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FIRST ANNUAL INSPECTION OF BUZZARDS BAY PILINGS

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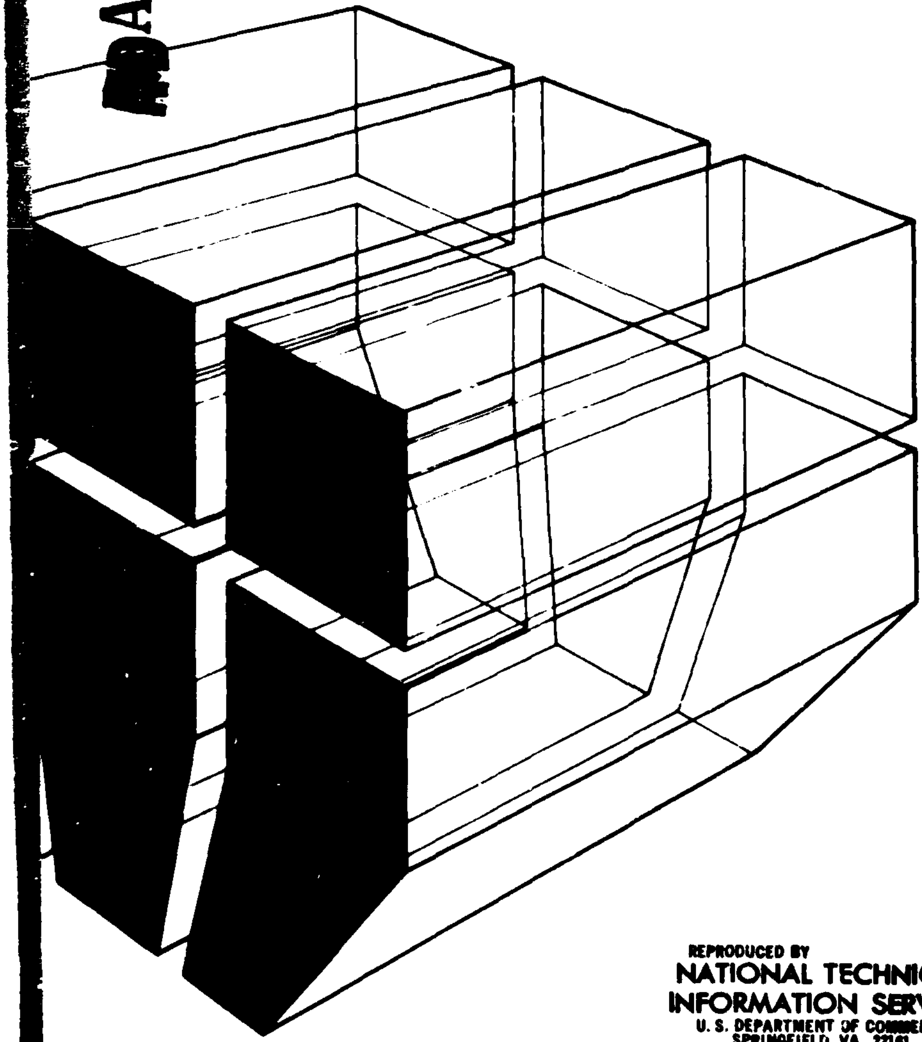

by
A. Kumar
C. Hahin

CERL

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This report presents the results of part of a study being conducted to determine the amount of coating deterioration on pilings in coastal areas. The 15-year study will consider the effects of sacrificial cathodic protection, temperature, and geography on coating deterioration in seawater. Results will be used to optimize coating selection.

The first annual inspection of the pilings at Buzzards Bay, MA, was conducted from 24 to 28 July 1975. The inspection consisted of a visual

evaluation of the piles and electrical measurements of the cathodic protection indices and corrosion potentials of the piles. The piles have developed slight biofouling in the tidal zone. Light guano covers the top 5 to 6 ft (1.5 to 1.8 m) of the pilings.

Visual inspection of the piling areas above the water determined that all the piles had a rating of 10 according to ASTM G10-68 standards. Only one coating, system #12, suffered installation damage. The top coat of system #12, epoxy over organic ceramic, flaked off during installation, but no bare steel was observed under the top coat; the remaining two coats were intact. Electrical measurements of cathodic protection indices showed that the pilings had good coatings. All piles with sacrificial anodes showed adequate protecting potentials.

FOREWORD

The inspection of pilings at Buzzards Bay, MA was conducted by the Metallurgy Branch, Materials Systems and Science Division (MS), Construction Engineering Research Laboratory (CERL) for the Directorate of Civil Works, Office of the Chief of Engineers (OCE). The work was performed under CWIS 31204 "Corrosion Mitigation in Civil Works Projects." Mr. J. Robertson is the OCE Technical Monitor.

The CERL inspection team consisted of R. Quattrone, A. Kumar, C. Hahin, F. Kisters, and J. Aleszka. The visual inspection was conducted by A. Kumar and the electrical measurements were taken by C. Hahin. Dr. A. Kumar is Acting Chief of the Metallurgy Branch. Dr. G. Williamson is Acting Chief of MS. COL M. D. Remus is Commander and Director of CERL and Dr. L. R. Shaffer is Deputy Director.

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FIRST ANNUAL INSPECTION OF BUZZARDS BAY PILINGS

1 INTRODUCTION

Background

The Directorate of Civil Works, Office of the Chief of Engineers, has jurisdiction over many structures, such as harbors, bridges, and buildings, which are supported on pilings in coastal areas. The design life of these structures can range from a few years to 100 years. Steel pipe and H-pilings have generally been used for foundations in coastal areas; more recently, prestressed concrete pilings have found extensive application.

Several types of protective coatings are available for the pilings. For steel pipe and H-pilings, vinyl paints have been shown to perform outstandingly in fresh water applications. In brackish or salt water applications, where the life of even the best available coatings is generally limited, cathodic protection is used. In addition, the chemical industry is continually developing new coatings for which vendors claim superior performance. Some newer coatings such as glass phenolic, though expensive, have potential for application in seawater. Also, zinc-rich primers have been useful for improving the performance of coatings.

Nondestructive electrical measurement techniques capable of predicting long-life (50-year) performance based on shorter duration tests are extremely useful for rapid screening of these newly developed coatings and primers. However, such tests performed in the laboratory, though indicative of coating performance, are not reliable. Field tests at various geographical locations are necessary because marine biofouling is an important parameter which cannot easily be simulated in the laboratory.

In response to this problem, the U. S. Army Corps of Engineers and the National Bureau of Standards (NBS) initiated a study of piling corrosion in 1967, when 31 sets of piles (three identical piles per set) were installed near Dam Neck, VA. Every 5 years, one row of pilings was to be extracted and examined for corrosion damage. To determine the effect of geography and temperature, two more sites (LaCosta Island, FL and Buzzards Bay, MA) were selected by the Coastal Engineering Research Laboratory (CERC), which evaluated the pilings through June 1974, when the inspection responsibility was transferred to the U.S. Army Construction Engineering Research Laboratory (CERL). The installation of 31 sets of three rows of piles at LaCosta Island was completed in January 1971, and annual inspections have been conducted since then. CERL was responsible for installation of the pilings at Buzzards Bay in October 1974, and conducted the first annual inspection in July 1975.

