



Project NY 450 004-2  
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PROTECTIVE COATING FOR STEEL PILING: Results of 6-Month Tests

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OBJECT OF PROJECT

To find or develop materials and techniques for arresting and/or preventing corrosion, rusting, or weathering of marine structures, shore establishment facilities, construction equipment, and materials, under normal usage and storage conditions.

OBJECT OF SUBPROJECT

To evaluate various coatings for use on steel piling.

OBJECT OF REPORT

To show results of evaluation tests with coating systems applied to steel piling driven in Port Hueneme Harbor and exposed for 6 months.

RESULTS

Saran resin coating was the most durable of those tested, although seven other coating systems offered good general protection during the 6-month evaluation program. Further tests of longer duration are in progress. Eight coating systems will be tested for periods of from 12 to 30 months.

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#### SUMMARY

Twenty-three protective coating systems for steel piling were evaluated at the Laboratory. After 6 months in Port Hueneme Harbor, eight of the coating systems were selected for further evaluation; 15 were eliminated because of defects caused by the driving operation and exposure conditions.

A Saran resin coating gave almost complete protection during the 6-month exposure period, and seven other coating systems appeared to provide adequate protection in all exposure zones - (atmospheric, tidal, mudline, and underground areas.).

A second, long-term phase of the driving-exposure tests is planned in which piling will be coated with the eight selected coating systems and exposed for periods ranging from 12 to 30 months.

INTRODUCTION

This is the second in a series of reports which began with a study<sup>1</sup> of piling coatings applied to 10-ft angle iron specimens exposed in Port Hueneme Harbor as a part of Project NY 450 004-2.

Results of 6 months of tests with 27-ft piling are given in this report. The short-term driving and exposure test was conducted to provide information which could not be obtained by tidal zone or corrosion dock exposure tests and to limit the number of coatings used in a long-term testing program.

Twenty-three protective coating systems were evaluated during the 6-month program; eight of these were selected for a long-term driving and exposure study, ~~at Port Hueneme~~. Local long-term exposure tests will be supplemented by parallel exposures at Guam using materials from the same sources as the NAVCERELAB materials.

It should be emphasized that the short-term driving and exposure test was an intermediate step in the evaluation program, and that the 6-month limitation was arbitrarily selected.

In the second long-term driving and exposure phase it is planned to pull the first piles at the end of 1 year, and at 6-month intervals thereafter. As the pile-driving and exposure tests continue, standard procedures, including an optimum exposure period, will be established for future use in evaluating coating systems for piling.

TEST PROCEDURES

Coating

Steel sheet piles weighing 36 lb per lineal foot, 27 ft long, and H-piles weighing 36 lb per lineal foot, 27 ft long, were used in tests. Surfaces were sandblasted to a gray matte finish, and a prime coat of paint was applied immediately. Each coat of paint was allowed to dry sufficiently hard to prevent lifting before the next coat was applied. Each complete system was allowed to cure at least 2 weeks before being driven. Twenty-three coating systems were used in the test;

1. NAVCERELAB Technical Note N-260, Corrosion Prevention and Protective Coatings for Steel Piling, A. L. Fowler, C. V. Brouillette, and H. Hochman

two sheet piles and two H-piles were coated with each system. In a few cases only three piles were coated with a particular coating system. A total of 87 piles were coated and driven in this phase of the program.

Two sheet piles and two H-piles provided approximately 440 sq ft of coated steel surface. This was considered sufficient to furnish information on coverage of the materials. The thicknesses of the coating systems (see Table I) were recommended by the manufacturers.

#### Driving

The 27-ft piles were driven to a firm base with approximately 7 ft of piling above the mudline. This upper area provided atmospheric exposures, alternate atmospheric and submerged exposures, but no continuously submerged exposure areas. A sea water-sand slurry action just above the mudline at low tide resulted in severe abrasion which caused some coatings to fail. Additional information was obtained from observations of damage to coatings during the pile driving and pulling procedures.

