneme harbor and 19 to 47 months in Pearl Harbor should be considered comparable to creosote or 70-30 creosote/coal-tar solution; and those treatments which give service lives less than 52 months in Hueneme harbor and 19 months in Pearl Harbor should be considered inferior to creosote or creosote/coal-tar solution as a preservative. Appendix B lists those treatments which were superior to creosote and 70-30 creosote/coal-tar solution based on the above criteria. From the information in Appendix B it is evident that few single chemical treatments are as good as or better than creosote as a wood preservative. Treatments of this type which are superior to creosote generally contain large quantities of copper salts. Some of these salts, however, are extremely corrosive to the construction materials in wood treating plants; copper naphthenate is safe to use in contact with mild steel.

A number of combination treatments based on the results of the CEL toxicity screening program are equal to or better than creosote. In each case there is one chemical which is specifically toxic to the crustacean borer *Limnoria*, and a second chemical which is specifically effective against the molluscan borers *Teredo*, *Bankia*, and to a lesser extent *Martesia*. Many of these combination treatments could be used in existing wood treating plants and would present little or no additional corrosion problems.

Creosote is quite effective in preventing attack by molluscan borers. In those waters where *Limnoria* attack is not a serious problem, creosoted wood lasts for many years. In those waters where creosoted wood does not last very long, its destruction is initiated by or entirely due to the action of *Limnoria* - almost always *Limnoria tripunctata*. The incorporation of an agent into creosote which is toxic to *Limnoria* is an effective means of prolonging the usefulness of creosote in such areas. Among the additives affecting such improved performance are copper salts of organic acids (such as copper naphthenate and copper stearate), chlorinated hydrocarbon insecticides (such as dieldrin, endrin and toxaphene), and organomercury compounds (such as phenylmercuric chloride). The usefulness of organomercury compounds as wood preservatives is questioned because the phenylmercuric oleate was almost completely lost from

the creosote solution in which it had been dissolved and used during a cooperative marine piling testing program.

In some instances the addition of a chemical specifically toxic to *Limnoria* to a creosote or creosote/coal-tar solution does not result in an improved preservative. One or more factors difficult to anticipate may operate. Among these are: (1) the quantity of additive may be too small to exert a toxic effect; (2) the additive may form a complex with some of the creosote constituents and become less toxic, more soluble, or more peptizable by seawater; or (3) the additive in the presence of creosote may be more readily detoxified by the harbor flora and fauna.

A number of treatment combinations are significantly superior to creosote as a wood preservative agent in those areas where creosote is now comparatively ineffective. These combinations, again, include one material, such as copper naphthenate, chlorinated hydrocarbon or organomercury compound, as the agent specifically toxic to *Limnoria* and one of the tributyltin compounds which is especially effective against molluscan borers. These combinations, in addition to being effective borer deterrents, cause little change in the appearance of the wood and leave the wood surface in a paintable condition.

In addition to impregnating wood with a single solution containing several ingredients, it is also possible to impregnate wood with incompatible materials by double or even triple treatment. Panels treated with solutions of copper sulfate followed by creosote lasted significantly longer at Pearl Harbor than did panels treated with creosote alone. The panels remained unattacked by *Teredo*, suffered only minor attack by *Limnoria* during their entire exposure period, but were destroyed by *Martesia*. When a more insoluble copper compound, such as copper arsenate, was used as the first treatment followed by creosote, the life of the panel was almost double that of a panel treated with creosote only.

CONCLUSIONS

1. High retentions of creosote and creosote/coal-tar solutions are effective against teredines and show some resistance to *Martesia* but not against *Limnoria*. Creosote and 70-30 creosote/coal-tar solution have about equal preservative ability.

2. Higher concentrations of acid copper chromate, copper naphthenate, and solubilized copper oxinate are superior to creosote and 70-30 creosote/coal-tar solution as preservatives.

3. Dual treatment with copper sulfate solution followed by creosote or triple treatment with copper sulfate solution followed by sodium arsenate solution followed by creosote produces a preservative superior to creosote or 70-30 creosote/coal-tar solution.

4. Solutions of copper naphthenate, dieldrin, endrin, phenyl ether, phenylmercuric chloride, phenylmercuric oleate, toxaphene, or

tributyltin oxide in creosote or creosote/coal-tar solutions produce preservatives superior to creosote or creosote/coal-tar solution.

5. Solutions of copper naphthenate, solubilized copper oxinate, dieldrin, phenylmercuric oleate, or toxaphene in tributyltin coconut fatty acid salt or tributyltin oxide produce preservatives superior to creosote or creosote/coal-tar solution.

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Appendix A

TABLES OF EXPOSURE DATA

SYMBOLS USED IN TABLES

***	One or more panels in this series were not attacked by this species during the entire period of harbor exposure.
NC	Not checked.
BYD	Panels furnished by the Naval Facilities Engineering Command.
FPL	Panels furnished by the Forest Products Laboratory, Madison, Wisconsin.
0	No attack.
T	Trace attack.
VL	Very light attack.
L	Light attack.
M	Moderate attack.
H	Heavy attack.
VH	Very heavy attack.
†	Does not include the weight of ammonium sulfide solution absorbed.

It should be noted that in some cases there are discrepancies between the time to initial attack and the total exposure time of the panel. This generally occurs when one or more panels in a series are not attacked by a given species. The data presented in the table are the average time to initial attack of those panels which were attacked by a given species, and the average of the total exposure time of all panels in the series. Also, where the "Total Exposure Time (mo)" columns are blank, this indicates that the entire set of panels was lost.