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Objective

The objective of this study was to determine the amount of coating deterioration with and without sacrificial cathodic protection after 15 years in seawater. This report covers the first annual inspection which determined deterioration after 9 months in seawater. Once the life of each coated pile in seawater is known, coating selection for a saline environment can be optimized.

2 APPROACH

General

Figure 1 shows the location of the Buzzards Bay test site; the installation arrangement is shown in Figure 2. Three rows of 24 steel piles were installed. The piles are made of either ASTM A-36 or ASTM 690 (Mariner Steel) (Table 1). The steel H-piles are 8 in. X 8 in. X 40 ft (20.32 cm X 20.32 cm X 12.19 m) and weigh 36 lb/ft (54 kg/m). Eight prestressed concrete pilings were also installed farther from tne Stoney Point Dike.

Some piles were installed without any coating or sacrificial anodes, while others have both coatings and cathodic protection. Most of the protective coating systems included in the Buzzards Bay test site are the same as those at the Dam Neck and LaCosta Island sites. The systems include organic coatings, metallic coatings, and zinc-rich primers with top coats. The organic coatings include coal tar epoxies, saran, vinyl, phenolic mastic, epoxy polyamide, epoxy over inorganic ceramic, and polyester over glass flake. Metallic coatings include flame-sprayed aluminum and zinc with and without organic top coats. (See Table 1 for a complete list of coatings and their sources.) The coatings were applied after sand blasting the base metal to "near white metal" according to Steel Structures Painting Council Specification SSPC-SP-10-63T.

The steel pilings form three rows designated A, B, and C. Row A piles are completely coated, row C piles are coated except for the lower 15 ft (4.57 m). Row B piles are coated except for uncoated areas covered by clear acrylic plastic windows, as shown in Figures 3 and 4. The piles are identified by raised weld bead numbers near the top. Row B is nearest the beach and row E, which contains the concrete pilings is farthest from the beach (Figure 5). Stainless steel rods are welded between the inside flanges of each pile so that electrical contact can be made for electrochemical measurements. The detailed section of the anode mounting is shown in Figure 6.

Inspection

Each 40-ft (12.19 m) length of piling can be divided into five zones: the buried zone (0 to 15 ft or 0 to 4.57 m), sand zone (15 to 17 ft or 4.57 to 5.18 m), immersion zone (17 to 27 ft or 5.18 to 8.23 m), tidal zone (27 to 31 ft or 8.23 to 9.45 m), and atmospheric zone (31 to 40 ft or 9.45 to 12.15 m). The pilings could be visually inspected only in the tidal and atmospheric zones, which are not under water. The inspection consisted of observations of coating deterioration in accordance with ASTM D 610-68 standard methods for evaluating paint coatings. The upper 5 to 6 ft (1.52 to 1.83 m) of the piles were coated with cormorant guano which was light enough not to obscure observations. The tidal zone was covered with marine biofouling, such as barnacles. Since the piles had been in the ocean for only 9 months, barnacle growth was still in its infancy.

Coatings are seldom perfect. They may contain pinholes not visible to the eye, and only when these pinholes become larger do corrosion products such as rust become visible. Thus, visual inspection must be supplemented by another measure of coating performance. One such measure is the cathodic protection index (CPI), which is the inverse of the amount of current required to shift the potential of the metal in a negative direction (referred to as cathodic polarization).

Both the undisturbed potential and change of potential caused by the application of current were monitored for each pile. Electrical contact to the piles via the stainless steel rods above the water surface was made with the help of vise clamps connected to a three-wire cable. Pile potential measurements were also made on the piles which had sacrificial cathodic protection. The current was passed between each test pile and an auxiliary pile for 5 minutes. A Miller Model M-3-M Multimeter was used to measure the potential with respect to a copper-copper sulfate half-cell buried in the water near the beach. The CPI on rows A, B, and C was measured by noting the current required to shift the potential of the pile to -0.85 V from its freely corroding potential with respect to the reference electrode. The CPI is defined as the ratio of ΔV to ΔI. The circuit for CPI measurement (Figure 7) consisted of a 12-V battery which was used to supply the driving voltage through a series of variable resistors. The current was measured by an ammeter connected in series with the battery.

3 DISCUSSION OF RESULTS

General

Corrosion problems encountered in the Buzzards Bay pilings were most severe in the tidal and sand zones. Alternate air and water immersion prevents adherence of corrosion products in the tidal zone, whereas erosion-corrosion leads to pronounced corrosion in the sand zone. Erosion-corrosion is the acceleration in the attack on a metal due to the movement between an abrasive sand slurry-fluid and the metal surface. The corroding metal forms solid corrosion products which are swept away, revealing fresh substrate for further corrosion.

Visual Observation

Since cormorants use the pilings as resting posts, the top 5 to 6 ft (1.52 to 1.83 m) were partially covered with guano. Since the pilings had been in the ocean for only 9 months, the coatings did not show any deterioration. Only the top coat of the three-layer system #12, which is epoxy over ceramic, showed flaking; this damage was caused during installation. The remaining coats were intact and no bare steel was exposed. An earlier piling coating study conducted by Alumbaugh[1] at Port Hueneme, CA, found that coating damage due to handling was not a significant factor in further deterioration.

All the pilings had a rating of 10 according to ASTM Reference Standard D 610-68. The ASTM rating is based on a numerical rust grade scale from 1 (worst) to 10 (best) and is an exponential function of the area of rust. Even a slight amount of rusting lowers the rust grade substantially.

Potential Measurements

The potentials of the protected piles were measured with respect to the copper-copper sulfate reference electrode. The results (Table 2) show that sacrificial anodes were providing protection. The potential of the bare steel piles measured -0.66 V with respect to the copper-copper-sulfate electrode. On piles that were coupled to zinc or aluminum anodes, the protection was shifted to the -1.0 V range. The protective potential of -0.85 V needed for complete protection against corrosion was achieved for both aluminum- and zinc-anode-protected piles.

Cathodic Protection Index (CPI) Measurements

The CPI was measured by making the test pile negative and the auxiliary pile positive and shifting the test pile in the negative or

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[1] R. Alumbaugh, "Coatings for Steel Piles in Sea Water," *Materials and Protection,* Vol 3 (1964), p 34.

protected direction. The CPI and current required to shift the potential are shown in Table 3.

The CPI can be used as a nondestructive evaluation technique to determine the amount of bare area immersed in the water. As the bare area increases because of coating deterioration, including enlargement of the original pinholes, the area to be polarized becomes larger, and more current is required, thereby decreasing the CPI. The exact correlation between the field measurement of CPI and bare area has not been established, however. In piles extracted from Dam Neck site, coatings with high CPI generally had less bare area.

Row C, which did not have any coating in the buried zone, had the minimum CPI (Table 3). In contrast, row A, which was completely coated, had a generally higher CPI than row B, which had windows. This confirms the expected result of bare area being proportional to CPI.