The first 27 coated piles were driven with a diesel pile hammer with an output energy of 5000 ft-lb per blow and a striking frequency of 95 blows per minute. The remaining 60 piles were driven with a diesel pile hammer with an output energy of 12,000 to 16,000 ft-lb per blow and a striking frequency of 50 blows per minute. Observations of damage done during driving and handling were made and taken into consideration when the systems were evaluated at the end of the 6-month exposure period.

#### Pulling

At the end of six months the coated piles were pulled from the harbor, cleaned by washing with a hose to remove dirt and loose corrosion products, and examined to determine the extent of damage to the coatings. The examination was based on:

- a. The effect of the driving and pulling operations on the coatings;
- b.. the amount of fouling growth and resultant damage observed on the coatings in the tidal zones;
- c. the resistance of the coatings to abrasion by a sea water-sand slurry at the mudline; and

d. the extent of rusting which had occurred on the underground area during the six months harbor exposure.

All four items of evaluation were considered in arriving at an overall performance rating for each system listed in Table I. The following paragraphs contain a discussion of each of the four main considerations used for rating the coating systems.

#### EVALUATION PROCEDURES

##### a. Effect of Driving and Pulling on Coating Systems

Damage during these operations consisted chiefly of spalling of brittle coatings, plastic flow of soft mastic coatings, and slitting or cutting of coatings by sharp rocks. Although slight damage occurred during the driving procedure (light scratches in the coating), the overall rating of the coating system was not generally lowered if the coating still was protecting the piling. The slight damage done to one piling coating during the driving and pulling operation is shown in Figure 1. Damage which obviously occurred during the pulling operation was not evaluated as contributing to coating failure since this situation would not normally be encountered. Spalling of a somewhat brittle coating is shown in Figure 2. Damage in this case was caused largely by the strain involved in separating two interlocked sheet piles during the pulling operation. Grooves in the coating shown in Figure 3 were cut by rocks. Plastic flow of the coating shown in Figure 4 was considered excessive. This was regarded as a serious defect since the protective film was very thin in many areas.

##### b. Fouling Attachment and Damage to Coatings in Tidal Zone

Fouling attachment found in the surf area of a piling is evidently limited in comparison to that generally exhibited by a piling driven in deeper water, subjected only to changes in tidal level. It was found that on 6 months' exposure to surf action, algae and barnacles were the predominant fouling growth. Light algae attachment was the only fouling observed on the flame-sprayed zinc metal coating (see Figure 5) while algae as well as light barnacle growth was noted on the aluminum vinyl coating (see Figure 6). In certain waters the useful life expectancy of soft bituminous coatings (such as asphalt or coal tar) has been considerably reduced because of penetration of the coatings by barnacles. It is not uncommon for a soft coating

to peel off almost entirely in the tidal zone because of penetration of the coating by barnacles and consequent rusting and loss of adhesion between the coating and the piling. (See Figure 8). Heavy fouling attachment was noted on the neoprene system shown in Figure 7, and the bituminous coating shown in Figure 8. Usually barnacle attachment has very little effect on harder coatings. Attachment in itself was not regarded as harmful to the coating systems. The system rating was lowered only when fouling organisms had penetrated the coatings and rusting had occurred.

c. Resistance of Coatings to Sea Water-Sand Slurry Abrasive Action at Mudline

The abrasive action of a sea water-sand slurry at the mudline seems to be a severe test for harder coatings. In general, coatings which exhibit a slight resiliency or rubber-like quality seem to stand up better under the action of this slurry. An exception to this is shown in Figure 11. Here a chlorinated rubber resin coating was removed from over one-half the area subjected to abrasion permitting the exposed metal to rust. Variations in resistance to this abrasive action are shown in Figures 9, 10, 11 and 12. A vinyl mastic coating that was not damaged by the slurry action is shown in Figure 9. The inorganic binder-type coating shown in Figure 10 was abraded to some extent, and slight rusting was observed in the more severely abraded areas. Hot plastic anti-fouling coating, as shown in Figure 12, had spalled from the anti-corrosive undercoating and considerable rust was observed on the sheet piling coated with this material. In this area the evaluation of the coating system was dependent upon the amount of coating removed and the degree of rusting observed.

