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AUTHOR: Thomas B. O'Neill

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# NOTE

NAVAL CIVIL ENGINEERING LABORATORY  
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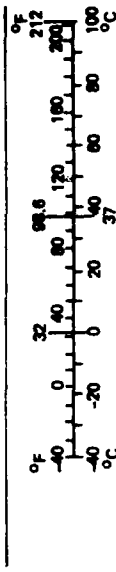
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures				Approximate Conversions from Metric Measures			
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			meters	m	meters	3.3	feet
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in <sup>2</sup> ft <sup>2</sup> yd <sup>2</sup> mi <sup>2</sup>	square inches square feet square yards square miles acres	6.5 0.09 0.8 2.6 0.4	square centimeters	cm <sup>2</sup>	square centimeters	0.16	square inches
			square meters	m <sup>2</sup>	square meters	1.2	square yards
			square kilometers	km <sup>2</sup>	square kilometers	0.4	square miles
			hectares	ha	hectares (10,000 m <sup>2</sup> )	2.5	acres
oz lb	ounces pounds short tons (2,000 lb)	28 0.45 0.9	grams	g	grams	0.035	ounces
			kilograms	kg	kilograms	2.2	pounds
tsp Tbsp fl oz c pt qt gal ft <sup>3</sup> yd <sup>3</sup>	teaspoons tablespoons fluid ounces cups pints quarts gallons cubic feet cubic yards	5 15 30 0.24 0.47 0.95 3.8 0.03 0.76	milliliters	ml	milliliters	0.03	fluid ounces
			milliliters	ml	liters	2.1	pints
°F	Fahrenheit temperature	5/9 (after subtracting 32)	°Celsius	°C	°Celsius	9/5 (then add 32)	Fahrenheit temperature
			°Celsius	°C	°Celsius	9/5 (then add 32)	Fahrenheit temperature



\*1 in. = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10-286.



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- > outstanding preservative qualities; the use of such preservatives, however, in the marine environment is subject to EPA restrictions. Basic zinc sulfate is an environmentally acceptable preservative that appears to show promise; its effects on the mechanical properties of wood should be more thoroughly investigated.

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PILING AT PEARL HARBOR, HAWAII, by  
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## INTRODUCTION

The history of wood preservation is characterized by the continuing search for new protective chemical systems; the present study is part of the Navy's and the Naval Civil Engineering Laboratory's (NCEL's) contribution to this search.

To determine the effectiveness of any wood preservative in the marine environment it is considered mandatory to expose full-size piles impregnated with test agents in seawater with endemic marine borer populations. When piles are placed in tropical waters where marine borer populations and their activity are great, the period of time required to obtain significant results is greatly reduced. NCEL, in cooperation with industry, has installed pilings with test preservatives in Pearl Harbor, Hawaii, and, since the installations, has observed and evaluated the preservatives.

Recently, additional stimuli have increased the concern for the development of new wood preservatives. The continued application of the most commonly used preservatives, creosote and metallic salts, is in jeopardy. In 1971, the Environmental Protection Agency (EPA) declared that creosote is an oil, and the amount of creosote generally released into the surrounding water during the driving of a pile is a reportable violation of the Water Quality Act of 1971. On 18 October 1978, the EPA issued Notices of Rebuttable Presumption against the registration of creosote on the basis that creosote exceeded the risk criteria for various acute and toxic effects on humans. At the same time inorganic arsenicals were placed in the same category; thus, the continued use of ammoniacal copper arsenite (ACA) and chromated copper arsenate (CCA) has been imperiled. The use of arsenic in antifouling paints has been prohibited because of demonstratable adverse effects on the marine environment. Both copper and chromium salts are considered to be suspect. Among the members of the wood preservative industry there is considerable speculation as to whether EPA currently has the desire, funding, and personnel to pursue legislation against the use of creosote and metallic salts. Despite the generally expressed view that creosote and the metallic salts will continue in use because their economic advantages are considered to outweigh their possible hazards, the prudent course for the Navy, with such a large investment in marine timbers and a great need for combat readiness, is to seek alternative methods of preserving wood that are also environmentally acceptable.

Another main concern among those using metallic salts is the embrittlement of wood. Eaton, Drelicharz, and Roe (Ref 1) have demonstrated that, using the American Wood Preservative Association (AWPA) standards of metallic salts ( $2.5 \text{ lb/ft}^3$ ) in dual treatment, the mechanical properties of both Douglas fir and southern yellow pine may be reduced by as much as 55%.

Many of the wood preservatives used in this study may be considered as possible alternatives to presently used systems; thus, the lengthy record of exposure in the warm and borer-laden water of Pearl Harbor assumes considerable significance.



## PILING TREATMENT AND INSTALLATION

From 1963 to 1966, NCEL, with the cooperation of members of the wood preserving industry and the Cooperative Marine Piling Committee, treated and installed 273 piles at Waipio Peninsula, Pearl Harbor, Hawaii. The Cooperative Piling Committee was an informal group consisting of representatives from the wood treating industry, the Forest Products Laboratory, and the W. F. Clapp Laboratory.

Of the 66 piles driven in 1963, 42 were inadvertently removed in August 1972. Most of the 42 piles were so damaged by borer activity that they broke up during removal, while others were lost or their identification tags were lost. A few of the piles removed were redriven; the 1982 inspection reported herein includes 27 of the piles driven in 1963.

In 1964, 69 piles treated by NCEL and industry were installed. Of these, many were accidentally removed as cited above; all but three were structurally sound and were redriven in May 1973.

In 1965, 78 NCEL-treated piles were installed. Many of these were removed in 1972, and 48 were subsequently redriven in May 1973.

The last group, consisting of 60 piles, was driven in 1966. The piles had been treated by private companies or by NCEL, or initially treated by private companies and subsequently treated by NCEL. None of this group was accidentally removed as described above.

A general summary of treatment given to all piles is found in Table 1, and more specific treatments are cited in the various tables recording observations.

## PILING INSPECTION

From the first inspection in 1967 through 1974 the piles were visually inspected from the surface of the water. Because of the difficulty encountered in trying to observe the damage of submerged surfaces, a decision was made to have a diver examine the piles. In 1975, NCEL contracted with Mr. Al Hanson, a diver with more than 30 years of experience inspecting piling at the Port of Los Angeles. During this period, Mrs. Hanson, who is both a licensed diver and diver tender, served as a tender and recorder. Similar contracts were given to the Hansons for the 1977, 1978, and 1982 inspections. During the most recent inspection certain piles were evaluated by ultrasonic methods by J. Agi and Associates for a work unit in the Specialized Inspection Systems project at NCEL; these results were compared with the visual observations. Where significant differences in evaluation by the two different techniques existed, pilings were removed and will be cut into cross sections for a possible explanation of observational discrepancies. The Hansons report the percentage loss of a cross-sectional area of a pile; this is expressed in a single number. The nature of the loss and the genus causing destruction are frequently cited, as is the presence of splits, checks, and other damage. Agi and Associates report the percentage of the

piling considered to be sound; often the results are stated within a range, (e.g., 10 to 25%). In comparing observations, the Agi results have been converted to express percentage loss so as to facilitate comparisons.

## FINDINGS AND CONCLUSIONS

The reader is referred to References 2 to 18 for reports on the inspections prior to 1982.

The principal borers recorded from Pearl Harbor are the crustaceans, Limnoria tripunctata and Sphaeroma terebransi; and the molluscs, Martesia striata, Teredo spp., and Bankia spp.

The Hanson and Agi evaluations are summarized in Tables 2 to 9. A comparison of findings during the inspections of 1976 and 1978 is also given in these tables. Summaries citing the number of piles showing a percent category of damage are also included. The categories used are as follows: (1) damage less than 5%, (2) damage between 5 and 15%, (3) damage between 15 and 50% and (4) damage greater than 50%. The degree of damage determines the method of repair. Piling is wrapped when damage is between 5 and 15%. When the damage is between 15 and 50% of the cross-sectional area the piling is repaired with grout or concrete. When damage exceeds 50% the damaged area is replaced with wood or concrete.

### 1963 Series

In this series all piling was treated with creosote and, in addition, most were treated with another preservative.