In some cases, however, the CPI was higher for row B than row A due to water velocity, which had a significant effect on the polarization current. The polarization products are continuously washed away, supplying oxygen to the metal surface with no impedance of ionic solvation by corrosion product barriers. Pilings where water velocity is high therefore show a lower CPI. The water velocity was estimated to be greater for row A, which was near Buzzards Bay, than for row B, which was closer to the Stoney Point Dike. To account for this effect, future inspections will attempt to measure water velocity in the vicinity of each row of piles to reveal whether velocity is a sensitive variable and should be considered for long-term measurements.

4 CONCLUSIONS AND RECOMMENDATIONS

1. Only system #12 (epoxy over ceramic) showed coating damage, which was attributed to installation. Only the top coat of the three-coat system was damaged. In future inspections, the deterioration of System #12 should be followed carefully.

2. The cathodic protection indices as well as visual inspection showed that the condition of the coatings on the piles at Buzzards Bay was generally excellent after 9 months of exposure.

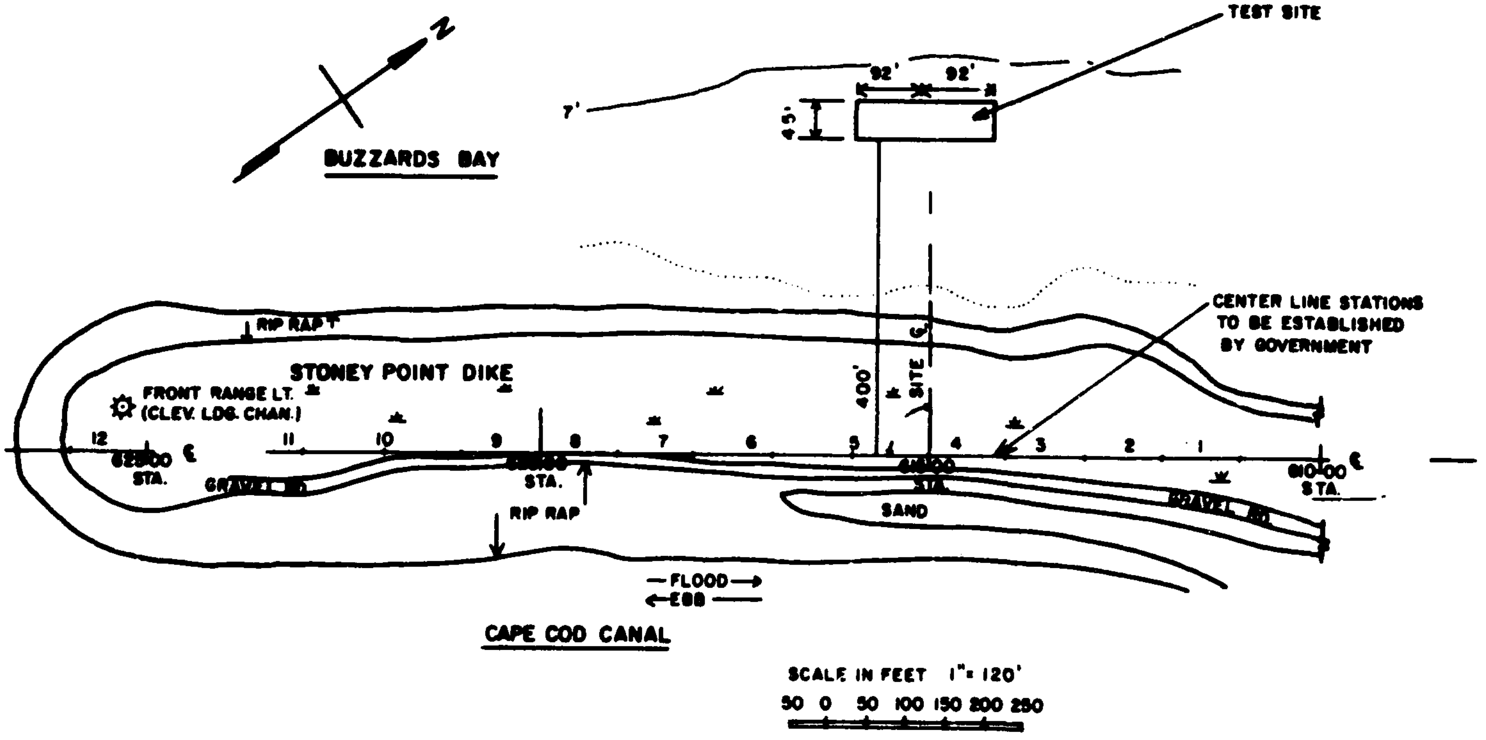
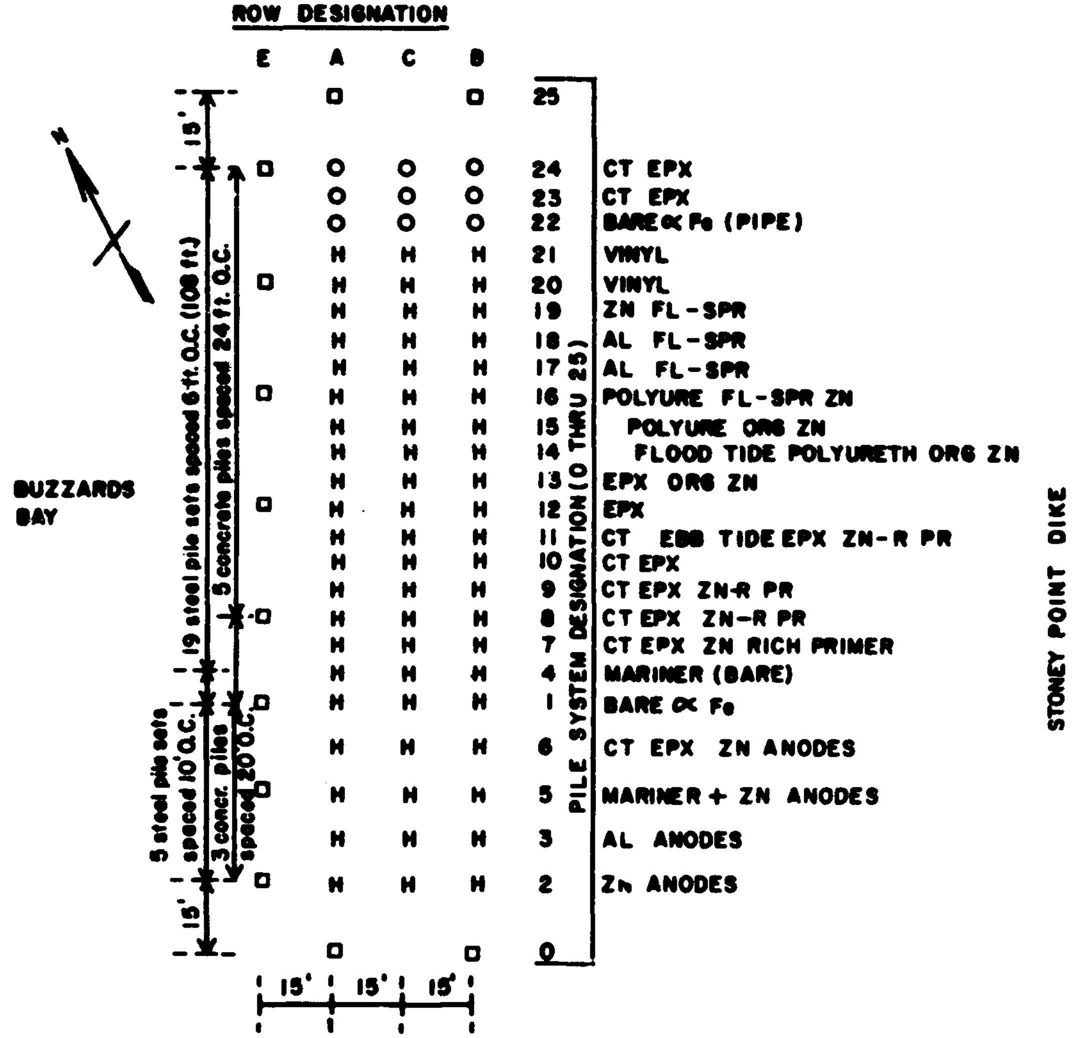


Figure 1. Buzzards Bay test site. Metric conversion factor: 1 ft = 0.3048 m.