d. Extent of Rusting on Underground Area of Driven Piling

Slitting, cutting, or spalling of the coating would be attributed to the driving operation and, consequently, rusting caused by this action should be evaluated accordingly. The main point of consideration under this section is directed toward the ability of a coating system to withstand the environment below the mudline. While coated piling would not be expected to exhibit marked corrosion in a 6-month underground exposure period, some systems failed to protect the steel completely. Variations in protection given by different coating systems are shown in Figures 13, 14, 15 and 16. Saran coating (see Figure 13) gave almost complete protection. A vinyl resin coating permitted only slight rusting, as can be seen at the bottom of the

piling shown in Figure 14. An epoxy resin coating (see Figure 15) was slightly less effective in protective properties than the vinyl coating just mentioned. An alkyd resin coating system failed badly in protecting the pile marked "A" in Figure 16.

One interesting aspect related to the protective property of coatings on the underground area of driven piling was that a scale deposit was formed on coatings containing metallic zinc or aluminum. This type of scale deposit on a piling coated with flame-sprayed aluminum is shown in Figure 17. A close-up view of a more uniform scale deposit on piling coated with a zinc dust pigmented inorganic binder-type paint is shown in Figure 18. The deposits formed were mostly sand or silicate materials. The scale was adherent, difficult to remove, and provided excellent protection in the short-term driving tests.

#### DISCUSSION OF RESULTS

The ratings assigned to coating systems listed in Table I are discussed below. Ratings were based on the ASTM Photographic Reference Standard for evaluating degree of resistance to rusting in which 10 indicates a coating which had an intact film and permitted no rusting in any area; and 0 indicates a coating which had lost all protective value. Coatings rated 8 or higher were considered suitable for use in the long-term evaluation of protective coatings for use on steel piling.

#### Alkyd Resin Coating (System 10)

This system consisted of a zinc chromate-iron oxide pigmented, alkyd resin primer with high gloss alkyd resin top coats. The rating of the system was 4. Failure was general, because of low resistance of the paint film to permeation by sea water.

#### Anti-Fouling Paint Coatings (Systems 18 and 22)

System 18, one of the Bureau of Ships alternate anti-fouling paint systems, consisted of one coat of Formula 117 pretreatment, two coats of Formula 14 anti-corrosive paint, and four coats of Formula 145 cold plastic anti-fouling paint. The total film thickness of the coating was 21 mils. This coating failed to give adequate protection to steel piling because of the brittle nature of the anti-fouling top coat which flaked off of the anti-corrosive undercoat in several areas. As a result, corrosion occurred in the areas protected only with the anti-corrosive undercoat. The cold plastic anti-fouling top

coat, like the hot plastic anti-fouling top coat, cracks and loses adherence when exposed to atmospheric conditions. System 18 was given a rating of 6.

System 22, the hot plastic anti-fouling paint combination, consisting of two coats of anti-corrosive paint, Formula 14AC, and one coat of hot applied anti-fouling paint, Formula 15HP, had a total thickness of 34 mils. Because of the loss of adherence of the anti-fouling top coat, large areas on the coated piling were protected only by anti-corrosive undercoats and corrosion was observed in these areas. The overall rating of system 22 was 4.