Table A-1. Creosote and Creosote/Coal-Tar Solution

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
100% Creosote (1/8" panel)	31.0	32	44			M	O	34.3	7		15			H	O	O
100% Creosote	35.7	22	86			VH	O	40.8	9		17			M	O	O
	40.2	26	77			VH	O	35.7	10	18***	52			H	VL	O
	32.7	29	104	1	107	VH	O									
	33.3	19	56	1	52	H	O	42.4	5		20			H	O	O
	37.2	17	81			VH	O	35.8	4	35***	37			VH	VL	O
	29.9	16	87			VH	O	33.0	7	24	51			M	M	O
	33.5	11	58	1	32	VH	T	32.4	6	14	29			VH	L	O
	39.1	2	65	2	58, 71	VH	O									
	25.7	8	91			VH	O									
	23.3	10	83	2	69, 90	VH	O									
	34.3	14	86	1	39	VH	O									
	31.1	19	100	4	52-110	M	T***									
100% Creosote (FPL)	45.8	45		4	22-114			45.8	7	29***	44			VH	T	O
100% Creosote in Douglas Fir	39.8			2	104-147			41.5	7	16	52			VH	VL	O
	41.0	2	144	1	79	M	O	24.3	7***	29	46			L***	L	O
	28.1	12	140	3	52-169	M	O									
70-30 Creosote-Coal Tar	40.4	28	75	3	107-125	H	O	38.4	10		22			M	O	O
	27.1	14	106			M	O	37.6	5		22			VH	O	O
	19.7	12	33	2	79-84	H	O	30.9	4	27	34			M	L	O
	23.1	7	43	2	41-52	M	O	33.2	6	10***	24			VH	T	O
								37.3	5	8***	12			VH	T***	O
	35.7	22		4	18-101			40.7	6***	10	43			T***	H	O
	34.4	29	68	4	45-166	VH	O									
	34.8	17	136	3	35-85	M	O									

continued

Table A-1. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
70-30 Creosote-Coal Tar in Douglas Fir	38.5	18		2	95-104			33.9	9	10	47			VH	VL	O
	41.4	4		4	51-123			9.7	3	8***	12			H	T***	O
	14.7	15	42	1	55	VH	T***									

Table A-2. Inorganic Compounds

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1.13% Acid Copper Chromate								0.45	13***	10	14			T***	M	T***
2.26% Acid Copper Chromate								0.87		12	23			O	M	VL***
4.53% Acid Copper Chromate								1.80		22	35			O	H	O
9.05% Acid Copper Chromate								3.83		29	55			O	H	O
1% Copper Acetate + ht. tr. in Douglas Fir	0.30	32***	54			T***	H									
2% Copper Acetate	0.75	34	51			T	M									
2% Copper Acetate + ht. tr.	0.74	30***	53			T***	H									
2% Copper Acetate in Douglas Fir	0.71	49	114[a]	2	77-86	L	O									
2% Copper Acetate + ht. tr. in Douglas Fir	0.67	40	65			VL	M									
5% Copper Acetate	1.86	53	92[b]			M	VL***									
5% Copper Acetate + ht. tr.	1.98	46	91	1	84	L	L									

continued

Table A-2. Continued

Treatment	Port Hueneme							Pearl Harbor								
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Copper Acetate in Douglas Fir	1.14	39	123	2	81-121	T	O									
5% Copper Acetate + ht. tr. in Douglas Fir	1.36	52		4	100											
2% Copper Formate + ht. tr. in Douglas Fir	0.95	45	54			VL	M	0.94	12	12	14			L	VL	L
1% Copper Naphthenate	0.29 0.28	43***	120 105	1	51	M*** O	L L	0.26	24	26	27			L	L	L
1% Copper Naphthenate in Douglas Fir	0.06	22	22	3	89-119	T	M	0.16	26***	15	26			VL***	M	VL
3% Copper Naphthenate in Douglas Fir	0.31	120	120[c]	3	86-124	T	T	0.45	39***	38	63			T***	H	O
6% Copper Naphthenate	1.18 1.31	***	 199[e]	2 2	108 108	 O	 O	1.22 1.38		74 71	76[d] 87	1 1	54.0 132.0	O O	VL L	O O
6% Copper Naphthenate in Douglas Fir	0.46	125***	109[f]			T***	VL***	0.32	20***	20	32			VL***	M	L
1% Copper Sulfate in Redwood	0.35 0.37	57 68	101[g] 82	2	71	H M	O O	0.38		9	11	1	6.5	O	H	O

continued

Table A-2. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Copper Sulfate in Western Red Cedar	0.34	29	78[b]			L	T***	0.46		6	9			O	H	O
2% Copper Sulfate in Douglas Fir	0.55	44	64	1	50	T	M									
5% Copper Sulfate in Douglas Fir	1.54	51	70	1	90	L	M									
5% Copper Sulfate + ht. tr. in Douglas Fir	1.75	34	56			VL	VL***									
10% Copper Sulfate in Douglas Fir	3.19	51	68	1	90	L	M									
10% Copper Sulfate + ht. tr. in Douglas Fir	3.51	39***	57			T***	M									
10% Copper Sulfate in Redwood	3.55	79	97			M	T***	3.32		17	17	1	6.5	O	L	O
10% Copper Sulfate in Western Red Cedar	2.52		75			O	M	3.88		9	11			O	M	VL
10% Solubilized Copper Oxinate	3.22		93			O	M	3.18		14.5	18			O	H	T