SYMBOLS: H DENOTES HP 8" x 8" x 36 LB. STEEL PILES
O DENOTES 8" DIA. SCH. 40 STEEL PIPE PILES
□ DENOTES 12" SQ. PRESTRESSED CONCRETE PILE (CONTRACTOR FURNISHED)
CT DENOTES COAL TAR
EPX DENOTES EPOXY

Figure 2. Installation plan. Metric conversion factors: 1 ft = 0.3048 m; 1 in. = 2.54 cm; 1 lb = 0.4536 kg.

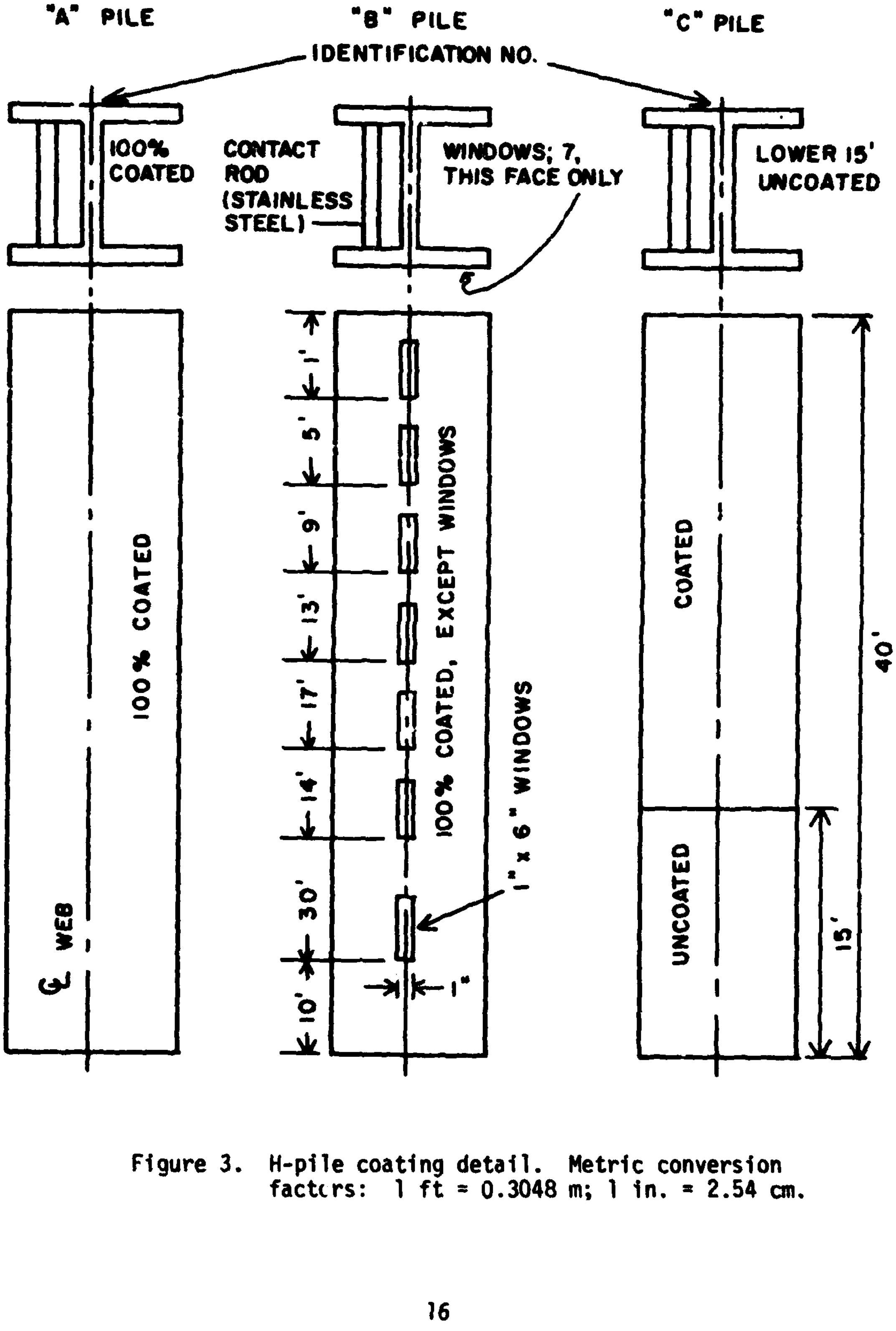


Figure 3. H-pile coating detail. Metric conversion factors: 1 ft = 0.3048 m; 1 in. = 2.54 cm.