#### Asphalt Coatings (Systems 16 and 17)

System 16, based on a wash prime pretreatment, Formula 117, an anti-corrosive undercoat, Formula 84, followed by an asphalt emulsion top coat, provided much better protection than system 17, in which an asphalt coating was applied directly to sand blasted steel. System 16 was rated 9, system 17 was rated 7; system 16 was selected for further testing. Other than the application of an anti-corrosive undercoating in system 16, the main variation between systems 16 and 17 consisted in using a mica-filled top coat in system 16. This top coat produced a more durable asphalt coating system than that obtained when unfilled asphalt was employed. Not only did it withstand the rigors of the driving operations to a greater degree (no plastic flow was noted during the driving operation of system 16 while this type of failure was common with system 17), but it also was superior in its resistance to the sea water-sand slurry at the mudline. Attack by barnacles in the tidal zone also caused considerably less damage than that observed when the asphalt system containing no mica filler was applied directly to sand-blasted steel.

It appears from the results obtained during the 6-month exposure period that the use of an anti-corrosive undercoat for asphalt systems is desirable.

#### Chlorinated Rubber Coating (System 11)

The chlorinated rubber coating system used in the 6-month test consisted of a red lead primer, followed by five coats of a high-gloss red finish paint. The coating was given a rating of 6. Failure of this chlorinated rubber-base coating was general, deterioration occurring in all areas.

### Coal Tar Coatings (Systems 12, 13, 14, 15 and 19)

Systems 12, 13, 14 and 15 were varied to determine the effect of wash prime pretreatments and bituminous emulsion top coats in cold-applied, coal tar base coating systems. While these coating systems showed only slight variations in ratings in the short-term tests (all four systems were rated 8), there was no evidence that the wash prime pretreatment increased adherence of the coating to steel. On the other hand, the coal tar emulsion top coat did add to the sunlight resistance of the system, in that alligatoring of the coating film was less severe in the systems provided with this additional protection. System 13 was included in the second phase of the pile driving and exposure tests since it performed as well as the other coal tar systems and did not necessitate application of a pretreatment coating.

One of the H-piling in system 15 was purposely damaged in each of the 3 zones of exposure. The damaged areas were repaired using a 34Yb patching compound. During the driving operation, the patching material exhibited a considerable degree of plastic flow. After the piling had been driven the patching material exposed to the atmosphere continued to flow, and by the end of the six months' test period the patching compound in all three areas had failed due to loss of adhesion.

The hot-applied coal tar coating, system 19, consisting of a solvent-type primer and a hot-applied top coat averaging 3/32 in. in thickness, also rated 8 in the 6-month driving and exposure test. However, since it was not superior to the cold-applied coal tar systems 12 to 15, and was much more difficult to apply, the hot-applied coating was omitted from those selected for the long-term driving and exposure tests.

### Epoxy Resin Paint Coating (System 3)

The epoxy resin coating system consisted of a red lead primer and a white pigmented finish paint. Both paints were catalyzed prior to application. Two coats of primer and three coats of finish paint were applied, giving a total dried film thickness of 7 mils. The coating lacked abrasion resistance at the mudline where spot corrosion occurred, and in the underground area where the paint film was removed by the driving action, allowing rusting to develop. The rating of this epoxy coating system was 7.

### Flame-Sprayed Metal Coatings (Systems 20 and 21)

Flame-sprayed aluminum and flame-sprayed zinc (both used

in wire form rather than as a powder) were applied at a thickness of 5 mils. A flame-sprayed "steel bond" coat was applied to the sand-blasted steel piling prior to application of the aluminum metal coating, but this additional bond coat was not considered necessary under the flame-sprayed zinc coating. These coatings were in good condition at the end of the test and each was given a rating of 9.

#### Furan Resin Mastic Coating (System 8)

The Furan resin top coat material was described as a prepolymerized furan protective coating containing no plasticizer. The material was furnished partially polymerized, gelation or hardening being prevented by volatile inhibitors which evaporated after application, leaving a non-porous, fused film. The system consisted of a coat of special primer and six coats of finish paint. Black and gray pigmented Furan paints were alternated in order to insure a more uniform coating. This Furan coating was given a rating of 7. Failure was attributed, for the most part, to rusting in the underground area, particularly at the interlock of the sheet piling. Very little scratching or scraping of the coating occurred during the driving and pulling operation; underground rusting was attributed to the inability of the coating system to withstand the environmental conditions existing below the mudline. A moderate degree of rusting had occurred just above the mudline where sea water-sand slurry had removed a small percentage of the coating exposed to this action; however, this was not considered extremely serious at the conclusion of the 6-month test period.