continued

Table A-2. Continued

Treatment	Port Hueneme							Pearl Harbor								
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
25% Solubilized Copper Oxinate	7.3	67		2	109-116			8.1	22***	21	30			VL	M	VL
50% Solubilized Copper Oxinate	15.5			2	109-121			14.9	***	37	62			M	M	O
5% Cuprammine Sulfate	1.33	52***	77[j]			T***	M	1.38	20	21***	23			H	VL***	M
5% Cuprammine Sulfate + ht. tr.	1.85	39	100[k]	2	91-102	L	O	1.89	15	21***	25			H	VL***	M
5% Cuprammine Sulfate in Douglas Fir	2.45	29	123[l]			T	O	2.33		31	44			O	H	O
5% Cuprammine Sulfate + ht. tr. in Douglas Fir	1.59	49	123	1	87	VL	T***	1.47		22	29			O	M	T***
5% Cupric Ethylenediamine Sulfate + ht. tr.	2.01	30***	30			T***	M	1.91	9	11	12			VL	VL	H
5% Cupric Ethylenediamine Sulfate in Douglas Fir	1.23	47***	69	1	90	L***	VL***	1.44	17***	16	24			VL***	VL	VL***
5% Cupric Ethylenediamine Sulfate + ht. tr. in Douglas Fir	1.69	45***	44			T***	L	1.85	17***	12	20			VL***	M	T***

continued

Table A-2. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Mercuric Acetate	2.03	35	93[m]			T	T	2.06	6***	19	31	1	29.0	T***	H	T***
5% Mercuric Acetate + ht. tr.	2.10	34	62[n]			T	VL	2.26		13	13			O	L	H

[a] Some erosion on remaining panels.

[b] Two panels eroded.

[c] Remaining panels eroded.

[d] Remaining panel split.

[e] Remaining panels exposed.

[f] Two of four panels eroded.

[g] Both panels failed at tag.

[h] One panel eroded.

[i] One panel split; one failed at tag.

[j] One panel eroded.

[k] Two panels eroded.

[l] One panel eroded.

[m] Panels eroded.

[n] Panels eroded.

Table A-3. Metal Organic Compounds

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% p-Aminophenylmercuric Acetate	0.39 0.41	19*** 15	30 38	2	21	T*** VL	H H	0.37	11***	8	13			T***	L	H
1% p-Dimethylaminophenylmercuric Acetate in Douglas Fir	0.35		53	2	19-38	O	H	0.35	30***	14	27			T***	H	VL***
1% Tributyltin Coconut Fatty Acid Salt	0.27	87		2	113-120			0.27 0.25	4 7		41 20	4	52-64	VH	O	O
10% Tributyltin Coconut Fatty Acid Salt	2.91	35	175	4	52-64	O	O	2.93	9			4	1-110			
0.5% Tributyltin Oxide	0.13	53		2	107											
1% Tributyltin Oxide	0.27			2	90-102			0.25 0.26	10 5	 60***	47 51			VH VH	O T***	O O
10% Tributyltin Oxide	2.66	NC	175	4	52-66	T	O	2.66				4	110			
1% Triphenyltin Acetate	0.30	23	64			L	O	0.31	5	42	43	1	20	VH	T	O

Table A-4. Organic Compounds

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Chloro o-phenylphenol	1.61	3	14			L	H	1.53	3	4	5			H	L	H
1% Decachlorotetracyclodecanone								0.26		7	15			O	H	O
1% Ether Soluble Alkaloids of Greenheart Sawdust								0.36	2		5	1	2	VH	O	T***
2% Ether Soluble Alkaloids of Greenheart Sawdust	0.71	2	12			VH	T***	0.67	2		6			VH	O	T***
10% Phenanthrene	3.2	4	14			H	L	2.9	3	4	5			L	M	T

Table A-5. Combination Treatments Containing Creosote, Coal Tar, or Creosote/Coal-Tar Solutions