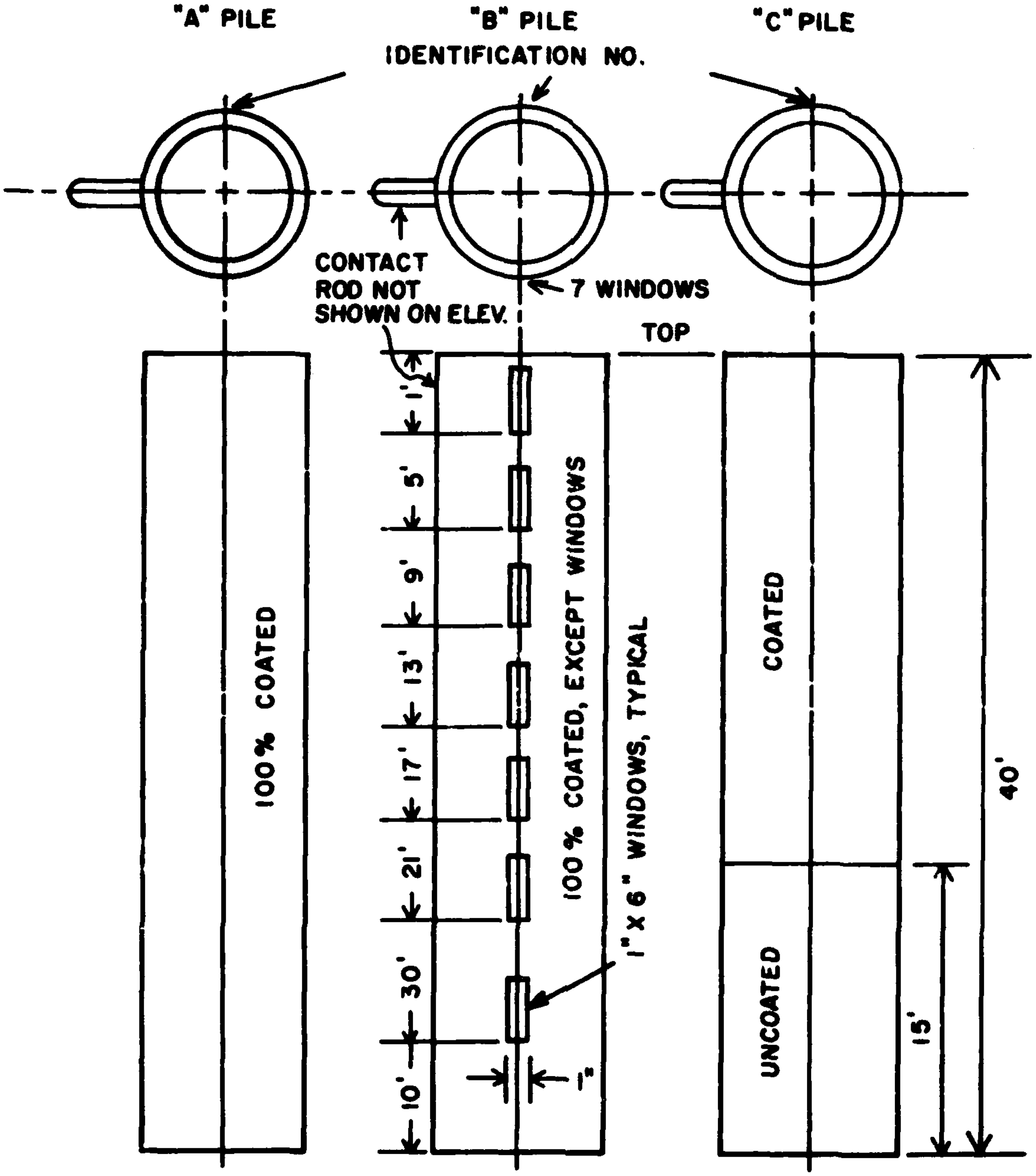


Figure 4. Pipe pile coating detail. Metric conversion factors: 1 ft = 0.3048 m; 1 in. = 2.54 cm.

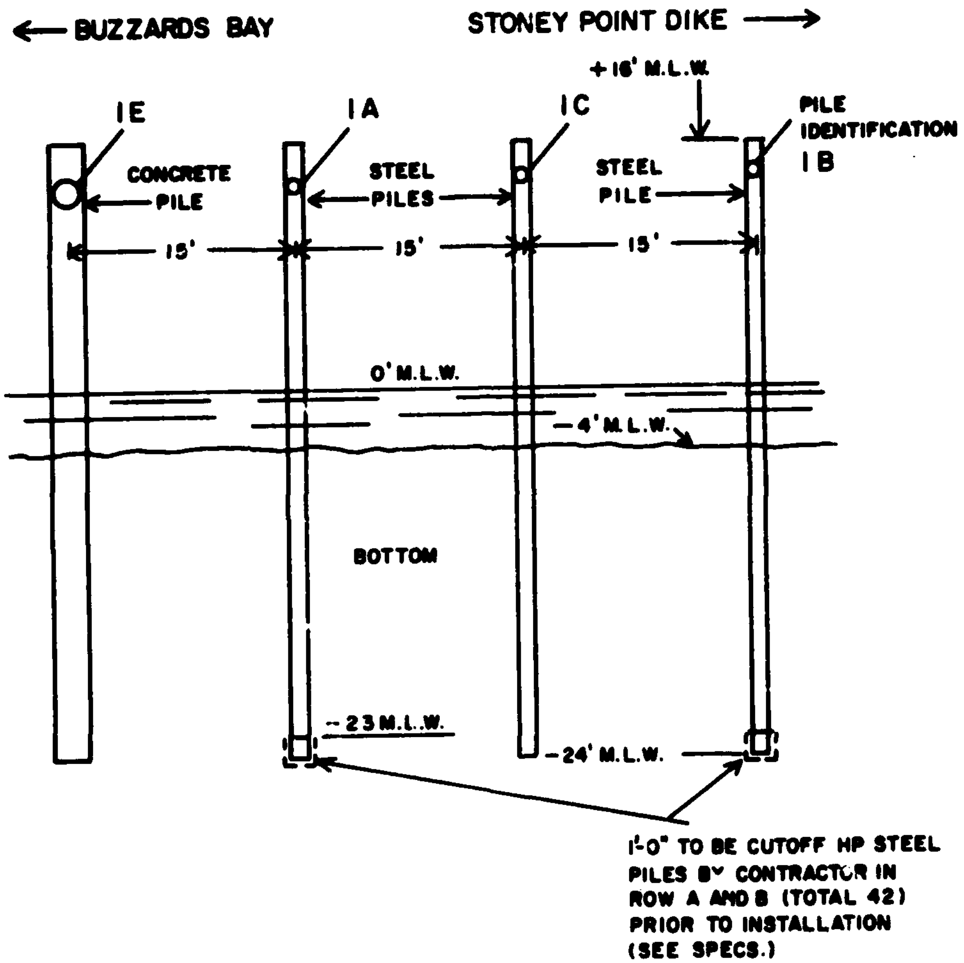


Figure 5. Pile system at Buzzards Bay. Metric conversion factors: 1 ft = 0.3048 m; 1 in. = 2.54 cm.