Treatment of piles with ammoniacal copper arsenite (ACA) followed by creosote appears to offer considerable protection against all borers, though it is believed that this protection is due to the high salt concentration (6.9 lb/ft<sup>3</sup> rather than the standard 2.5 lb/ft<sup>3</sup>). When a standard amount of chromated copper arsenate (CCA) is used in combination with a below-standard amount of creosote (8.4 lb/ft<sup>3</sup>), in lieu of the standard 25 lb/ft<sup>3</sup>, the results are significantly poorer, with damage resulting from Limnoria, Teredo, and Martesia. When the standard amounts of both CCA and creosote are used the results are nondefinitive. Widely varying results in only three pilings offers no statistical reliability. One of the pilings had but 2% damage due to Limnoria after 19 years, a second had 5% damage due to Martesia, and the third piling was completely destroyed by Limnoria. This author believes that a "weakest link" concept should be applicable: if all pilings are basically the same, as has been their treatment with preservatives, and only one has been destroyed by borers, then the others are equally susceptible but happened to be placed in a location where borer populations are minimal.

Single treatment using 70-30 creosote-coal tar appears to offer slightly better protection for Douglas fir than for southern yellow pine, although the small number of pilings observed offers no firm statistical basis for definitive conclusions.

Dual treatment of 70-30 creosote-coal tar followed by either 1 or 5% phenylmercuric oleate (PMO) gave promising results except for two piles: one of Douglas fir with 1% PMO had 50% damage due to Limnoria in 1982; and another, of southern yellow pine with 5% PMO, was rated as having 90% damage, again due to Limnoria attack, in 1982.

The single pile treated with 70-30 creosote-coal tar and covered with cupro-nickel sheeting is, after 19 years of immersion, in excellent condition.

The damage to the five control piles (Douglas fir) impregnated with NCEL creosote only (17.2 lb/ft<sup>3</sup>) was 5, 5, 5, 7, and 7%, respectively.

#### 1964 Series

All of the piles in this series were treated with creosote and, with the exception of controls, other preservatives.

Chlordane, both in 2.5 and 5% additives to creosote, gave excellent results against all borers with a maximum damage of 4%. All of the damage was due to Limnoria. A 1.25% chlordane additive gave good results, with damage from Limnoria varying from 2 to 15%. Copper naphthenate in high concentrations (30%) yielded good results, even when added to less-than-standard amounts of creosote (8.3 lb/ft<sup>3</sup>). In lower concentrations of 7.5 and 15%, copper naphthenate gave poor results, with damage resulting from both Martesia and Limnoria activity. No significant preservative power was imparted by the use of 1% tributyltin oxide (TBTO) as the sole additive or with copper naphthenate, damage from Limnoria activity being most significant. A combination of 1% dieldrin and 1% TBTO was very effective, though the dieldrin is believed to be chiefly responsible for the effectiveness. Where 1% TBTO was the sole additive, piling damage was 92 to 100%.

#### 1965 Series

In this series the solvent for preservatives was xylene, not creosote. Copper oxinate appears to give good protection against all borers only when the amount of retention is 0.50 lb/ft<sup>3</sup> or more. In lesser amounts copper oxinate appears to offer only fair protection, either alone or when used with other agents, such as tributyltin oxide, Victoria green base, and creosote. Limnoria and to a lesser extent Martesia appear to be most prevalent. In this series 5% chlordane yielded encouraging results when used with TBTO, with damage varying from 2 to 6% in 12 piles. This damage was caused by both Limnoria and Martesia.

#### 1966 Series

This series has the greatest number of variations as to piling sources as well as preservatives used. Four groups were treated with one preservative, and six were treated with two anti-borer agents.

Chromated copper arsenate (CCA) gave poor results as did dual treatment with copper sulfate and TBTO. Limnoria caused the greatest amount of damage. Martesia was found in approximately one-half the piles, and Teredo was found in only a few. Chromated copper arsenate (CCA) gave good results when used with TBTO. Basic zinc sulfate also yielded good results when used alone or in combination with TBTO, showing a maximum damage of 4%.

## Visual Evaluation Compared With Ultrasonic Evaluation

In a comparison of visual inspection by a diver with ultrasonic testing of 52 piles, findings were comparable in 30 of the piles. This conclusion may be misleading because the ultrasonic results are frequently expressed in a range of two figures, a low and a high. A piling rated visually by a diver as having a 3% loss was evaluated by the ultrasonic device as having a 0 to 25% loss. Eleven of the piles evaluated by both methods had a significant variation. A visually determined 2% loss of cross-sectional area was, in several piles, rated by the ultrasonic technique as having a 10 to 25% loss.

## DISCUSSION AND RECOMMENDATIONS

The existence of a relatively large number of pilings experimentally treated with different preservatives and placed, 17 to 20 years ago, in a tropical marine environment with heavy populations of different species of marine borers is of great value. The experimental pilings at Pearl Harbor are, for the above reasons, unique and thus should be maintained and evaluated at periodic intervals, and the results should be used to program future research.

Certain treatments have demonstrated outstanding preservative qualities (e.g., chlorinated hydrocarbons, such as chlordane and dieldrin). The EPA has banned their use in the marine environment; thus, research should be based on alternative forms of these materials. Analogues of the chlorinated hydrocarbons might be prepared so that a moiety, toxic to marine borers and yet environmentally acceptable, could be released. A second approach would be to investigate the mechanism of toxicity to borers and duplicate the reaction using alternative, environmentally safe agents.

The protection of piling with cupro-nickel sheathing, once common in the past, has been discontinued because of the expense of the material and difficulty in its application. After 20 years in Pearl Harbor, it is rated as excellent. A study of its cost effectiveness is in order, as is the possible use of thinner sheets. When cupro-nickel was extensively used, it was primarily considered as a mechanical barrier to borers. Today the role of sheathing in the exclusion of oxygen for borer activity is considered preeminent. Perhaps thinner and thus less expensive and more manageable sheets should be considered.

Basic zinc sulfate appears to be a promising wood preservative against all borers in Pearl Harbor. It is environmentally safe and thus should be more extensively tested. At the present moment no knowledge of possible embrittlement resulting from zinc sulfate treatment exists; therefore, this characteristic must be investigated.

Certain compounds traditionally believed to be promising as preservatives have, in the present study, been clearly unacceptable and yet they continue to be tested. Copper naphthenate and tributyltin oxide are examples of such compounds.

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Table 1. Experimentally Treated Piles Driven at Pearl Harbor

Year Driven	Source of Piles <sup>a</sup>	Number of Different Treatments	Number of Piles Per Treatment	Total Piles	Summary of Treatments
1963	Coop	10	6	60	Inorganic salt followed by creosote (double treatment); 70-30 creosote-coal tar solution; phenylmercuric oleate dissolved in 70-30 creosote-coal tar solution; 70-30 creosote-coal tar solution followed by sheathing with 90:10 cupro-nickel alloy
1963	NCEL	1	6	6	Type III creosote
1964	NCEL	9	6	54	Creosote solutions of specific organic compounds and/or metal organic compounds
1964	OWPC	1	4	15	Creosote solutions of specific organic and metal organic compounds
1965	NCEL	13	6	78	Solutions of specific organic and metal organic compounds in xylene or creosote
1966	NCEL	2	6	12	Double treatment: copper sulfate followed by tributyltin oxide
1966	BCCWP	1	6	6	Chromated copper arsenate (Type B)
1966	AZLS	3	6	6	Basic zinc sulfate
1966	AZLS	3	6	18	Ammoniacal copper arsenite; 70-30 creosote-coal tar solution; double treatment: ammoniacal copper arsenite followed by 70-30 creosote-coal tar solution
1966	AZLS/ NCEL	1	6	6	Double treatment: basic zinc sulfate followed by tributyltin oxide
1966	BCCWP/ NCEL	1	6	6	Double treatment: chromated copper arsenate (Type B) followed by tributyltin oxide
1966	JHB/ NCEL	1	6	6	Double treatment: ammoniacal copper arsenite followed by tributyltin oxide

<sup>a</sup>AZLS = American Zinc, Lead, and Smelting Co.  
 BCCWP = British Columbia Clean Wood Preservers, Ltd.  
 Coop = Cooperative Marine Piling Committee  
 JHB = J.H. Baxter and Co.  
 NCEL = Naval Civil Engineering Laboratory  
 OWPC = Osmose Wood Preserving Company of America