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Aluminum Oxinate in Creosote (1/8" panel)	0.35 34.5	37	72			M	O	0.34 33.7	6	9	20			M	T	O
0.9% p-Aminophenylmercuric-Acetate + 100% Creosote (double treatment)	0.28 28.5	32	148	2	41-69	M	O	0.26 23.7	12	18	36	2	14	VH	L	O
10% Biphenyl	3.0	11	127			H	T***	3.1 15.7	5.5	12	44			H	H	O
50% Creosote	15.6							3.1 15.5	5	18	46	1	138	T	M	O
5% Chlordan 50% Creosote	1.51 15.1		122	1	146	O	L	1.53 15.3	21	13	35	1	38	T	H	O
5% Chlordan 50% 70-30 Creosote-Coal Tar	1.52 15.2		108			O	M	1.59 15.9	19***	15	32			T***	H	O
10% Chlordan 50% Creosote	2.45 12.2		142[a]	2	109	O	O	3.02 14.5	10***	21	40	1	15	T***	H	O
10% Chlordan 50% 70-30 Creosote-Coal Tar	3.49 17.5	7***	117	3	125-141	O	L	3.07 15.5		14	31			O	H	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
0.5% Copper Naphthenate 50% Coal Tar	0.15 15.2	22	65			L	H	0.14 13.6	9	9	20			M	M	VL
1% Copper Naphthenate 50% Coal Tar	0.28 14.1	29	138			L	O	0.26 12.9	18	NC	39	1	6	VH	M	T
2% Copper Naphthenate 50% Coal Tar	0.60 15.0	16	37			H	O	0.59 14.9	10	5	17			M	M	O
3% Copper Naphthenate 50% Creosote in Douglas Fir	0.41 8.6	35	100	2	86-179	T	VL	0.64 10.7	35***	50***	66	3	72-84	O	M	O
3% Copper Naphthenate 50% 70-30 Creosote-Coal Tar in Douglas Fir	0.56 9.3			4	79-121			0.43 7.1	18***	21	55			T***	M	VL***
1% Copper Oxinate in Creosote (1/8" panel)	0.34 33.1	39	85[b]	3	60-62	L	O	0.35 35.0	10	8	34			H	T	O
2.5% Copper Oxinate in Creosote (1/8" panel)	0.58 22.2	35	57[c]	6	54-62			0.72 27.3	6	7	17			L	L	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Copper Oxinate in Creosote (1/8" panel)	1.58 30.0 1.30 24.4	36 32	64 63[d]	1		H M	O O	1.45 27.5	6	6	15			M	L	O
3% Solubilized Copper Oxinate 50% Creosote	0.50 8.2	121	148	2	40-115	VL	O	0.59 9.9 0.46 7.7	22 27	18 18	41	1	29	L	M	O
0.4% Copper Stearate in Creosote	0.13 34.1	14	134	3	52-99	M	O	0.13 31.7	9	38	47	3	2-122	VH	VL	O
6% Copper Sulfate 100% Creosote (dbl treatment)	2.0 36.9		97[e]	3	59-178	O	O	2.0 34.6	15	21	59	1	25	L	H	O
12% Copper Sulfate 100% Creosote (dbl treatment)	5.2 35.8		127[f]	2	59-68	O	O	5.1 34.5	26	22	59			M	H	O
14.73% Copper Sulfate 20.06% Sodium Mono H Arsenate 100% Creosote (triple treatment) (FPL)	3.23 3.01 38.7			5	56-198			3.23 3.01 38.7		72	97			O	M	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5.3% Copper Salt of Naphthenic Acid 50% Creosote	1.64 15.5	7	63[g]			H	O	1.53 15.1	9	10	26			H	VL	O
1% Dieldrin 50% Creosote	0.29 14.8	12	98	2	89-119	M	M	0.29 14.2		8	32			O	H	O
1% Dieldrin 50% Creosote in Douglas Fir	0.22 10.9	15	86	3	48-100	H	L	0.24 11.8		9	67	2	28-29	O	VH	O
100% Dieldrin in Creosote	0.35 33.2	27		4	36-89			0.34 33.2	33***	23	81	3	22-72	T***	H	O
1% Dieldrin in Creosote in Douglas Fir	0.22 21.6	25***	136	2	89-119	L***	T***	0.22 22.0	22***	10	47	1	19	T***	M	O
1% Dieldrin 50% 70-30 Creosote-Coal Tar	0.30 15.1	20	107	2	78	H	L	0.31 15.5		8	36			O	M	T***
1% Dieldrin 50% 70-30 Creosote-Coal Tar in Douglas Fir	0.25 12.8	40	174[b]	3	89-160	T	O	0.20 9.9		8	34	1	20	O	M	T***
1% Dieldrin in 70-30 Creosote-Coal Tar	0.29 28.9	20***	208	3	67-179	VL***	O	0.32 31.5		20	63			O	H	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Dieldrin in 70-30 Creosote-Coal Tar in Douglas Fir	0.23 22.7	40***	128	1	30	T***	T***	0.25 24.7	23***	24	65	2	80-145	O	H	O
5% Dieldrin	1.53			4	31-115			1.31 13.1		8	34	1	25	O	H	O
50% Creosote	15.3							0.84 8.4		6	28			O	M	O
5% Dieldrin 50% 70-30 Creosote-Coal Tar	1.50 15.0		113	2	115-120	O	H	1.48 14.8		9	32			O	H	O
1% p-Dimethylaminophenylmercuric Acetate	0.38	25	100	2	34-80	VH	O	0.39	13***	28	64	1	13	VL***	L	O
100% Creosote (dbl treatment)	29.3							33.5								
10% Diphenylmethane 50% Creosote	2.81 14.1	9	94	2	33-82	VH	O	3.07 15.4	6	11	41			H	H	O
1% Endrin 50% Creosote in Douglas Fir	0.24 11.8	27***	152[i]			VL***	L	0.27 13.4		11	49	1	145	O	H	O
1% Endrin in Creosote in Douglas Fir	0.24 24.1		174[j]	2	103-167	O	O	0.26 26.0		9	67	2	3-27	O	VH	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Endrin 50% 70-30 Creosote-Coal Tar in Douglas Fir	0.25 12.2	35***	128[k]	2	89-98	VL***	L***	0.25 12.4		11	48			O	M	O
1% Endrin in 70-30 Creosote-Coal Tar in Douglas Fir	0.24 23.7	68	141[l]	3	89-208	T	O	0.23 23.2		11	63	1	36	O	VH	O
5% Endrin 50% Creosote	1.41 14.1	17***		4	40-204			1.43 14.3 1.38 13.8		4 6	25 45	1	20	O O	H VH	O O
5% Endrin 50% 70-30 Creosote-Coal Tar	1.67 16.7		150[m]	2	71-143	O	VL	1.49 14.9		7	36	1	142	O	H	O
2% Malachite Green Oxalate 10% Creosote (dbl treatment)	0.79 2.87	7	35			VH	O	0.79 2.89	5.5	6	11			VH	L	O
2% Malachite Green Oxalate 25% Creosote (dbl treatment)	0.77 7.28	6	44			VH	O	0.76 7.12	5	6	12			VH	M	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
2% Malachite Green Oxalate 50% Creosote (dbl treatment)	0.78 15.5	5	68	1	19	VH	O	0.81 16.7	5.5	7	16	1	6	VH	M	O
2% Malachite Green Oxalate 100% Creosote (dbl treatment)	0.76 33.8	32	126	3	19-71	H	O	0.77 34.0	7	10	35			VH	VL	O
5% Manganous Oxinate in Creosote (1/8" panel)	1.60 30.3 1.86 37.0	35 36	62 137[o]	2 1		L L	O O	1.87 34.8	11	11	18[n]	4		VL	VL	O
14.86% Nickel Sulfate 20.06% Sodium Mono H Arsenate 100% Creosote (triple treatment) (FPL)	3.71 3.43 20.7		117[p]	4	67-79	O	O	3.71 3.43 20.7		15	32			O	H	O
10% Phenyl Ether 50% Creosote	3.02 15.1	7		4	115-163			2.91 14.6	7	10	50	1	25	M	M	O
1% Phenylmercuric Chloride in Creosote	0.26 2.62	28	62	1	93	VH	O	0.42 41.9	12	15	43			M	L	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Phenylmercuric Chloride 50% 70-30 Creosote-Coal Tar in Douglas Fir	0.23 11.8	37	176[9]	3	86	T	L	0.23 11.4	15	7	47	1	14	H	M	O
1% Phenylmercuric Chloride in 70-30 Creosote-Coal Tar in Douglas Fir	0.16 15.1	16	139	2	86-98			0.19 20.9	22	17	55	1	145	H	L	O
1% Phenylmercuric Oleate in Creosote	0.37 36.8	29	97			VH	T***	0.37 37.3	6	NC	11			M	T	O
1% Phenylmercuric Oleate (solid) in Creosote	0.37 36.9	20	97	3	7-178	VH	O	0.27 26.8	7	12	32	1	7	VH	L	O
1% Phenylmercuric Oleate (solid) in 70-30 Creosote/ Coal-Tar Solution	0.17 16.1	17	52	1	42	H	O	0.14 14.2	7	6	14			VH	L	O
1% Phenylmercuric Oleate 10% Creosote 30% Coal Tar	0.36 3.6 10.7	29	56			VH	O	0.32 3.2 9.5	6	15	15			M	M	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Phenylmercuric Oleate	0.27	30	110	1	27	VH	O	0.26	9	NC	20	1	20	M	T	O
50% Creosote	13.7							12.9								
10% Coal Tar	2.7							2.6								
1% Phenylmercuric Oleate	0.31	34	63	1		VH	O	0.37	6	9***	25			VH	VL	O
50% Creosote	15.7							18.6								
30% Coal Tar	9.4							11.1								
1% Phenylmercuric Oleate	0.34	45	143	1	124	VH	O	0.33	17	23	49			VH	H	O
66% Creosote	22.5							21.5								
30% Coal Tar	10.3							9.8								
1% Phenylmercuric Oleate	0.20	34	84			VH	O	0.29	7	18	56			H	L	O
74% Creosote	15.1							21.1								
10% Coal Tar	2.0							2.9								
5% Phenylmercuric Oleate	1.20	30***	62			T	M	1.15	15	19	20			VL	H	VL
10% Coal Tar	2.38							2.29								
5% Phenylmercuric Oleate	1.97	29	68			H	O	1.74	17	15	36			H	M	T
50% Creosote	19.7							17.4								