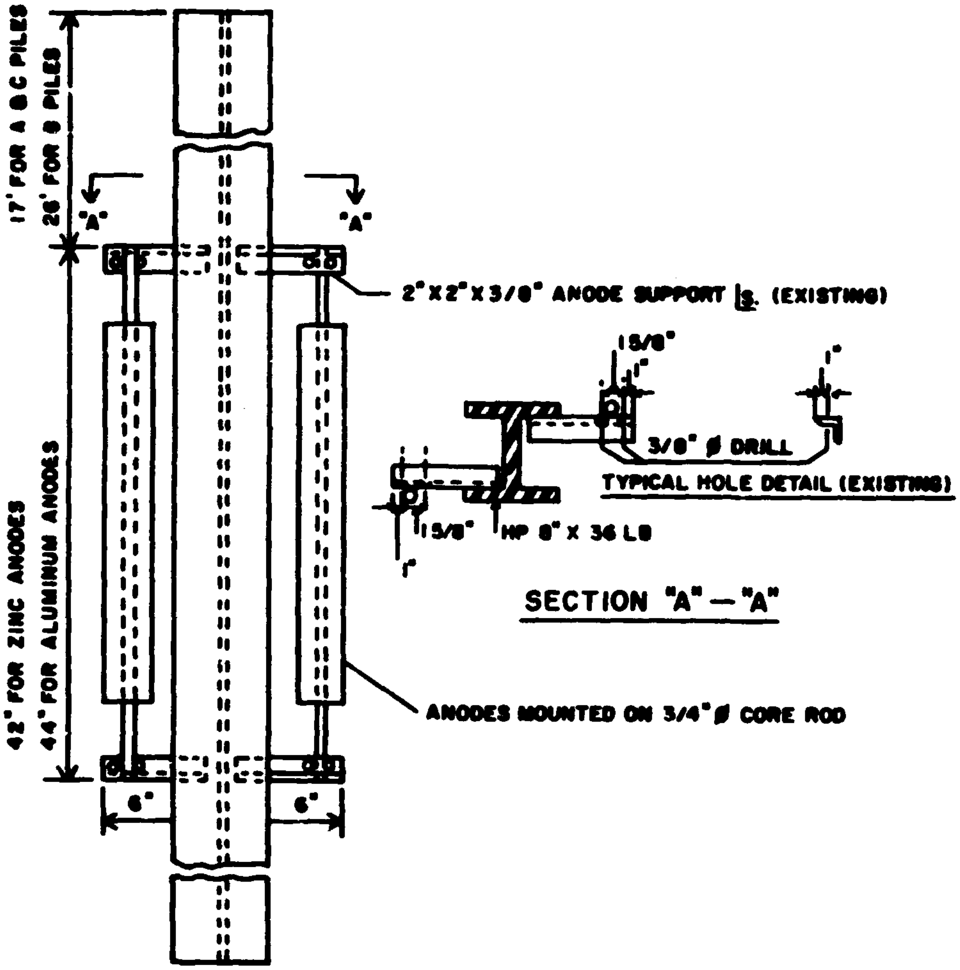
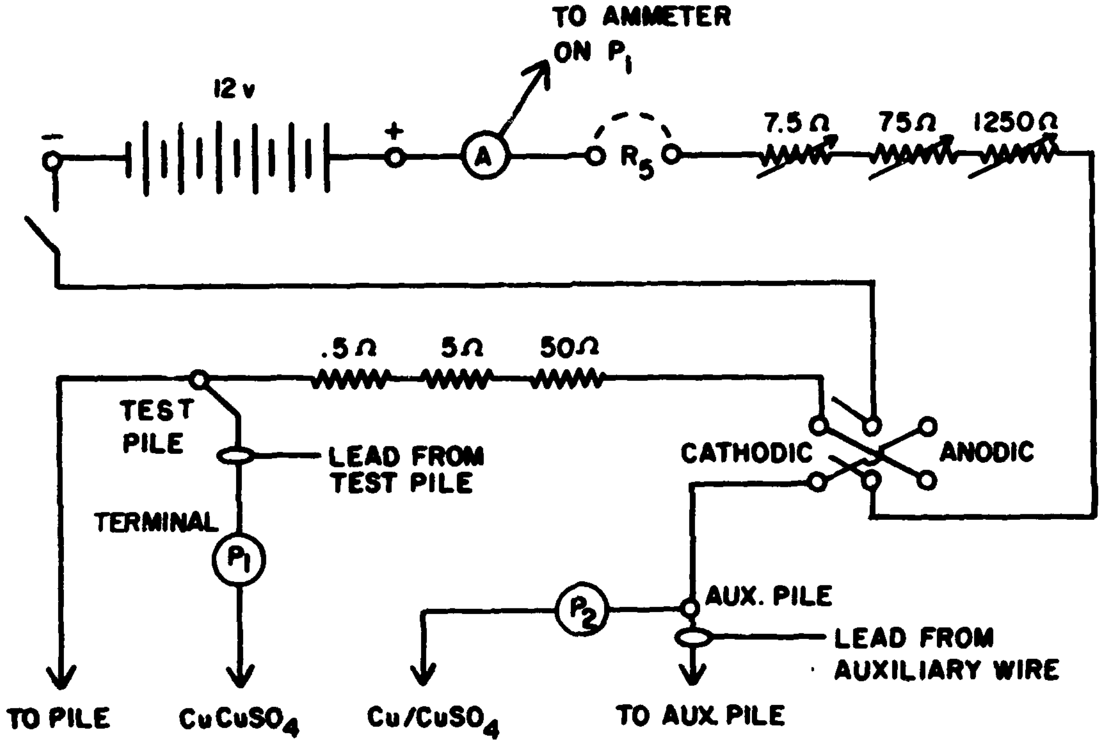


Figure 6. Anode mounting detail. Metric conversion factors: 1 ft = 0.3048 m; 1 in. = 2.54 cm.



P_1 = MILLER M-3 PM/VM OR HIGH RESISTANCE VM; USED FOR MONITORING POTENTIAL/VOLTAGE OF TEST PILES.

P_2 = MILLER M-3; FOR AUXILIARY PILE VOLTAGE

Figure 7. Circuit diagram for measurement of cathodic protection index.

Table 1

Test Pile Preparation Details

System No.	Type of Pile*	Type Pile and Protection	No. of Coats	Total Dry Coating Thickness (mils)**	Coating Source†	Remarks
1	H	Bare Carbon Steel	------	---------	--------------	-------
2	H	Bare Carbon Steel with Zinc Anodes	------	---------	--------------	2 Anodes
3	H	Bare Carbon Steel with Aluminum Anodes	------	---------	--------------	2 Anodes
4	H	Bare Mariner Steel	------	---------	--------------	--------
5	H	Bare Mariner Steel with Zinc Anodes	------	---------	--------------	2 Anodes
6	H	Coal Tar Epoxy, over Zinc-rich Primer, with Zinc Anodes	------	---------	--------------	2 Anodes
		- Epoxy Zinc-rich Primer CERL Formula No. E-303	1	2.5 (0.06 mm)	Iowa Paint Mfg. Co. (Via CERL Paint Lab)	
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	
7	H	Coal Tar Epoxy, over Zinc-rich Primer				
		- Epoxy Zinc-rich Primer CERL Formula No. E-303	1	2.5 (0.06 mm)	Iowa Paint Mfg. Co. (Via CERL Paint Lab)	
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	

Table 1 (cont'd)

System No.	Type of Pile *	Type Pile and Protection	No. of Coats	Total Dry Coating Thickness** (mils)	Coating Source†	Remarks
8	H	Coal Tar Epoxy, over Zinc-rich Primer				
		- Porter Zinc-Lok No. 352 Primer	1	1 (0.03mm)	Porter Paint Co.	
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51mm)	Koppers	
9	H	Coal Tar Epoxy, over Zinc-rich Primer, Aluminum Oxide Armored at Mud Line				
		- Epoxy Zinc-rich Primer NCR Formula No. E-303	1	2.5 (0.06 mm)	Iowa Paint Mfg. Co. Via CERL Paint Lab	4th coat + grit to be applied 17 ft and 23 ft (5.18 and 7.01 m) from bottom of pile
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	
		- Formula C-200, Coal Tar Epoxy + Aluminum Oxide Grit (No. 30) Broadcast into Wet Final Coat				
10	H	Coal Tar Epoxy, over Epoxy Resin Primer				
		- Epoxy Resin Primer	1	3 (0.08 mm)	Porter Paint Co.	
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	
11	H	Coal Tar Epoxy, over Zinc-rich Primer, on Mariner Steel				Mariner steel pile

Table 1 (cont'd)