Table 2. Results of Three Yearly Inspections of Piles Installed in 1963

Treatment	Retention (lb/ft <sup>3</sup> )			Percent Loss of Cross-Sectional Area for--															
	Coopers- tive Assay		NCEL Assay	Piling No. 1			Piling No. 2			Piling No. 3			Piling No. 4			Piling No. 5			
	Oil	Salt	Oil	Salt	1976	1978	1982	1976	1978	1982	1976	1978	1982	1976	1978	1982	1976	1978	1982
Ammiacal copper arsenate followed by creosote in Douglas fir	16.2	6.9	9.7	--	0	0	2	0	1	3 <sup>a</sup>	0	0	4 <sup>b</sup>	--	--	--	--	--	--
Chromated copper arsenate followed by creosote in Douglas fir	8.4	2.7	2.7	--	4	12	88 <sup>c,d</sup>	7	55	95 <sup>c,d,e</sup>	2	2	10 <sup>f</sup>	--	--	--	--	--	--
Chromated copper arsenate followed by creosote in southern yellow pine	23.2	2.7	17.3	--	0	100 <sup>g</sup>	100 <sup>g</sup>	0	1	2 <sup>f</sup>	0	0	5 <sup>a</sup>	--	--	--	--	--	--
70-30 creosote-coal tar solution in Douglas fir	15.3	--	11.1	--	0	1	3 <sup>f</sup>	0	7	7 <sup>c</sup>	0	0	4 <sup>f</sup>	--	--	--	--	--	--
70-30 creosote-coal tar solution in southern yellow pine	17.7	--	13.5	--	6	15	40 <sup>c,d</sup>	2	10	20 <sup>c,h</sup>	2	--	--	--	--	--	--	--	--
70-30 creosote-coal tar solution containing 1% phenyl-mercuric oleate in Douglas fir	20.7	--	18.5	--	5	13	50 <sup>c</sup>	0	0	2 <sup>c</sup>	0	1	5 <sup>c</sup>	--	--	--	--	--	--
70-30 creosote-coal tar solution containing 1% phenyl-mercuric oleate in southern yellow pine	24.1	--	18.5	--	0	3	3 <sup>c</sup>	--	--	--	--	--	--	--	--	--	--	--	--

continued



Table 2. Continued

Treatment	Retention (lb/ft <sup>3</sup> )						Percent Loss of Cross-Sectional Area for--														
	Cooperative Assay		MCEL Assay		Piling No. 1			Piling No. 2			Piling No. 3			Piling No. 4			Piling No. 5				
	Oil	Salt	Oil	Salt	1976	1978	1982	1976	1978	1982	1976	1978	1982	1976	1978	1982	1976	1978	1982		
70-30 creosote-coal tar solution containing 5% phenylmercuric oleate in Douglas fir	13.0	--	10.0	--	0	2	7 <sup>d,f</sup>	--	--	--	--	--	--	--	--	--	--	--	--	--	
	27.5	--	22.1	--	7	12	90 <sup>c</sup>	0	3	5 <sup>c</sup>	--	--	--	--	--	--	--	--	--	--	
70-30 creosote-coal tar solution containing 5% phenylmercuric oleate in southern yellow pine	--	--	--	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
	--	--	17.2	--	3	4	5 <sup>c,d</sup>	0	2	5 <sup>c</sup>	3	5	5 <sup>c</sup>	0	3	7 <sup>c</sup>	3	4	7 <sup>c,d</sup>	--	
MCEL creosote in Douglas fir	--	--	17.2	--	3	4	5 <sup>c,d</sup>	0	2	5 <sup>c</sup>	3	5	5 <sup>c</sup>	0	3	7 <sup>c</sup>	3	4	7 <sup>c,d</sup>	--	

<sup>a</sup>Dead Martesia.  
<sup>b</sup>Few Limnoria.  
<sup>c</sup>Limnoria.  
<sup>d</sup>Martesia.  
<sup>e</sup>Teredo.  
<sup>f</sup>Slight Limnoria.  
<sup>g</sup>Spile hit and broken.  
<sup>h</sup>Slight Martesia.  
<sup>i</sup>Nominal percentages. Analyses of core borings showed that considerably less than the nominal percentage penetrated into the wood. No individual retention figures were reported.

Table 3. Summary of Three Yearly Inspections of Piles Installed in 1963, Pulled in 1972, and Redriven in 1973

Treatment	No. of Piles	Number of Piles According to Damage Categories Attacked in--												
		1976			1978			1982						
		<5%	5-15%	>15%	<5%	5-15%	15-50%	<5%	5-15%	15-50%	>50%			
Ammoniacal copper arsenite followed by creosote in Douglas fir	3	3/3 <sup>a</sup>	--	3/3	--	--	3/3	--	--	--	3/3	--	--	--
Chromated copper arsenate followed by creosote in Douglas fir	3	2/3	1/3	1/3	1/3	1/3	--	1/3	1/3	--	--	1/3	--	2/3
Chromated copper arsenate followed by creosote in southern yellow pine	3	3/3	--	2/3	--	1/3	1/3	--	1/3	1/3	--	1/3	--	1/3
70-30 creosote-coal tar solution in Douglas fir	3	2/3	--	2/3	1/3	--	2/3	1/3	--	--	2/3	1/3	--	--
70-30 creosote-coal tar solution in southern yellow pine	2	1/2	1/2	--	2/2	--	--	--	2/2	--	--	--	2/2	--
70-30 creosote-coal tar solution containing 1% phenylmercuric oleate in Douglas fir	3	2/3	1/3	2/3	1/3	--	2/3	1/3	1/3	--	1/3	1/3	1/3	--
70-30 creosote-coal tar solution containing 1% phenylmercuric oleate in southern yellow pine	1	1/1	--	1/1	--	--	1/1	--	--	--	--	--	--	--

continued

Table 3. Continued

Treatment	No. of Piles	Number of Piles According to Damage Categories Attacked in--											
		1976			1978			1982					
		<5%	5-15%	>15%	<5%	5-15%	15-50%	<5%	5-15%	15-50%	>50%	>50%	
70-30 creosote-coal tar solution containing 5% phenylmercuric oleate <sup>b</sup> in Douglas fir	1	1/1	--	1/1	--	--	--	1/1	--	--	--	--	--
70-30 creosote-coal tar solution containing 5% phenylmercuric oleate <sup>b</sup> in southern yellow pine	2	1/2	1/2	1/2	--	--	--	1/2	--	--	--	1/2	--
70-30 creosote-coal tar solution in southern yellow pine followed by sheathing with cupro-nickel alloy	1	1/1	--	1/1	--	--	1/1	--	--	--	--	--	--
NCEL creosote in Douglas fir	5	5/5	--	4/5	1/5	--	--	5/5	--	--	--	--	--

<sup>a</sup>The fraction is interpreted as follows. The denominator denotes the number of piles inspected, and the numerator designates the number of piles in a specific category. Thus, for example, in the 1982 inspection of the three Douglas fir piles treated with chromated copper arsenate and creosote, two had greater than 50% damage and one had 5 to 15% damage.

<sup>b</sup>Nominal percentages. Analyses of core borings showed that considerably less than the nominal percentage penetrated into the wood.