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Phenylmercuric Oleate (solid) in Creosote	1.76 33.2 1.76 33.3	32	125	3 5	6-178 45-55	M	O	1.56 29.5 1.49 28.1	12 11***	12 26	48 48	1 2	4 22-40	M L***	M H	O O
5% Phenylmercuric Oleate (solid) in Creosote in Douglas Fir	0.89 16.9	10	62	3	52-110	M	L	0.70 13.3	7	20	29			VH	L	O
5% Phenylmercuric Oleate (solid) in 70-30 Creosote/ Coal-Tar Solution	1.00 19.0	44	105[7]					0.79 14.9	7	9	21	1	10	H	M	O
5% Phenylmercuric Oleate 10% Creosote 10% Coal Tar	1.14 2.26 2.26	40	126			L	M	1.27 2.52 2.52	18	21	36	1	20	T	M	VL
5% Phenylmercuric Oleate 10% Creosote 30% Coal Tar	1.57 3.13 9.39	34	64	1	124	M	T	1.84 3.67 10.55		20	28			O	H	O
5% Phenylmercuric Oleate 50% Creosote 10% Coal Tar	1.93 19.3 3.86	41	122	1	143	VH	O	1.65 16.5 3.27	19	22	39			M	L	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Phenylmercuric Oleate 50% Creosote 30% Coal Tar	1.53 15.3 9.23	38		2	46-143			1.69 16.9 10.0	27	22	51			VH	M	O
5% Phenylmercuric Oleate 51.2% Creosote 30% Coal Tar	1.79 18.4 10.2	36		2	115-143			1.60 16.4 9.58	19	21	46			H	VL	O
5% Phenylmercuric Oleate 71% Creosote 10% Coal Tar	1.75 24.8 3.50	38	122	1	113	VH	O	2.03 28.8 4.05	25	15	58			VH	L	O
6% Phenylmercuric Oleate in Creosote	2.19 39.6	31	82	2	124	H	O	2.48 41.4	21	24	53			L	M	O
1% Tributyltin Oxide, Solubilized 50% Coal Tar	0.33 16.3	11	43			H	T***	0.31 15.4	6	12***	21			VH	L	O
1% Toxaphene 50% Creosote	0.29 14.5	4	112	3	69-78	L	T	0.30 14.8	2	25	42			H	M	O
1% Toxaphene 50% Creosote in Douglas Fir	0.25 12.4	12	156	1	41			0.26 12.6	3	13		4	17-28			