#### Neoprene Brushing Composition (System 9)

In system 9, a special-type primer was applied and allowed to dry 2 to 4 hours. Four coats of a catalyzed Neoprene finish paint were then applied at intervals of at least 6 hours. The complete coating was allowed to cure on the piling approximately 30 days before driving. At the end of the 6-month test period the Neoprene coating was rated 9. The only failures noted were a few cuts due to sharp rock in the underground area resulting in slight corrosion.

#### Phenolic Resin Mastic Coating (System 7)

This system consisted of one coat of a mica filled, orange colored, modified phenolic resin primer, and one coat of a gray finish paint, both paints being catalyzed just prior to application. The primer was allowed to cure 24 hours before the top coat was applied. The cured system exhibited extreme hardness

and toughness as well as excellent adhesion to the metal substrate. Damage to the modified phenolic resin system was limited to slight flaking in the underground areas where little or no scratching or scraping was evident. Very little damage, if any, could be attributed to the sea water-sand slurry at the mudline. Although barnacles were quite abundant in the tidal areas, they were unable to penetrate the coating system, and caused no damage. The system was rated 9.

#### Saran Coating (System 23)

This system was the regular Navy Formula 113 material, with the white and orange pigmented paints being alternated to insure a uniform coating. At the end of the 6-month test period this coating was rated 9. Actually, this was the best coating system tested and only one small area in the mudline zone was found where the coating failed to adhere to the steel piling.

#### Vinyl Resin Coatings (Systems 1, 5 and 6)

The first of the vinyl resin systems (system 1) consisted of: a wash primer pretreatment, Formula 117; four coats of red lead vinyl anti-corrosive paint; and three coats of aluminum vinyl finish paint, giving a total thickness of 5.5 mils. Slight damage to the aluminum vinyl coating was noted at the mudline due to abrasion, and at the bottom end of the sheet piling where the aluminum top coat was removed, and the red lead anti-corrosive coating was visible. This system was rated 8.

The second vinyl system (system 5) consisted of one coat of a special primer and three coats of a gray vinyl top coat to give a total film thickness of 5.4 mils. Only slight rusting of the piling coated with system 5 was noted at the mudline. However, below the mudline, rusting was more severe because of slitting or cutting during the driving operation. The overall rating of system 5 was 7.

The other vinyl resin system (system 6) was a vinyl mastic applied in a two-coat application over a special vinyl resin primer. This system produced a film thickness of 10.0 mils. The vinyl mastic coating showed only slight damage at the mudline and at the bottom end of the piling, and was rated 9.

Zinc Dust Pigmented Coatings (Systems 2 and 4)

System 2 consisted of three coats of a polystyrene resin paint pigmented with zinc dust. In this paint the "zinc particles," according to the manufacturer, "were ground down to 6 microns and the polystyrene polymerized to act as a conductor." This coating failed to protect the steel against rusting at the mudline and at the bottom of the pile. There was some checking and blistering at the top of the pile. Failure was caused by a lack of adherence of the coating. The overall rating assigned was 5.

System 4 also utilized a zinc dust-type pigment, but the binder was an inorganic silicate composition. The coating was applied by spraying in one coat to give a thickness of 2.5 mils. After the coating had dried approximately 2 hours, a curing solution was applied. The inorganic silicate-zinc dust coating gave excellent protection to the piling in the underground area because of the formation of a thick sand scale or deposit on the piling. However, there was some abrasion at the mudline which lowered the overall rating of the system to 7.