Table 4. Results of Three Yearly Inspections of

Creosote Additive	Creosote Retention (lb/ft <sup>3</sup> )	Additive Retention (lb/ft <sup>3</sup> )	Percent Loss of Cross-												
			Piling No. 1				Piling No. 2				Piling No. 3				
			1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976
None	32.9	0.00	2	3	3 <sup>b</sup>	0-25	2	2	3 <sup>b</sup>	0	0	1-2	3	0	3
None	18.6	0.00	26	33	94 <sup>b,d</sup>	100	26	26	94 <sup>b</sup>	100	30	67	100 <sup>b</sup>	100	16
1.25% chlordane	26.3	0.3	0	1	2 <sup>b</sup>	10-25	0	0	2 <sup>b</sup>	10	0	0	4 <sup>b</sup>	--	1
2.5% chlordane	28.5	0.7	0	1	3 <sup>b</sup>	0	0	0	2 <sup>b</sup>	--	2	3	4 <sup>b</sup>	0-25	3
5% chlordane	28.6	1.4	0	0	2 <sup>b</sup>	0-25	0	0	3 <sup>b</sup>	10	0	1	2 <sup>b</sup>	--	0
7.5% copper naphthenate	10.9	0.09 <sup>f</sup>	65	97	100 <sup>b</sup>	100	0	0	2 <sup>b</sup>	10-25	35	73	100 <sup>b</sup>	--	2
15% copper naphthenate	9.4	0.15 <sup>f</sup>	2	8	28 <sup>b,e</sup>	100	0	0	3 <sup>b</sup>	--	32	42	92 <sup>b,e</sup>	100	0
30% copper naphthenate	8.3	0.27 <sup>f</sup>	0	2	2 <sup>b</sup>	--	0	5	7 <sup>b</sup>	--	1	3	4 <sup>b,e</sup>	0-25	2
7% copper naphthenate 0.5% tributyltin oxide	8.6	0.07 <sup>f</sup> 0.08	0	1	3 <sup>b</sup>	0-25	4	8	38 <sup>b</sup>	--	0	1	2 <sup>b</sup>	--	2
14% copper naphthenate 1% tributyltin oxide	14.8	0.23 <sup>f</sup> 0.15	8	18	92 <sup>b,e</sup>	100	3	8	22 <sup>b</sup>	25-50	0	2	3 <sup>b</sup>	0	7
1% tributyltin oxide	13.9	0.14	4	18	92 <sup>b</sup>	100	40	63	100 <sup>b</sup>	100	13	28	100 <sup>b</sup>	100	30
1% tributyltin oxide 1% dieldrin	17.4	0.18 0.18	0	2	2 <sup>b</sup>	10	0	0	2 <sup>b</sup>	--	0	0	0	--	0

<sup>a</sup>Agi and Associates.

<sup>b</sup>Limnoria.

<sup>c</sup>Few Martesia.

<sup>d</sup>Some Martesia.

<sup>e</sup>Martesia.

<sup>f</sup>As metallic copper.

<sup>g</sup>Teredo.

of Three Yearly Inspections of Piles Installed in 1964

Percent Loss of Cross-Sectional Area for--

1982 <sup>a</sup>	Piling No. 3				Piling No. 4				Piling No. 5				Piling No. 6			
	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>
0	0	1-2	3	0	3	5	20 <sup>b</sup>	0-25	3	5	9 <sup>b,c</sup>	10	3	3	3 <sup>b</sup>	10
100	30	67	100 <sup>b</sup>	100	16	30	100 <sup>b,e</sup>	100	--	--	--	--	--	--	--	--
10	0	0	4 <sup>b</sup>	--	1	2	15 <sup>b</sup>	25-20	0	1	3 <sup>b</sup>	--	3	4	10 <sup>b</sup>	0-25
--	2	3	4 <sup>b</sup>	0-25	3	3	4 <sup>b</sup>	--	0	0	2 <sup>b</sup>	--	0	0-1	2 <sup>b</sup>	10-25
10	0	1	2 <sup>b</sup>	--	0	1	1 <sup>b</sup>	0-25	0	0	3	0	0	0	0	0
10-25	35	73	100 <sup>b</sup>	--	2	3	5 <sup>b</sup>	--	3	4	7 <sup>b</sup>	--	2	4	5 <sup>b</sup>	--
--	32	42	92 <sup>b,e</sup>	100	0	3	4 <sup>b,e</sup>	10	15	18	55 <sup>b</sup>	100	18	92	100 <sup>b,e,g</sup>	100
--	1	3	4 <sup>b,e</sup>	0-25	2	7	11 <sup>b,e</sup>	25-50	2	5	9	25-50	0	1	2 <sup>b</sup>	0-25
--	0	1	2 <sup>b</sup>	--	2	7	42 <sup>b</sup>	100	30	77	99 <sup>b,c</sup>	--	7	28	100 <sup>b,c</sup>	--
25-50	0	2	3 <sup>b</sup>	0	7	28	93 <sup>b</sup>	--	48	94	98 <sup>b</sup>	100	8	69	100 <sup>b,c</sup>	100
100	13	28	100 <sup>b</sup>	100	30	94	100 <sup>b</sup>	100	29	65	100 <sup>b,e,g</sup>	100	--	--	--	--
--	0	0	0	--	0	0	0	0-25	0	0	2 <sup>b</sup>	--	0	0	2	0-25

2



Table 6. Results of Three Yearly Inspections of NCEL-Treated Piles Ins

Treatment (Solutions in Xylene)	Retention (lb/ft <sup>3</sup> )	Percent Loss of Cross-Sectional Area												
		Piling No. 1				Piling No. 2				Piling No. 3			Piling No. 4	
		1976	1978	1982 <sup>b</sup>	1982	1976	1978	1982	1982 <sup>b</sup>	1976	1978	1982	1976	1978
4% copper oxinate	0.87 <sup>c</sup>	0	4	8 <sup>d</sup>	--	0	1	2 <sup>d</sup>	--	1	1	3 <sup>d</sup>	1	5
2% copper oxinate	0.49 <sup>c</sup>	0	2	2 <sup>d,e</sup>	--	2	4	6 <sup>d</sup>	--	10	20	40 <sup>d,e</sup>	0	0
2% copper oxinate 2% tributyltin oxide	0.25 <sup>c</sup> 0.25	3	20	70 <sup>d,e,f</sup>	100	4	12	85 <sup>d,e</sup>	--	2	5	20 <sup>d,e</sup>	0	4
3% copper oxinate 1% Victoria green base	0.69 <sup>c</sup> 0.26	0	3	25 <sup>d,e</sup>	--	2	5	8 <sup>d,e</sup>	--	0	--	--	0	2
5% chlordane 1% tributyltin oxide	1.3 0.27	0	2	3 <sup>d</sup>	--	0	0	2 <sup>h</sup>	--	0	1	4 <sup>e</sup>	0	3
5% chlordane 2% tributyltin oxide	1.5 0.62	0	0	2 <sup>d</sup>	--	1	1	3 <sup>e</sup>	--	0	0	2 <sup>d</sup>	0	0
1.5% copper oxinate 0.5% Victoria green base 30% creosote	0.27 <sup>c</sup> 0.09 9.2	4	6	8 <sup>d</sup>	50	7	12	70 <sup>d,e,f</sup>	100	5	5	90 <sup>d,e</sup>	3	5
0.75% copper oxinate 0.25% Victoria green base 75% creosote	0.25 <sup>c</sup> 0.08 24.7	0	0	3 <sup>d</sup>	--	2	6	85 <sup>d</sup>	--	0	3	8 <sup>d</sup>	0	0

<sup>a</sup>These were accidentally removed in August 1972 and redriven in May 1973.

<sup>b</sup>Agi and Associates.

<sup>c</sup>As metallic copper.

<sup>d</sup>Limnoria.

<sup>e</sup>Martesia.

<sup>f</sup>Teredo.

<sup>g</sup>Pile missing.

<sup>h</sup>Few Limnoria.

Three Yearly Inspections of NCEL-Treated Piles Installed in 1965<sup>a</sup>

Percent Loss of Cross-Sectional Area for--																	
Piling No. 2				Piling No. 3			Piling No. 4				Piling No. 5				Piling No. 6		
1976	1978	1982	1982 <sup>b</sup>	1976	1978	1982	1976	1978	1982 <sup>b</sup>	1982	1976	1978	1982	1982 <sup>b</sup>	1976	1978	1982
0	1	2 <sup>d</sup>	--	1	1	3 <sup>d</sup>	1	5	12 <sup>d,e</sup>	--	1	3	6 <sup>d</sup>	--	0	0	3 <sup>d</sup>
2	4	6 <sup>d</sup>	--	10	20	40 <sup>d,e</sup>	0	0	5 <sup>d,e</sup>	--	3	4	7 <sup>d</sup>	--	0	2	7 <sup>d</sup>
4	12	85 <sup>d,e</sup>	--	2	5	20 <sup>d,e</sup>	0	4	18 <sup>d,e</sup>	--	0	7 <sup>d</sup>	100 <sup>g</sup>	--	3	6	15 <sup>d</sup>
2	5	8 <sup>d,e</sup>	--	0	--	--	0	2	3 <sup>d,e</sup>	--	0	1	8 <sup>d</sup>	--	3	6	9 <sup>d,e</sup>
0	0	2 <sup>h</sup>	--	0	1	4 <sup>e</sup>	0	3	6 <sup>d</sup>	--	0	0	5 <sup>d</sup>	10	0	0	2 <sup>d</sup>
1	1	3 <sup>e</sup>	--	0	0	2 <sup>d</sup>	0	0	2 <sup>d</sup>	--	0	2	4 <sup>d</sup>	--	0	0	2 <sup>d</sup>
7	12	70 <sup>d,e,f</sup>	100	5	5	90 <sup>d,e</sup>	3	5	20 <sup>d</sup>	--	3	7	35 <sup>d,e</sup>	--	5	28	80 <sup>d,e</sup>
2	6	85 <sup>d</sup>	--	0	3	8 <sup>d</sup>	0	0	7 <sup>d</sup>	25	3	6	8 <sup>d,e</sup>	--	7	9	12 <sup>d,e</sup>

by 1973.