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Toxaphene in Creosote	0.30 29.3	9	188	3	78-159	VL	O	0.34 33.6	7***	32	65			L	M	O
1% Toxaphene in Creosote in Douglas Fir	0.24 23.6	9	104	2	32-140	L	O	0.25 23.8	2	24	64			T***	H	O
5% Toxaphene 50% Creosote	1.62 16.2	11***	160	2	49-69	T	M	1.50 15.0	7	18	42			T	M	O
5% Toxaphene in Creosote	1.50 28.4			4	46-115			1.64 30.9	4	23	83	2	29	T	VH	O
5% Toxaphene 50% Creosote in Douglas Fir	1.42 14.2	68	188	1	26	T	O	1.40 14.0		19	56			O	VH	O
5% Toxaphene in Creosote in Douglas Fir	1.19 22.5	4	188	3	55-83	L	O	1.07 20.1	3***	15	58			VL	H	O
0.5% Tributyltin Oxide 50% Coal Tar	0.15 14.6	12	40			VH	O									
1% Tributyltin Oxide 50% Coal Tar	0.27 13.5	12	62	1	93	VH	O	0.31 15.8	6		31			VH	O	O

continued

Table A-5. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Tributyltin Oxide 50% Creosote	0.33 16.6	26		4	85-104			0.30 14.6	11	42	49			VH	T	O
1% Tributyltin Oxide 2% Toxaphene in Creosote (BYD)								21.2		44	61	2	11-13	O	H	O
2% Tributyltin Oxide in Creosote (BYD)								19.2	10	48	84	1	78	O	M	O

[a] Two panels eroded.
[b] One panel split.
[c] One panel split.
[d] Panel split.
[e] One panel softened.
[f] Two panels eroded.
[g] Two panels split.
[h] One panel eroded.
[i] Two panels lost.
[j] Two panels eroded.
[k] One panel eroded.
[l] One panel eroded.
[m] One panel eroded.
[n] Split.
[o] Split.
[p] One panel eroded and softened.
[q] One panel eroded.
[r] One panel split after 59 months' exposure; one panel eroded after 142 months' exposure.

Table A-6. Other Combination Treatments

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% p-Aminophenyl-mercuric Acetate + 2% Malachite Green Oxalate (dbl treatment)	0.39 0.76	41	103[a]	1	78	L	T	0.39 0.77	29	21	39			L	H	O
1% p-Aminophenyl-mercuric Acetate + 1% Tributyltin Coconut Fatty Acid Salt (dbl treatment)	0.39 0.27	55	112	3	13-48	T	O	0.39 0.27	12	22	29			H	L	T***
5% Biphenyl 2% Malachite Green Oxalate	1.66 0.66	4	41			VH	O	1.75 0.70	3	7	13			VH	L	O
5% Chlordan 2% Malachite Green Oxalate	1.87 0.72	2***	90[b]	1	88	T***	O	1.73 0.69		16	50	2	15-25	O	M	O
2% Copper Acetate 1% Malachite Green Oxalate	0.75 0.38	41	56			VH	O	0.75 0.38	10	11	15			H	L	O
2% Copper Acetate 1% Malachite Green Oxalate in Douglas Fir	1.00 0.51	49	55	2	98	L	H	1.14 0.57	18***	12	18			L	M	O

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
3% Copper Naphthenate 50% Linseed Oil	0.61 10.1		66[c]	2	63	O	M	0.66 11.0	34	28	49	1	55	M	L	T***
3% Copper Naphthenate 50% Linseed Oil in Douglas Fir	0.35 5.9		43	2	77-169	O	H	0.21 3.5	23	22	33			M	M	O
3% Copper Naphthenate 1% Tributyltin Coconut Fatty Acid Salt	0.69 0.23	188	188	3	41-124	T	O	0.75 0.25	51***	77***	103	1	102	T	T	T***
3% Copper Naphthenate 5% Tributyltin Coconut Fatty Acid Salt	0.82 1.35		188	2	34-78			0.84 1.40		94		4	103-125			
5% Copper Sulfate 3.2% PVM/MA	1.43 0.92	41	54[d]	1		L	L									
10% Copper Sulfate 3.2% PVM/MA	3.70 1.22	42	90			H	T***									

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
14.73% Copper Sulfate 20.06% Sodium Mono H Arsenate (dbl treatment) (FPL)	3.23 3.01		111	3	53-77	O	T	3.23 3.01		35	40			O	L	O
50% Solubilized Copper Oxinate 1% Tributyltin Coconut Fatty Acid Salt	12.5 0.25		191	3	21-126	O	O	10.6 0.22	47***	43	76	1	22	T***	L	M
50% Solubilized Copper Oxinate 5% Tributyltin Coconut Fatty Acid Salt	13.0 1.30			4	101-126			13.2 1.32				4	35-125			
5% Cuprammine Sulfate 3.2% PVM/MA	1.83 1.17		123	1	93	O	H									
1% Dieldrin 1% Malachite Green Oxalate	0.30 0.30	2***	61			T***	VL	0.32 0.32 0.33 0.33		4 4	9 12			O O	H H	O T***