## CONCLUSIONS

1. Coating systems having a total dry film thickness of less than 5 mils proved to be inadequate for protecting the piling in the 6-month driving and exposure test.
2. The Bureau of Ships anti-fouling coating systems tested (hot plastic, Formula 15HP, and cold plastic, Formula 145) are not practical for applications where they will be exposed to air and sunlight; they invariably crack and flake from the prime coat.
3. A wash prime pretreatment, Formula 117, and an anti-corrosive prime coat, Formula 84, increase corrosion resistance when used under an asphalt emulsion top coat.
4. In the different cold-applied coal tar coating systems that were evaluated, the use of a wash prime pretreatment apparently did not increase adherence of the coal-tar coating to the steel substrate.
5. Flame-sprayed aluminum metal provided adequate protection for the steel piling in the 6-month exposure test. However, since piling protection provided by the aluminum spray was not superior to the protection provided by the flame-sprayed zinc

metal, and since it also required a flame-sprayed "Steel bond" coat, further investigation of this system does not seem justified.

6. As in previous evaluations, Saran proved to be the most durable coating system tested. It gave excellent protection to the piling in all three zones of exposure, and its use as a high quality standard should be continued.

#### RECOMMENDATIONS

1. As a result of the 6-month driving and exposure test, coating systems rating 8 or higher on the scale of 10 to 0 are recommended for use in the long-term piling investigations at Port Hueneme and Guam. In some cases it was considered advisable to eliminate coatings from the long-term tests, even though they rated 8 on the scale. For example, in the 6-month exposure test it was found that the hot-applied coal tar enamel was not superior to the cold-applied coal tar paint. Since the hot enamel has the disadvantage of requiring a 475-500 degree Fahrenheit application temperature, its use in the long-term test is not recommended. The coating systems rating below 8 were evaluated carefully to discover reasons for lower ratings; some of these systems, or modifications of them, are recommended for retesting under tidal zone conditions, as discussed in paragraph (3) below.

2. The following coating systems are recommended for use in the long-term driving and exposure tests of coating systems for steel piling:

No. 16 - Asphalt emulsion, mica filled, with wash prime pretreatment and Formula 84 anti-corrosive intermediate coats.

No. 13 - Coal tar base cold-applied paint applied directly to sandblasted steel, with coal tar emulsion top coats. (Note: it is recommended that the coal tar base coating have a dried film thickness of 20 mils, and the coal tar emulsion top coat have a thickness of 10 mils).

The 34Yb coal tar patching material was found inadequate for the protection of damaged areas coated with cold-applied coal tar paint (see Figure 19). It is recommended that piling coated with cold-applied coal tar, and subsequently damaged because of handling procedures, be patched with the original coating material.

No. 20 - Flame-sprayed zinc metal.

No. 9 - Neoprene brushing composition.

No. 7 - Phenolic resin mastic coating.

No. 23 - Saran resin coating.

No. 1 - Vinyl resin - Aluminum coating.

No. 6 - Vinyl resin mastic coating.

3. Coatings which are recommended for testing in tidal zone exposures at Port Hueneme are:

a. Anti-fouling paint systems utilizing vinyl resin top coats and/or thick undercoats possessing good insulation properties.

b. A coal tar base coating blended with an epoxy resin to provide a harder film, more resistant to penetration by barnacles and to abrasion than the systems tested, (12 to 15).

c. System 4, zinc dust pigmented inorganic binder paint, protected from the mudline up with an organic-type finish paint. (Note: this system gave excellent protection in the underground area, partially because of the formation of a silica scale deposit, as shown in Figure 18).

d. One or more modifications of an epoxy resin paint system. There are several modifications of epoxy resin paints available (amine cured, polyamide cured, thiokol modified epoxies, coal tar-epoxy blends). It should be determined which of these modifications possesses better protective qualities when exposed to marine environment. It is recommended that one coating of each modification be selected and tested.