Table 7. Summary of Inspections on NCEL-Treated Piles Installed in 1965<sup>a</sup>

Treatment (Solutions in Xylene)	Retention (lb/ft <sup>3</sup> )	No. of Piles	Number of Piles According to Damage Category Attacked in--												
			1976			1978			1982			1982			
			<5%	5-15%	>15%	<5%	5-15%	>15%	<5%	5-15%	>15%	<5%	5-15%	>15%	
4% copper oxinate	0.87 <sup>b</sup>	6	6/6	--	5/6	1/6	1/6	--	2/6	4/6	--	--	--	--	
2% copper oxinate	0.49 <sup>b</sup>	6	5/6	1/6	5/6	1/6	--	1/6	4/6	1/6	--	1/6	--	--	
2% copper oxinate	0.25 <sup>b</sup>	6	6/6	--	1/6	4/6	1/6	1/6	--	--	3/6	3/6	3/6	3/6	
2% tributyltin oxide	0.25		5/5	--	3/5	2/5	--	1/5	3/5	1/5	--	--	--	--	
3% copper oxinate	0.69 <sup>b</sup>	5	6/6	--	6/6	--	--	4/6	2/6	--	--	--	--	--	
1% Victoria green base	0.26	6	3/6	3/6	--	5/6	1/6	1/6	4/6	3/6	--	1/6	4/6	1/6	
5% chlordane	1.3	6	5/6	1/6	5/6	1/6	--	1/6	4/6	3/6	--	1/6	4/6	1/6	
2% tributyltin oxide	0.62		6/6	--	6/6	--	--	4/6	2/6	--	--	--	--	--	
1.5% copper oxinate	0.27 <sup>b</sup>	6	3/6	3/6	--	5/6	1/6	1/6	--	3/6	3/6	--	3/6	--	
0.5% Victoria green base	0.09		6	3/6	3/6	--	5/6	1/6	1/6	--	3/6	3/6	--	3/6	--
50% creosote	9.2	6	5/6	1/6	3/6	3/6	--	1/6	4/6	4/6	--	1/6	4/6	1/6	
0.75% copper oxinate	0.25 <sup>b</sup>	6	5/6	1/6	3/6	3/6	--	1/6	4/6	4/6	--	1/6	4/6	1/6	
0.25% Victoria green base	0.08		6	5/6	1/6	3/6	3/6	--	1/6	4/6	4/6	--	1/6	4/6	1/6
75% creosote	24.7		6	5/6	1/6	3/6	3/6	--	1/6	4/6	4/6	--	1/6	4/6	1/6

<sup>a</sup>These piles were accidentally pulled in August 1972 and redriven in May 1973.

<sup>b</sup>As metallic copper.

Table 8. Results of Inspections of NCEL- and Industry-Treated P

Treatment	Retention (lb/ft <sup>3</sup> )	Percent Loss of Cross-Section												
		Piling No. 1				Piling No. 2				Piling No. 3				
		1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976
Chromated copper arsenate, Type B	0.50	89	100 <sup>c,d</sup>	100 <sup>e</sup>	--	82	100 <sup>c,f</sup>	100 <sup>e</sup>	--	2	6	70 <sup>c,f</sup>	--	100
Basic zinc sulfate	2.77	0	2	4 <sup>c</sup>	--	0	0	2 <sup>c</sup>	--	2	2	2 <sup>c</sup>	25-50	0
Ammoniacal copper arsenite	0.51	0	1	8 <sup>c,f</sup>	25-50	2	2	30 <sup>c,f</sup>	75-100	0	4	11 <sup>c</sup>	50-75	1
Chromated copper arsenate, Type B	0.50	0	0	3 <sup>c</sup>	10	0	0	7 <sup>c</sup>	--	3	5	10 <sup>c</sup>	10	0
Tributyltin oxide	0.13													
Basic zinc sulfate	2.66	0	0	0 <sup>c</sup>	0	0	0	0	10	0	0	2 <sup>c</sup>	--	0
Tributyltin oxide	0.09													
Ammoniacal copper arsenite	0.51	0	0	3 <sup>f</sup>	--	0	2	3 <sup>c</sup>	0	0	1	2 <sup>c</sup>	10	0
Tributyltin oxide	0.11													
70-30 creosote-coal tar	31.7	0	0	7 <sup>c</sup>	--	7	15	40 <sup>c,f</sup>	50-75	0	0	2 <sup>c</sup>	10	0
Ammoniacal copper arsenite	0.51	0	0	2 <sup>g</sup>	--	0	0	2 <sup>g</sup>	--	0	1	2	--	0
70-30 creosote-coal tar	19.6													
Copper sulfate	0.06 <sup>b</sup>	6	18	95 <sup>c,f</sup>	100	4	7	10 <sup>c,f</sup>	--	3	7	40 <sup>c</sup>	50-75	3
Tributyltin oxide	0.19													
Copper sulfate	0.03 <sup>b</sup>	3	7	15 <sup>c</sup>	--	2	5	40 <sup>c,d</sup>	--	0	3	4 <sup>c</sup>	--	88
Tributyltin oxide	0.20													

<sup>a</sup> Agi and Associates.

<sup>b</sup> As metallic copper.

<sup>c</sup> Limnoria.

<sup>d</sup> Teredo.

<sup>e</sup> Pile missing.

<sup>f</sup> Martesia.

<sup>g</sup> Few Limnoria.

of NCEL- and Industry-Treated Piles Installed in 1966

Percent Loss of Cross-Sectional Area for--																
Piling No. 3				Piling No. 4				Piling No. 5				Piling No. 6				
1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1978	1982	1982 <sup>a</sup>	1976	1977	1982	1982 <sup>a</sup>
--	2	6	70 <sup>c,f</sup>	--	100	100 <sup>c</sup>	100 <sup>e</sup>	--	38	100 <sup>c,d,f</sup>	100 <sup>e</sup>	--	2	3	7 <sup>f</sup>	--
--	2	2	2 <sup>c</sup>	25-50	0	1	2 <sup>c</sup>	10	1	3	4 <sup>c</sup>	--	0	2	7 <sup>c,f</sup>	--
75-100	0	4	11 <sup>c</sup>	50-75	1	2	5 <sup>c,f</sup>	--	1	4	7 <sup>c,f</sup>	--	1	4	18 <sup>c,f</sup>	0-25
--	3	5	10 <sup>c</sup>	10	0	1	10 <sup>c</sup>	0-25	0	1	4 <sup>c,f</sup>	--	1	4	5 <sup>c</sup>	--
10	0	0	2 <sup>c</sup>	--	0	0	2 <sup>c</sup>	--	0	0	1 <sup>c</sup>	--	0	1	3 <sup>c</sup>	0-25
0	0	1	2 <sup>c</sup>	10	0	0	0	--	0	0	2 <sup>c</sup>	0	0	3	4 <sup>c</sup>	10
50-75	0	0	2 <sup>c</sup>	10	0	3	3 <sup>c</sup>	0	0	4	10 <sup>c</sup>	--	0	1	2 <sup>c</sup>	--
--	0	1	2	--	0	0	2	--	0	0	0	--	0	0	2	--
--	3	7	40 <sup>c</sup>	50-75	3	3	10 <sup>c,d</sup>	10-25	0	2	40 <sup>c</sup>	--	3	6	45 <sup>c</sup>	100
--	0	3	4 <sup>c</sup>	--	88	98 <sup>c</sup>	100 <sup>e</sup>	100	1	1	12 <sup>c</sup>	--	16	90	100 <sup>c,f</sup>	100