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Dieldrin 1% Tributyltin Coconut Fatty Acid Salt	0.30 0.30		166	3	27-87	O	T***	0.25 0.25		95	97	1	93	O	L	T***
5% Dieldrin 5% Tributyltin Coconut Fatty Acid Salt	1.44 1.44			4	31-73			1.32 1.32	11		119	3	64-125	O	O	O
1% p-Dimethyl-aminophenyl-mercuric Acetate 1% Tributyltin Coconut Fatty Acid Salt (dbl treatment)	0.39 0.27	82	107	2	39			0.40 0.28	15	34***	45	1	125	M	T***	T***
1% p-Dimethyl-aminophenyl-mercuric Acetate 2% Malachite Green Oxalate (dbl treatment)	0.38 0.75	103	103[e]	2	41-69	VL	T***	0.40 0.79	19	15	30			H	H	O
5% Diphenyl-methane 2% Malachite Green Oxalate	1.60 0.64	3	48			M	O	1.66 0.67	4	7	12			VH	L	O

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Endrin 1% Malachite Green Oxalate	0.36 0.36	11	59	1	41	T***	T***	0.32 0.32		4	10			O	M	O
2% Malachite Green Oxalate 5% Dieldrin (dbl treatment)	0.74 1.43		80[f]	2	41-94	O	O	0.78 1.52		7	19	1	31	O	H	O
2% Malachite Green Oxalate 5% *Endrin (dbl* treatment)	0.72 1.44		87	3	32-85	O	O	0.75 1.44		10	36			O	M	O
2% Malachite Green Oxalate 1% Toxaphene (dbl treatment)	0.84 0.31		89[g]			O	T	0.86 0.29		6	16			O	H	O
2% Malachite Green Oxalate 5% Toxaphene (dbl treatment)	0.79 1.45		97[h]	1	7	O	O	0.57 1.24		9	22	1	10	O	VH	O
14% Phenylmercuric Oleate 50% Linseed Oil	3.99 14.3	56	106[i]	3	91-93	O	O	3.87 13.7	20	18	34			H	M	O

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
14% Phenylmercuric Oleate 50% Linseed Oil in Douglas Fir	1.80 6.5	48***	74			T	M	2.38 8.5	17	12	29	1	29	L	L	L
1% Toxaphene 1% Tributyltin Coconut Fatty Acid Salt	0.26 0.26	6	199	2	46	O	T***	0.28 0.28		NC	91[j]	2	38-80	O	T	O
1% Toxaphene 1% Tributyltin Coconut Fatty Acid Salt in Douglas Fir	0.18 0.18	6	148[k]	1	124	T	T***	0.26 0.26	5		168[l]	2	65-88			
1% Toxaphene 1% Tributyltin Oxide	0.27 0.27	56	188	3	69-124	O	T***	0.25 0.25	8***		111	2	102-125	O	O	O
1% Toxaphene 1% Tributyltin Oxide in Douglas Fir	0.27 0.27	31	188	3	66-99	T	O	0.22 0.22	15***	47***	102	2	33-125			
1% Toxaphene 5% Tributyltin Oxide	0.31 1.54	NC	175	3	52-85	T***	O	0.28 1.44				4	4-110			

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
1% Toxaphene 10% Tributyltin Oxide	0.29 2.81		175	3	55-170			0.33 3.27				4	4-110			
5% Toxaphene 5% Tributyltin Coconut Fatty Acid Salt	1.40 1.40		188	2	104-188	O	O	1.41 1.41	11			4	77-125			
5% Toxaphene 5% Tributyltin Coconut Fatty Acid Salt in Douglas Fir	1.29 1.29	13***	188	2	69-115	T***	O	1.29 1.29	30			4	93-125			
5% Toxaphene 1% Tributyltin Oxide	1.51 0.30	7***	175	4	52-162	T***	T***	1.39 0.28	7	38	38	3	10-110	VH	T	O
5% Toxaphene	1.34 1.34		109	4	66-192	O	O	1.39 1.39				4	33-125			
5% Tributyltin Oxide	1.59 1.59		175			O	T***	1.47 1.47	12			4	19-110			
5% Toxaphene 5% Tributyltin Oxide in Douglas Fir	1.35 1.35	58***	188	2	83	T***	O	1.36 1.36	14		14[m]	3	88-125	T	O	O

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
5% Toxaphene 10% Tributyltin Oxide	1.67 3.29	NC	175	4	52-175	T	O	1.57 3.13	***			4	2-110			
1% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate	0.29 0.29	21	45	1	52	H	O	0.31 0.31	5		11			H	O	L***
1% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate	0.26 1.32	33	66[n]	1	52	L	L	0.28 1.41	8	17	21	2	2-17	VH	L	H
5% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate	1.43 0.28	146***	175	2	55	T	T***	1.34 0.27	8		51	1	17	H	O	O
5% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate	1.52 1.52	NC	175	2	85-90	T	O	1.52 1.52	9	17	19	2	5-19	VH	L	T***