4. During this first driving phase of the piling coating program, the sheet piling were driven interlocked. At the conclusion of the test, separation of the sheet piling was attempted during the pulling operations. The interlocked joints had become tightly bound together during the test period and were difficult or impossible to separate. The strong bond may have been caused by friction and/or rusting between interlocked edges. Shearing of an edge due to forceable separation of two piling sheets is shown in Figure 2. It is recommended, therefore, that in future test operations, the sheet piling be driven separately.

TABLE I. Coating application data and performance ratings after 6-month harbor exposure.\*

System number	Coating description <sup>1</sup>	Primer <sup>2</sup>		Undercoat thickness (mils)	Top coats		Film thickness		Rating <sup>3</sup>
		Type	Coats		Type	Coats	Top coat	Total	
1	Aluminum vinyl	Formula <sup>5</sup> 119	4	3.5	Aluminum vinyl	3	2.0	5.5	8
2	Zinc dust pigment w/polystyrene binder				Zinc dust pigment w/polystyrene binder	3	1.9	1.9	5
3	Epoxy resin	Epoxy AC	2	4.0	Epoxy resin white	3	3.0	7.0	7
4	Zinc dust pigment w/inorganic binder				Zinc dust inorganic <sup>4</sup>	1	2.5	2.5	7
5	Vinyl resin paint	Vinyl primer	1	1.0	Gray vinyl	3	4.4	5.4	7
6	Vinyl mastic	Vinyl primer	1	1.0	Vinyl mastic	2	9.0	10.0	9
7	Fucolic resin mastic	Mica-filled mastic	1	8.5	Gray mastic	1	9.0	17.5	9
8	Furan resin paint	Special primer	1	0.8	Furan resin paint black and gray	6	6.0	6.8	7
9	Neoprene brushing composition	Neoprene primer	1	1.3	Catalyzed neoprene	4	30.0	31.3	9
10	Alkyd resin paint	Iron oxide - zinc chromate alkyd-type	2	2.0	Gray alkyd	2	2.0	4.0	4
11	Chlorinated rubber resin paint	AC red lead quick-drying	1	1.0	High gloss (red)	5	4.0	5.0	6
12	Cold-applied coal tar paint	Coal tar paint <sup>5</sup>	3	28.5	Bituminous emulsion	1	3.0	31.5	8

TABLE I. (continued)

System number	Coating description <sup>1</sup>	Primer <sup>2</sup>		Undercoat thickness (mils)	Top coats		Film thickness		Rating <sup>3</sup>
		Type	Coats		Type	Coats	Top coat	Total	
13	Cold-applied coal tar paint	Coal tar paint	3	22.0	Bituminous emulsion	1	4.0	26.0	8
14	Cold-applied coal tar paint	Coal tar paint <sup>5</sup>	4	29.0				29.0	8
15	Cold-applied coal tar paint <sup>6</sup>	Coal tar paint	5	25.0				25.0	8
16	Mica-filled asphalt emulsion	AC formula <sup>5</sup> 84	1	2.3	Asphalt emulsion black	6	28.8	31.1	9
17	Gilsonite asphalt paint				Gilsonite paint (black)	5	25.0	25.0	7
18	Cold plastic anti-fouling paint, Formula 145	AC formula <sup>5</sup> 14	2	4.4	Formula 145	4	17.0	21.4	6
19	Hot-applied coal tar enamel and primer 347b	Coal tar primer	1	1.3	Coal tar enamel	1	90.0	91.3	8
20	Flame-sprayed zinc metal				Flame-sprayed zinc metal		5.0	5.0	9
21	Flame-sprayed aluminum metal	Steel bond coat (flame-sprayed)		0.5	Flame-sprayed aluminum metal		5.0	5.5	9
22	Hot plastic anti-fouling paint Formula 15 IP	AC formula <sup>5</sup> 14	2	3.0	Hot plastic anti-fouling	1	31.0	34.0	4
23	Saran-Formula 113/49				Saran resin paint	6	5.0	5.0	9

TABLE I. (continued)  
References

Painting were prepared for painting by sandblasting the surface to a uniform, dull matte finish.