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Table 9. Summary of Inspection Results on NCEL- and Industry-Treated Piles Installed in 1966

Treatment	Retention (lb/ft <sup>3</sup> )	Number of Piles According to Damage Category Attacked in--											
		1976				1978				1982			
		<5%	5-15%	15-50%	>50%	<5%	5-15%	15-50%	>50%	<5%	5-15%	15-50%	>50%
Chromated copper arsenate, Type B	0.50	2/6	--	1/6	3/6	1/6	1/6	--	4/6	--	1/5	--	5/6
Basic zinc sulfate	2.77	6/6	--	--	--	6/6	--	--	--	--	2/6	--	--
Ammoniacal copper arsenite	0.51	6/6	--	--	--	6/6	--	--	--	--	4/6	2/6	--
Chromated copper arsenate, Type B	0.50	6/6	--	--	--	5/6	1/6	--	--	2/6	4/6	--	--
Tributyltin oxide	0.13												
Basic zinc sulfate	2.66	6/6	--	--	--	6/6	--	--	--	6/6	--	--	--
Tributyltin oxide	0.09												
Ammoniacal copper arsenite	0.51	6/6	--	--	--	6/6	--	--	--	6/6	--	--	--
Tributyltin oxide	0.11												
70-30 creosote-coal tar	31.7	5/6	1/6	--	--	5/6	1/6	--	--	3/6	2/6	1/6	--
Ammoniacal copper arsenite	0.51	6/6	--	--	--	6/6	--	--	--	6/6	--	--	--
70-30 creosote-coal tar	19.6												
Copper sulfate	0.06 <sup>a</sup>	5/6	1/6	--	--	2/6	3/6	1/6	--	--	2/6	3/6	1/6
Tributyltin oxide	0.19												
Copper sulfate	0.03 <sup>a</sup>	4/6	--	1/6	1/6	2/6	2/6	--	2/6	1/6	1/6	2/6	2/6
Tributyltin oxide	0.20												

<sup>a</sup>As metallic copper.

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ARMY ARRADCOM, Dover, NJ; BMDSC-RE (H. McClellan) Huntsville AL; Contracts - Facs Engr  
Directorate, Fort Ord, CA; DAEN-CWE-M, Washington DC; DAEN-MPE-D Washington DC;  
DAEN-MPO-U, Washington, DC; DAEN-MPU, Washington DC; ERADCOM Tech Supp Dir. (DELS-D)  
Ft. Monmouth, NJ; Tech. Ref. Div., Fort Huachuca, AZ  
ARMY - CERL Library, Champaign IL  
ARMY COASTAL ENGR RSCH CEN Fort Belvoir VA; R. Jachowski, Fort Belvoir VA  
ARMY COE Philadelphia Dist. (LIBRARY) Philadelphia, PA  
ARMY CORPS OF ENGINEERS Fac Engr Supp Agency, Ft. Belvoir, VA; MRD-Eng. Div., Omaha NE;  
Seattle Dist. Library, Seattle WA  
ARMY CRREL R.A. Eaton  
ARMY DARCOM Code DRCMM-CS Alexandria VA  
ARMY ENG DIV HNDED-CS, Huntsville AL; HNDED-FD, Huntsville, AL  
ARMY ENG WATERWAYS EXP STA Library, Vicksburg MS  
ARMY ENGR DIST. Library, Portland OR  
ARMY ENVIRON. HYGIENE AGCY HSE-EW Water Qual Eng Div Aberdeen Prov Grnd MD  
ARMY MATERIALS & MECHANICS RESEARCH CENTER Dr. Lenoe, Watertown MA  
ARMY MTMC Trans Engr Agency MTT-CE, Newport News, VA  
ARMY-DEPOT SYS COMMAND DRSDS-AI Chambersburg, PA  
BUREAU OF RECLAMATION Code 1512 (C. Selander) Denver CO  
CINCPAC Fac Engrng Div (J44) Makalapa, HI  
CNAVRES Code 13 (Dir. Facilities) New Orleans, LA  
CNM Code MAT-08E, Washington, DC; NMAT - 044, Washington DC  
CNO Code NOP-964, Washington DC; OP-098, Washington, DC; OP987J, Washington, DC  
COMCBPAC Operations Off, Makalapa HI  
COMFLEACT, OKINAWA PWD - Engr Div, Sasebo, Japan; PWO, Kadena, Okinawa; PWO, Sasebo, Japan  
COMNAVAIRLANT NUC Wpns Sec Offr Norfolk, VA  
COMOCEANSYSLANT PW-FAC MGMNT Off Norfolk, VA  
COMOCEANSYSPAC SCE, Pearl Harbor HI  
DEFFUELSUPPCEN DFSC-OWE (Term Engrng) Alexandria, VA; DFSC-OWE, Alexandria VA  
DOE Div Ocean Energy Sys Cons/Solar Energy Wash DC  
DTIC Defense Technical Info Ctr/Alexandria, VA  
DTNSRDC Anna Lab, Code 4121 (R A Rivers) Annapolis, MD  
DTNSRDC Code 172 (M. Krenzke), Bethesda MD  
DTNSRDC Code 284 (A. Rufolo), Annapolis MD  
DTNSRDC Code 4111 (R. Gierich), Bethesda MD; Code 42, Bethesda MD  
FLTCOMBATRACENLANT PWO, Virginia Bch VA  
FMFLANT CEC Offr, Norfolk VA  
GDEP OIC, Corona, CA  
GSA Assist Comm Des & Cnst (FAIA) D R Dibner Washington, DC  
KWAJALEIN MISRAN BMDSC-RKL-C  
LIBRARY OF CONGRESS Washington, DC (Sciences & Tech Div)  
MARINE CORPS BASE Code 406, Camp Lejeune, NC; M & R Division, Camp Lejeune NC; Maint Off Camp  
Pendleton, CA; PWD - Maint. Control Div, Camp Butler, Kawasaki, Japan; PWO Camp Lejeune NC;  
PWO, Camp Pendleton CA; PWO, Camp S. D. Butler, Kawasaki Japan  
MARINE CORPS HQS Code LFF-2, Washington DC  
MCAS Facil. Engr. Div, Cherry Point NC; CO, Kaneohe Bay HI; Code S4, Quantico VA; Facs Maint Dept -  
Operations Div, Cherry Point; PWD - Utilities Div, Iwakuni, Japan; PWD, Dir. Maint. Control Div.,  
Iwakuni Japan; PWO, Iwakuni, Japan; PWO, Yuma AZ  
MCDEC M&L Div Quantico VA  
MCRD SCE, San Diego CA  
NAF PWD - Engr Div, Atsugi, Japan; PWO, Atsugi Japan  
NALF OINC, San Diego, CA  
NARF Code 100, Cherry Point, NC; Code 640, Pensacola FL; Equipment Engineering Division (Code 61000),  
Pensacola, FL; SCE Norfolk, VA