System No.	Type of Pile*	Type Pile and Protection	No. of Coats	Total Dry Coating Thickness (mils)**	Coating Source†	Remarks
		- Epoxy Zinc-rich Primer NCR Formula No. E-303	1	2.5 (0.06 mm)	Iowa Paint Mfg. Co. (Via CERL Paint Lab)	
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	
12	H	Epoxy over Inorganic Ceramic				
		- Plas-Chem Zinc-ite Primer	1	3-4 (0.08-0.09 mm)	Plas Chem Corp.	
		- Plas-Chem Ceram-ite No. 101	1	5-6 (0.12-0.15 mm)	Plas Chem Corp.	
		- Plas-Chem 2140Z High Build Epoxy	1	7-8 (0.18-0.20 mm)	Plas Chem Corp.	
13	H	Epoxy over Organic Zinc Primer				
		- Zincor No. 11 Primer	1	1-1.5 (0.03 mm-.04 mm)	Plas Chem Corp.	
		- Chem-Pon 2310X Red	1	8-9 (0.20-0.23 mm)	Plas Chem Corp.	
		- Chem-Pon 2310X Gray	1	8-9 (0.20-0.23 mm)	Plas Chem Corp.	
14	H	Polyurethane over Organic Zinc Rich				
		- Chem Glaze Zinc-Rich Primer 9927	1	3 (0.08 mm)	Hughson Chem	
		- Chemglaze II	2	3-5 (0.08-0.12 mm)	Hughson Chem	
15	H	Polyurethane over Organic Zinc-rich with an intermediate Elastomer Coat				
		- Chemglaze Zinc Rich Primer 9927	1	3 (0.08 mm)	Hughson Chem	

Table 1 (cont'd)

System No.	Type of Pile*	Type Pile and Protection	No. of Coats	Total Dry Coating Thickness (mils)**	Coating Source†	Remarks
		- M312 Elastomer	1	6-8 (0.15-0.20 mm)	Hughson Chem	M312 is High Build - 1 coat up to 10 mils (0.25 mm)
		- Chemglaze II	2	3-5 (0.08-0.12 mm)	Hughson Chem	
16	H	Polyurethane over Flame Sprayed Zinc, with Intermediate Washcoat Primer				
		- Flame Sprayed Zinc	1	3-4 (0.08-0.09 mm)	Metalweld or Metco Urecal Co. Via Seaguard Co.	
		- Washcoat Primer Formula 117, MIL-P-15328	1	0.5 (0.12 mm)		
		- Urecal 9301 Polyurethane	2	4 (0.09 mm)		
17	H	Aluminum, Flame Sprayed (wire)	1	6 (0.15 mm)	Metalweld, Metco or equal	Steel Wire Flash Bonding Coat, 1 mil (0.03 m
18	H	Aluminum, Flame Sprayed with Washcoat Primer and Aluminum Vinyl Sealer				Steel Wire
		- Flame Sprayed Aluminum (Wire)	1	3-4 (0.08-0.09 mm)	Metalweld, Metco or equal Via Seaguard Co.	
		- Washcoat Primer Formula 117, MIL-P-15328	1	0.5 (0.12 mm)		
		- Metcoseal AV, Aluminum Vinyl Sealer	2	2 (0.05 mm)	Metco	

Table 1 (cont'd)

System No.	Type of Pile*	Type Pile and Protection	No. of Coats	Total Dry Coating Thickness (mils)**	Coating Source†	Remarks
19	H	Zinc, Flame Sprayed, with Coal Tar Emulsion over Coal Tar Solution Top coats				
		- Flame-Sprayed Zinc (Wire)	1	3-4 (0.08-0.09 mm)	Metalweld or Metco	
		- Wise Chem T-265 Coal Tar Solution	1	15 (0.38 mm)	Wise Chem Co.	
		- Wise Chem T-264 Coal Tar Emulsion	1	7-8 (0.18-0.20 mm)	Wise Chem Co.	
20	H	Vinyl Glass Flake, over Vinyl Zinc-rich				
		- Vinyl Zinc Rich	1	2-3 (0.05-0.08 mm)	CERL Paint Lab	
		- Vinyl Glass Flake	3	6 (0.15 mm)	CERL Paint Lab	
21	H	Vinyl Mastic over Synthetic Resin Tiecoat over Washcoat Inorganic Zinc Primer				Curing Solution to be removed by fresh water
		- Dimetcote No. 3 + D3 Curing Solution	1	3 (0.08 mm)	Amercoat Corp.	
		- No. 54 Tiecoat	1	1 (0.03 mm)	Amercoat Corp.	
		- Vinyl Mastic No. 87	1	10 (0.25 mm)	Amercoat Corp.	
22	Pipe	Bare Carbon Steel	------	--------	--------------	-------

Table 1 (cont'd)

System No.	Type of Pile*	Type Pile and Protection	No. of Coats	Total Dry Coating Thickness (mils)**	Coating Source†	Remarks
23	Pipe	Coal Tar Epoxy over Zinc-rich Primer				
		- Epoxy Zinc-rich Primer NCR Formula No. E-303	1	2.5 (0.06 mm)	Iowa Paint Mfg.Co. (Via CERL Paint Lab)	
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	
24	Pipe	Coal Tar Epoxy, Armored at Mud Line, over Zinc-rich Primer				
		- Epoxy Zinc-rich Primer NCR Formula No. E-303	1	2.5 (0.06 mm)	Iowa Paint Mfg. Co. (Via CERL Paint Lab)	4th coat & Al Oxide to be applied between 17 and 23 ft (5.18 and 7.01 mm) from bottom of pile
		- Formula C-200, Coal Tar Epoxy	2	16-20 (0.41-0.51 mm)	Koppers	
		- Formula C-200, + Aluminum Oxide (No. 30 Grit) Broadcast into Wet Final Coat	1	10 (0.25 mm)	Koppers	

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* Steel H-piles are 40 ft (12.19 m) lengths of 8 in. x 8 in. x 36 lb (20.32 cm x 20.32 cm x 16.33 kg) mild carbon steel, except systems 4, 5, and 11 which are "Mariner" steel H-piles. Systems 22, 23, and 24 are pipe piles, mild carbon steel, 8 in. (20.32 cm) diameter, schedule 40, 0.322 in. (0.82 cm) wall thickness.

** Film thickness tolerance per coat may be plus or minus 15 percent of given thickness per coat when no thickness range is given.

† An approximately equal brand name coating with application and preparation instructions can be furnished by the Government from the same or another source. CERL is symbol for the Paint Laboratory at the U. S. Army Construction Engineering Research Laboratory.