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
10% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate	3.20 0.32		175	4	28-55			2.97 0.30	6			4	13-110			
10% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate	2.95 1.48	NC	175	1	64	T	O	3.03 1.52				4	2-4			
1% Tributyltin Oxide 20-24% Ammonium Sulfide (dbl treatment)	0.28†	11		4	49-76			0.27†	5	36***	60	1	8	H	T	O
1% Tributyltin Oxide 3% Copper Naphthenate	0.27 0.82			5	52-110			0.27 0.81			97	3	110	O	O	O
5% Tributyltin Oxide 3% Copper Naphthenate	1.59 0.96		175	3	55	O	O	1.32 0.79				4	13-110			

continued

Table A-6. Continued

Treatment	Port Hueneme							Pearl Harbor							
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
10% Tributyltin Oxide 3% Copper Naphthenate	2.89 0.84	NC***	175	2	133-175	T	O	3.11 0.94				4	19-110			
1% Tributyltin Oxide 1% Thiodan in #5 Fuel Oil (BYD)								21.1[o]	7	44	44[p]	3	13-103	T	T	O
1% Tributyltin Oxide 2% Toxaphene in #5 Fuel Oil (BYD)								20.5[q]	4		60	2	103	H	O	O

[a] Three panels eroded.
[b] Three panels eroded.
[c] Two panels failed at tag.
[d] Failed at tag.
[e] Two panels eroded.
[f] Two panels eroded.
[g] Four panels eroded.
[h] Three panels eroded.
[i] One panel failed at tag.
[j] Two panels eroded.
[k] Two panels eroded.
[l] Two panels eroded.
[m] One panel split.
[n] Four panels failed at tag.
[o] Including weight of fuel oil.
[p] One panel split.
[q] Including weight of fuel oil.

Table A-7. Untreated Panels and Solvent-Extracted Untreated Panels

Treatment	Port Hueneme							Pearl Harbor								
	Weight Solute Absorbed (lb/cu ft)	Months to Initial *Limnoria* Attack	Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo.)	Panels Lost		Damage When Removed From Test		
				No.	Exposure Time (mo.)	*Limnoria*	*Teredo*		*Limnoria*	*Martesia*		No.	Exposure Time (mo.)	*Limnoria*	*Martesia*	*Teredo*
Afambeau				4	87					8	22			O	H	O
Antidesma pulvinatum		45	94	1[a]		T***	T***									
Greenheart			75 53 65	 1 1	 53 41	O O O	VH VH VH			5	13			O	H	O
Greenheart, acetic acid extracted			84[b]			O	H									
Greenheart, chloroform extracted		27***	72			T	H									
Greenheart, methanol extracted			79			O	VH									
Lignum Vitae		72***	100[c]			T	L			11	12			O	M	M

[a] Nine panels eroded.

[b] Two panels split.

[c] Two panels broken in two during examination.

Appendix B

TREATMENTS SUPERIOR TO CREOSOTE OR 70-30 CREOSOTE/COAL-TAR SOLUTION IN PRESERVATIVE ABILITY

This information is based on service lives greater than 114 months (83 average + 31 months) in Hueneme harbor and greater than 47 months (33 average + 14 months) in Pearl Harbor.

Treatment

9.05% Acid Copper Chromate

3% Copper Naphthenate

6% Copper Naphthenate

50% Solubilized Copper Oxinate

1% Tributyltin Oxide

3% Copper Naphthenate
50% Creosote

3% Copper Naphthenate
50% 70-30 Creosote/Coal-Tar Solution

6% Copper Sulfate
100% Creosote
(dual treatment)

12% Copper Sulfate
100% Creosote
(dual treatment)

14.73% Copper Sulfate
20.06% Sodium Mono-Hydrogen Arsenate
100% Creosote
(triple treatment)

1% Dieldrin in 70-30 Creosote/Coal-Tar Solution

1% Endrin
50% Creosote

1% Endrin in Creosote

Treatment

1% Endrin in 70-30 Creosote/Coal-Tar Solution

10% Phenyl Ether
50% Creosote

1% Phenylmercuric Chloride in 70-30 Creosote/Coal-Tar Solution

5% Phenylmercuric Oleate (solid) in Creosote

5% Phenylmercuric Oleate (solid) in 70-30 Creosote/Coal-Tar Solution

1% Toxaphene in Creosote

5% Toxaphene
50% Creosote

5% Toxaphene in Creosote

1% Tributyltin Oxide
2% Toxaphene in Creosote

2% Tributyltin Oxide in Creosote

3% Copper Naphthenate
1% Tributyltin Coconut Fatty Acid Salt

3% Copper Naphthenate
5% Tributyltin Coconut Fatty Acid Salt

50% Solubilized Copper Oxinate
1% Tributyltin Coconut Fatty Acid Salt

1% Dieldrin
1% Tributyltin Coconut Fatty Acid Salt

5% Dieldrin
5% Tributyltin Coconut Fatty Acid Salt

1% Toxaphene
1% Tributyltin Coconut Fatty Acid Salt

1% Toxaphene
1% Tributyltin Oxide

5% Toxaphene
5% Tributyltin Coconut Fatty Acid Salt

5% Toxaphene
5% Tributyltin Oxide

5% Toxaphene
10% Tributyltin Oxide

5% Tributyltin Coconut Fatty Acid Salt
1% Phenylmercuric Oleate

10% Tributyltin Coconut Fatty Acid Salt
1% Phenylmercuric Oleate

1% Tributyltin Oxide
20-24% Ammonium Sulfide
(dual treatment)

5% Tributyltin Oxide
3% Copper Naphthenate

10% Tributyltin Oxide
3% Copper Naphthenate

1% Tributyltin Oxide
2% Toxaphene in No. 5 Fuel Oil

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