NAS CO, Guantanamo Bay Cuba; Code 114, Alameda CA; Code 183 (Fac. Plan BR MGR); Code 18700,  
 Brunswick ME; Code 18U (ENS P.J. Hickey), Corpus Christi TX; Code 6234 (G. Trask), Point Mugu CA;  
 Code 70, Atlanta, Marietta GA; Code 8E, Patuxent Riv., MD; Dir of Engrng. PWD, Corpus Christi, TX;  
 Dir. Maint. Control Div., Key West FL; Dir. Util. Div., Bermuda; Lakehurst, NJ; Lead. Chief. Petty Offr.  
 PW.Self Help Div. Beeville TX; OIC, CBU 417, Oak Harbor WA; PW (J. Maguire), Corpus Christi TX;  
 PWD - Engr Div Dir. Millington, TN; PWD - Engr Div. Gtmo. Cuba; PWD - Engr Div. Oak Harbor, WA;  
 PWD Maint. Cont. Dir., Fallon NV; PWD Maint. Div., New Orleans, Belle Chasse LA; PWD, Code 1821H  
 (Pfankuch) Miramar, SD CA; PWD, Maintenance Control Dir., Bermuda; PWD, Willow Grove PA; PWO  
 Belle Chasse, LA; PWO Chase Field Beeville, TX; PWO Key West FL; PWO Lakehurst, NJ; PWO Sigonella  
 Sicily; PWO, Dallas TX; PWO, Glenview IL; PWO, Kingsville TX; PWO, Millington TN; PWO, Miramar,  
 San Diego CA; PWO., Moffett Field CA; SCE Norfolk, VA; SCE, Barbers Point HI; SCE, Cubi Point, R.P;  
 Security Offr. Alameda CA  
 NASDC-WDC T. Fry, Manassas VA  
 NATL BUREAU OF STANDARDS B-348 BR (Dr. Campbell), Washington DC  
 NATL RESEARCH COUNCIL Naval Studies Board, Washington DC  
 NAVACT PWO, London UK  
 NAVACTDET PWO, Holy Lock UK  
 NAVAEROSPREGMEDCEN SCE, Pensacola FL  
 NAVAIRDEVCEEN Code 813, Warminster PA  
 NAVAIRPROTESTCEN CO, Trenton, NJ  
 NAVAIRTESTCEN PATUXENT RIVER PWD (F. McGrath), Patuxent Riv.,MD  
 NAVAVIONICFAC PW Div Indianapolis, IN; PWD Deputy Dir. D/701, Indianapolis, IN  
 NAVAVNWPNSFAC Wpns Offr, St. Mawgan, England  
 NAVCHAPGRU Engineering Officer, Code 60 Williamsburg, VA  
 NAVCOASTSYSCEN Code 423 Panama City, FL; Code 715 (J Quirk) Panama City, FL; Code 715 (J.  
 Mittleman) Panama City, FL; Library Panama City, FL; PWO Panama City, FL  
 NAVCOMMAREAMSTRSTA Code W-60, Elec Engr. Wahiawa, HI; PWO, Norfolk VA; SCE Unit 1 Naples  
 Italy; SCE, Wahiawa HI  
 NAVCOMMSTA Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWO, Exmouth,  
 Australia; SCE, Balboa, CZ  
 NAVCONSTRACEN Curriculum/Instr. Stds Offr, Gulfport MS  
 NAVEDTRAPRODEVCEEN Technical Library, Pensacola, FL  
 NAVEDUTRACEN Engr Dept (Code 42) Newport, RI  
 NAVENVIRHLTHCEN CO, NAVSTA Norfolk, VA  
 NAVEODTECHCEN Code 605, Indian Head MD  
 NAVFAC PWO, Centerville Bch, Ferndale CA; PWO, Point Sur, Big Sur CA  
 NAVFACENGCOM Alexandria, VA; Code 03 Alexandria, VA; Code 03T (Essoglou) Alexandria, VA; Code  
 043 Alexandria, VA; Code 0453 (D. Potter) Alexandria, VA; Code 0453C, Alexandria, VA; Code 0454B  
 Alexandria, VA; Code 046; Code 0461D (V M Spaulding) Alexandria, VA; Code 04A1 Alexandria, VA;  
 Code 04B3 Alexandria, VA; Code 051A Alexandria, VA; Code 09M54, Tech Lib, Alexandria, VA; Code  
 100 Alexandria, VA; Code 1002B (J. Leimanis) Alexandria, VA; Code 1113, Alexandria, VA; Code 461D,  
 Alexandria, VA  
 NAVFACENGCOM - CHES DIV, Code 101 Wash, DC; Code 403 Washington DC; Code 405 Wash, DC; Code  
 407 (D Scheesele) Washington, DC; Code FPO-1C Washington DC; Contracts, ROICC, Annapolis MD;  
 FPO-1 Washington, DC; FPO-1EA5 Washington DC; Library, Washington, D.C.  
 NAVFACENGCOM - LANT DIV, Code 403, Norfolk, VA; Eur. BR Deputy Dir, Naples Italy; Library,  
 Norfolk, VA; RDT&ELO 102A, Norfolk, VA  
 NAVFACENGCOM - NORTH DIV, CO; Code 04 Philadelphia, PA; Code 09P Philadelphia PA; Code 111  
 Philadelphia, PA; Code 405 Philadelphia, PA; Code 04AL, Philadelphia PA; ROICC, Contracts, Crane IN  
 NAVFACENGCOM - PAC DIV, (Ky) Code 101, Pearl Harbor, HI; CODE 09P PEARL HARBOR HI; Code  
 2011 Pearl Harbor, HI; Code 402, RDT&E, Pearl Harbor HI; Commander, Pearl Harbor, HI; Library,  
 Pearl Harbor, HI  
 NAVFACENGCOM - SOUTH DIV, Code 405 Charleston, SC; Code 411 Soil Mech & Paving BR Charleston,  
 SC; Code 90, RDT&ELO, Charleston SC; Library, Charleston, SC  
 NAVFACENGCOM - WEST DIV, 102; AROICC, Contracts, Twentynine Palms CA; Code 04B San Bruno,  
 CA; Library, San Bruno, CA; 09P/20 San Bruno, CA; RDT&ELO Code 2011 San Bruno, CA  
 NAVFACENGCOM CONTRACTS AROICC, NAVSTA Brooklyn, NY; AROICC, Quantico, VA; Colts Neck,  
 NJ; Contracts, AROICC, Lemoore CA; Dir, Eng. Div., Exmouth, Australia; Eng Div dir, Southwest Pac,  
 Manila, PI; NAS, Jacksonville, FL; OICC, Southwest Pac, Manila, PI; OICC-ROICC, NAS Oceana,  
 Virginia Beach, VA; OICC/ROICC, Balboa Panama Canal; OICC/ROICC, Norfolk, VA; ROICC AF Guam;  
 ROICC Code 495 Portsmouth VA; ROICC Key West FL; ROICC MCAS El Toro; ROICC Rota Spain;  
 ROICC, Diego Garcia Island; ROICC, Keflavik, Iceland; ROICC, NAS, Corpus Christi, TX; ROICC,  
 Pacific, San Bruno CA; ROICC, Point Mugu, CA; ROICC, Yap; ROICC-OICC-SPA, Norfolk, VA  
 NAVMAG PWD - Engr Div, Guam; SCE, Guam; SCE, Subic Bay, R.P.  
 NAVOCEANO Code 3432 (J. DePalma), Bay St. Louis MS; Library Bay St. Louis, MS