Table 2

Corrosion Potential of Protected Pilings

Piling System No.	Nature of Coating	Corrosion Potential (Voltage)
2B	Bare Carbon Steel with Zn Anodes	-.97
C		-1.05
A		-1.05
3B	Bare Carbon Steel with Al Anodes	-.95
C		-1.03
A		-1.04
5B	Bare Mariner Steel with Zn Anodes	-.96
C		-1.06
A		-1.05
6B	Coal Tar Epoxy over Zinc-rich Primer with Zn Anodes	-1.09
C		-1.07
A		-1.06

Table 3

Corrosion Potential/CPI Measurements

CPI = ΔV/ΔI	Piling System No.	Type of Coating	Initial V	Final V	ΔI, amps	ΔV, volts	Aux Electr	Top Bar to Water Surface Distance	
								ft	in.
15.15	13B	Org Zn	-.70	-.85	.0095	.15	1C	2 (0.61 m)	1 (2.54 cm)
0.15	C	Org Zn	-.64	-.85	1.28	.19	1C	2 (0.61 m)	-3 (-7.62 cm)
5.68	A	Org Zn	-.60	-.85	.044	.25	1C	2 (0.61 m)	-11 (-27.94 cm)
15.18	14B	Org Zn	-.68	-.85	.0112	.17	1C	2 (0.61 m)	1 (2.54 cm)
0.17	C	Org Zn	-.66	-.85	1.14	.19	1C	2 (0.61 m)	-1 (-2.54 cm)
7.65	A	Org Zn	-.59	-.85	.034	.26	1C	2 (0.61 m)	-9 (-22.86 cm)
13.71	15B	Org Zn	-.68	-.85	.0124	.17	1C	2 (0.61 m)	2 (5.08 cm)
0.17	C	Org Zn	-.65	-.85	1.16	.20	1C	2 (0.61 m)	1 (2.54 cm)
7.22	A	Org Zn	-.59	-.85	.036	.26	1C	2	-7 (-17.78 cm)
	16B	Fl Spr Zn	-.97				1C		
0.16	C	Fl Spr Zn	-.80	-.85	.32	.05	1C	2 (0.61 m)	10 (25.40 cm)
	A	Fl Spr Zn	-.87				1C		
	17B	Fl Spr Al	-.88				1C		
0.15	C	Fl Spr Al	-.78	-.85	.47	.07	1C	2 (0.61 m)	9 (22.86 cm)
	A	Fl Spr Al	-.87				1C		
	18B	Fl Spr Al	-.88				1C		
0.16	C	Fl Spr Al	-.78	-.85	.45	.07	1C	2 (0.61 m)	8 (20.32 cm)
1.61	A	Fl Spr Al	-.80	-.85	.031	.05	1C	2 (0.61 m)	-9 (-22.86 cm)
	19B	Fl Spr Zn	-1.00				1C		
	C	Fl Spr Zn	-.91				1C		
	A	Fl Spr Zn	-.96				1C		
7.39	20B	Vinyl	-.68	-.85	.023	.17	1C	2 (0.61 m)	6 (15.24 cm)
.23	C	Vinyl	-.69	-.85	.690	.16	1C		
6.36	A	Vinyl	-.57	-.85	.044	.28	1C	2 (0.61 m)	-6 (15.24 cm)

Table 3 (cont'd)

CPI = ΔV/ΔI	Piling System No.	Type of Coating	Initial V	Final V	ΔI, amps	ΔV, volts	Aux Electr	Top Bar to Water Surface Distance	
								ft	in.
.058	1B	Bare	-.66	-.85	3.3	.19	1C	1 (0.30 m)	6 (15.24 cm)
	C	Bare							
.0487	A	Bare	-.66	-.85	3.9	.19	1C	1 (0.30 m)	7 (17.78 cm)
.0667	4B	Bare	-.63	-.85	3.3	.22	1C	1 (0.30 m)	6 (15.24 cm)
	C	Bare	-.58		>4.0		1C	1 (0.30 m)	6 (15.24 cm)
.0472	A	Bare	-.68	-.85	3.6	.17	1C	1 (0.30 m)	7 (17.78 cm)
6.21	7B	Zn Primer	-.67	-.85	.029	.18	1C	1 (0.30 m)	8 (20.32 cm)
.19	C	Zn Primer	-.68	-.85	.90	.17	1C	1 (0.30 m)	6 (15.24 cm)
7.65	A	Zn Primer	-.59	-.85	.034	.26	1C	1 (0.30 m)	6 (15.24 cm)
7.20	8B	Zn Primer	-.67	-.85	.025	.18	1C	1 (0.30 m)	8 (20.32 cm)
0.18	C	Zn Primer	-.68	-.85	.94	.17	1C	1 (0.30 m)	6 (15.24 cm)
7.19	A	Zn Primer	-.62	-.85	.032	.23	1C	1 (0.30 m)	8 (20.32 cm)
7.50	9B	Zn Primer	-.67	-.85	.024	.18	1C	1 (0.30 m)	10 (25.40 cm)
0.18	C	Zn Primer	-.66	-.85	1.06	.19	1C	1 (0.30 m)	-6 (-15.24 cm)
6.13	A	Zn Primer	-.64	-.85	.031	.19	1C	1 (0.30 m)	-10 (-25.40)
16.16	10B	CT Epoxy	-.69	-.85	.0099	.16	1C	2 (0.61 m)	
0.19	C	CT Epoxy	-.67	-.85	.94	.18	1C	2 (0.61 m)	-5 (-12.70 cm)
6.0	A	CT Epoxy	-.64	-.85	.035	.21	1C	2 (0.61 m)	-9 (-22.86 cm)
8.7	11B	Zn Primer	-.65	.85	.023	.20	1C	2 (0.61 m)	
0.16	C	Zn Primer	-.65	-.85	1.22	.20	1C	2 (0.61 m)	-5 (-12.70 cm)
5.33	A	Zn Primer	-.61	-.85	.045	.24	1C	2 (0.61 m)	-9 (-22.86 cm)
	12B	Epoxy	-.96				1C		
.16	C	Epoxy	-.76	-.85	.93	.15	1C	2 (0.61 m)	-5 (-12.70 cm)
	A	Epoxy	-.90				1C		

Table 3 (cont'd)

CPI = ΔV/ΔI	Piling System No.	Type of Coating	Initial V	Final V	ΔI, amps	ΔV, volts	Aux Electr	Top Bar to Water Surface Distance	
								ft	in.
6.25	21B	Vinyl	-.70	-.85	.024	.15	1C	2 (0.61 m)	10 (25.40 cm)
	C	Vinyl	-.71	-.85	.500	.14	1C		
1.47	A	Vinyl	-.62	-.85	.156	.23	1C	2 (0.61 m)	-6 (-15.24 cm)
	22B	Bare					22C	2 (0.61 m)	-3 (-7.62 cm)
	C	Bare							
	A	Bare					22C		
4.22	23B	Epoxy	-.64	-.85	.645	.19	22C	2 (0.61 m)	-3 (-7.62 cm)
0.26	C	Epoxy	-.70	-.85	.57	.15	22C	2 (0.61 m)	-5 (-12.70 cm)
11.03	A	Epoxy	-.53	-.85	.029	.32*	22C	2 (0.61 m)	-7 (-17.78 cm)
4.29	24B	Epoxy	-.64	-.85	.049	.21	22C	2 (0.61 m)	-3 (-7.62 cm)
0.48	C	Epoxy	-.73	-.85	.25	.12	22C	2 (0.61 m)	-2 (-5.08 cm)
22.50	A	Epoxy	-.58*	-.85	.012	.27*	22C	2 (0.61 m)	-2 (-5.08 cm)

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* Heavy fluctuation of reading; vise clamp may not have been connected to pile