NAVOCEANSYSCEN Code 09 (Talkington), San Diego, CA; Code 4473 Bayside Library, San Diego, CA;  
 Code 4473B (Tech Lib) San Diego, CA; Code 5221 (R.Jones) San Diego Ca; Code 6700, San Diego, CA  
 NAVORDMISTESTFAC PWD - Engr Dir, White Sands, NM  
 NAVORDSTA PWO, Louisville KY  
 NAVPETOFF Code 30, Alexandria VA  
 NAVPHIBASE CO, ACB 2 Norfolk, VA; Code S3T, Norfolk VA; Harbor Clearance Unit Two, Little Creek,  
 VA; SCE Coronado, SD,CA  
 NAVRADREFAC PWO, Kami Seya Japan  
 NAVREGMEDCEN Code 3041, Memphis, Millington TN; PWD - Engr Div, Camp Lejeune, NC; PWO  
 Portsmouth, VA; PWO, Camp Lejeune, NC  
 NAVREGMEDCEN PWO, Okinawa, Japan  
 NAVREGMEDCEN SCE; SCE San Diego, CA; SCE, Camp Pendleton CA; SCE, Guam; SCE, Newport, RI;  
 SCE, Oakland CA  
 NAVREGMEDCEN SCE, Yokosuka, Japan  
 NAVSCOLCECOFF C35 Port Hueneme, CA; CO, Code C44A Port Hueneme, CA  
 NAVSCSOL PWO, Athens GA  
 NAVSEASYSCOM Code 05E1, Wash, DC; SEA05E1, Washington, D.C.  
 NAVSECGRUACT Facil. Off., Galeta Is, Panama Canal; PWO, Adak AK; PWO, Edzell Scotland; PWO,  
 Puerto Rico; PWO, Torri Sta, Okinawa  
 NAVSECSTA PWD - Engr Div, Wash., DC  
 NAVSHIPREFAC Library, Guam; SCE Subic Bay  
 NAVSHIPYD Bremerton, WA (Carr Inlet Acoustic Range); Code 134, Pearl Harbor, HI; Code 202.4, Long  
 Beach CA; Code 202.5 (Library) Puget Sound, Bremerton WA; Code 380, Portsmouth, VA; Code 382.3,  
 Pearl Harbor, HI; Code 400, Puget Sound; Code 410, Mare Is., Vallejo CA; Code 440 Portsmouth NH;  
 Code 440, Norfolk; Code 440, Puget Sound, Bremerton WA; Commander, Philadelphia, PA; L.D. Vivian;  
 Library, Portsmouth NH; PWD (Code 420) Dir Portsmouth, VA; PWD (Code 450-HD) Portsmouth, VA;  
 PWD (Code 457-HD) Shop 07, Portsmouth, VA; PWD (Code 460) Portsmouth, VA; PWO, Bremerton, WA;  
 PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI; Tech Library, Vallejo, CA  
 NAVSTA CO Roosevelt Roads P.R. Puerto Rico; CO, Brooklyn NY; Code 4, 12 Marine Corps Dist, Treasure  
 Is., San Francisco CA; Dir Engr Div, PWD, Mayport FL; Dir Mech Engr 37WC93 Norfolk, VA; Engr. Dir.,  
 Rota Spain; Long Beach, CA; Maint. Cont. Div., Guantanamo Bay Cuba; PWD (LTJG.P.M. Motolenich),  
 Puerto Rico; PWD - Engr Dept, Adak, AK; PWD - Engr Div, Midway Is.; PWO, Guantanamo Bay Cuba;  
 PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam; SCE, Pearl Harbor HI; SCE, San Diego CA; SCE,  
 Subic Bay, R.P.; Utilities Engr Off, Rota Spain  
 NAVSUBASE Code 23 (Slowey) Bremerton, WA; SCE, Pearl Harbor HI  
 NAVSUPPACT PWO Naples Italy  
 NAVSUPPFAC PWD - Maint. Control Div, Thurmont, MD  
 NAVSURFWPCEN PWO, White Oak, Silver Spring, MD  
 NAVTECHTRACEN SCE, Pensacola FL  
 NAVWPNCEN Code 2636 China Lake; Code 3803 China Lake, CA; PWO (Code 266) China Lake, CA; ROICC  
 (Code 702), China Lake CA  
 NAVWPNSTA (Clebak) Colts Neck, NJ; Code 092, Colts Neck NJ; Code 092, Concord CA; Maint. Control  
 Dir., Yorktown VA  
 NAVWPNSTA PW Office Yorktown, VA  
 NAVWPNSTA PWD - Maint. Control Div., Concord, CA; PWD - Supr Gen Engr, Seal Beach, CA; PWO,  
 Charleston, SC; PWO, Seal Beach CA  
 NAVWPNSUPPCEN Code 09 Crane IN  
 NCBU 405 OIC, San Diego, CA  
 NCTC Const. Elec. School, Port Hueneme, CA  
 NCBC Code 10 Davisville, RI; Code 15, Port Hueneme CA; Code 155, Port Hueneme CA; Code 156, Port  
 Hueneme, CA; Code 400, Gulfport MS; Code 430 (PW Engrng) Gulfport, MS; PWO (Code 80) Port  
 Hueneme, CA; PWO, Davisville RI; PWO, Gulfport, MS  
 NCBU 411 OIC, Norfolk VA  
 NCR 20, Code R70; 20, Commander  
 NMCB 74, CO; FIVE, Operations Dept; Forty, CO; THREE, Operations Off.  
 NOAA Library Rockville, MD  
 NORDA Code 440 (Ocean Rsch Off) Bay St. Louis MS  
 NRL Code 5800 Washington, DC; Code 8441 (R.A. Skop), Washington DC  
 NROTC J.W. Stephenson, UC, Berkeley, CA  
 NSC Code 54.1 Norfolk, VA  
 NSD SCE, Subic Bay, R.P.  
 NTC OICC, CBU-401, Great Lakes IL  
 NUSC Code EA123 (R.S. Munn), New London CT; Code TA131 (G. De la Cruz), New London CT  
 OFFICE SECRETARY OF DEFENSE OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC  
 ONR Central Regional Office, Boston, MA; Code 485 (Silva) Arlington, VA; Code 700F Arlington VA  
 PACMISRANFAC HI Area Bkg Sands, PWO Kekaha, Kauai, HI

PHIBCB 1 P&E, San Diego, CA  
 PWC ACE Office Norfolk, VA; CO Norfolk, VA; CO, (Code 10), Oakland, CA; CO, Great Lakes IL; CO, Pearl Harbor HI; Code 10, Great Lakes, IL; Code 105 Oakland, CA; Code 110, Oakland, CA; Code 120, Oakland CA; Code 128, Guam; Code 154 (Library), Great Lakes, IL; Code 200, Great Lakes IL; Code 200, Guam; Code 400, Great Lakes, IL; Code 400, Oakland, CA; Code 400, Pearl Harbor, HI; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code 424, Norfolk, VA; Code 500 Norfolk, VA; Code 505A Oakland, CA; Code 600, Great Lakes, IL; Code 610, San Diego Ca; Code 700, Great Lakes, IL; Code 700, San Diego, CA; Library, Code 120C, San Diego, CA; Library, Pensacola, FL; Library, Guam; Library, Norfolk, VA; Library, Oakland, CA; Library, Pearl Harbor, HI; Library, Subic Bay, R.P.; Library, Yokosuka JA; Utilities Officer, Guam  
 SPC PWO (Code 120) Mechanicsburg PA  
 SUPANX PWO, Williamsburg VA  
 TVA Smelser, Knoxville, Tenn.; Solar Group, Arnold, Knoxville, TN  
 UCT ONE OIC, Norfolk, VA  
 UCT TWO OIC, Port Hueneme CA  
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 USAF SCHOOL OF AEROSPACE MEDICINE Hyperbaric Medicine Div, Brooks AFB, TX  
 USCG (Smith), Washington, DC; G-EOE-4 (T Dowd), Washington, DC  
 USDA Forest Products Lab, Madison WI; Forest Products Lab. (R. DeGroot), Madison WI; Forest Service Reg 3 (R. Brown) Albuquerque, NM; Forest Service, Bowers, Atlanta, GA  
 USNA ENGRNG Div, PWD, Annapolis MD; PWO Annapolis MD; USNA/SYS ENG DEPT ANNAPOLIS MD  
 USS FULTON WPNS Rep. Offr (W-3) New York, NY  
 WATER & POWER RESOURCES SERVICE (Smoak) Denver, CO  
 AMERICAN CONCRETE INSTITUTE Detroit MI (Library)  
 BERKELEY PW Engr Div, Harrison, Berkeley, CA  
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 CALIF. MARITIME ACADEMY Vallejo, CA (Library)  
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 DAMES & MOORE LIBRARY LOS ANGELES, CA  
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 UNIVERSITY OF DELAWARE (Dr. S. Dexter) Lewes, DE  
 FLORIDA ATLANTIC UNIVERSITY Boca Raton FL (W. Hartt); Boca Raton, FL (McAllister)  
 HARVARD UNIV. Dept. of Architecture, Dr. Kim, Cambridge, MA  
 INSTITUTE OF MARINE SCIENCES Morehead City NC (Director)  
 WOODS HOLE OCEANOGRAPHIC INST. Woods Hole MA (Winget)  
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 MAINE MARITIME ACADEMY CASTINE, ME (LIBRARY)  
 MICHIGAN TECHNOLOGICAL UNIVERSITY Houghton, MI (Haas)  
 MIT Cambridge MA; Cambridge MA (Rm 10-500, Tech. Reports, Engr. Lib.)  
 NATL ACADEMY OF ENG. ALEXANDRIA, VA (SEARLE, JR.)  
 NATURAL ENERGY LAB Library, Honolulu, HI  
 NEW MEXICO SOLAR ENERGY INST. Dr. Zwibel Las Cruces NM  
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 SCRIPPS INSTITUTE OF OCEANOGRAPHY LA JOLLA, CA (ADAMS); San Diego, CA (Marina Phy. Lab. Spiess)  
 SEATTLE U Prof Schwaegler Seattle WA  
 SOUTHWEST RSCH INST R. DeHart San Antonio TX  
 STATE UNIV. OF NEW YORK Buffalo, NY  
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 DOBROWOLSKI, J.A. Altadena, CA  
 ERVIN, DOUG Belmont, CA  
 GERWICK, BEN C. JR San Francisco, CA

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