1. Coating systems are described by the type of top or finish coat applied.
2. Primer classification: AC - containing anticorrosive pigments, such as red lead or zinc chromate; other types classified by the binder present.
3. Ratings were based on the ASTM Photographic Reference Standard for evaluating degree of resistance to rusting in which 10 indicates coating which had an intact film and permitted no rusting in any area; and 0 indicates coating which had lost all protective value.
4. A curing solution was applied after the paint coating had dried approximately 2 hours.
5. One coat of pretreatment formula 117 applied over sand-blasted steel.
6. 34Y coal tar patching material applied over purposely damaged areas of system 15.

TABLE II. Code designation of coating systems used in the 6-month pile-driving and exposure tests.

OFFICIAL USE ONLY

System number	Primer	Finish coat	Supplier
1	Formula 117 (MIL-C-15323) Formula 119 (MIL-C-15929)	Aluminum vinyl S-2432-C	Stoner Midge Inc. 200 West Hall Street Pittsburgh, Pa.
2		Galvicon	Galvicon Corporation 40 West 29th Street New York, New York
3	Nupon A - orange	Nupon A - white	The Glidden Company San Francisco 7, Calif.
4		Dimetcote No. 3	Amercoat Corporation 4809 Firestone Blvd. South Gate, Calif.
5	Amercoat No. 86	Amercoat No. 33	"
6	Amercoat No. 86	Amercoat No. 87	"
7	Phenoline No. 300 - Orange (mica filled)	Phenoline No. 300 (gray)	Carboline Company 331 Thornton Avenue St. Louis 19, Missouri
8	Rustbond primer	Furan B resin (black and gray)	"
9	Neoprene 100 primer	Neoprene 100, finish	"
10	Kerostal TM 1	Kerostal TM 131	Kerostal Products 353 Tehama Street San Francisco, Calif.
11	Inertol No. 626	Torex enamel	Utilities Supply Co. 1736 East 15th Street Los Angeles 21, Calif.
12-15 Incl.	Formula 117 (MIL-C-15323)	(MIL-G-18400) Bitumastic No. 50 (MIL-C-15203) Bituplastic No. 28 34% patching and maintenance material	Koppers Company Post Office Box 486 Fontana, California  Middlewest Engineering Company, Inc. P. O. Box 111 Kansas City, Missouri
16	Formula 117 (MIL-C-15323) Zinc chromate, Formula 24 (Jan-P-735)	Laykold fibre coat No. 3	American Bitumuls and Asphalt Company 200 Bush Street San Francisco, Calif.

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TABLE II. (continued)

System number	Primer	Finish coat	Supplier
17		Gilsomastic	American Marietta Valdura Division 101 East Ontario St. Chicago, Illinois
18	Formula 117 (MIL-C-15328) Formula 14 (MIL-P-18996)	Formula 145 - cold plastic	Navy Supply
19	Bitumastic 70-B primer (MIL-P-15147)	Bitumastic 70-B-coal tar enamel (MIL-P-15147)	Koppers Company Post Office Box 486 Fontana, California
20		(MIL-M-3800) zinc wire	Navy Supply
21	(MIL-M-3800) steel bond	(MIL-M-3800) aluminum wire	"
22	Formula 117 (MIL-C-15328) Formula 14 (MIL-P-18996)	Formula 15, hot plastic (MIL-P-18994-A)	"
23		Formula 113/49	"

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Figure 1. Phenolic resin coating. Slight damage.



Figure 2. Cold plastic AF 145 coating. Spalling at bottom of piling.



Figure 3. Mica filled asphalt emulsion. Damage due to cutting action of rocks.



Figure 4. Asphalt mastic. Plastic flow resulted in non-uniform coating.



Figure 5. Flame sprayed zinc metal. Light fouling attachment mostly algae.

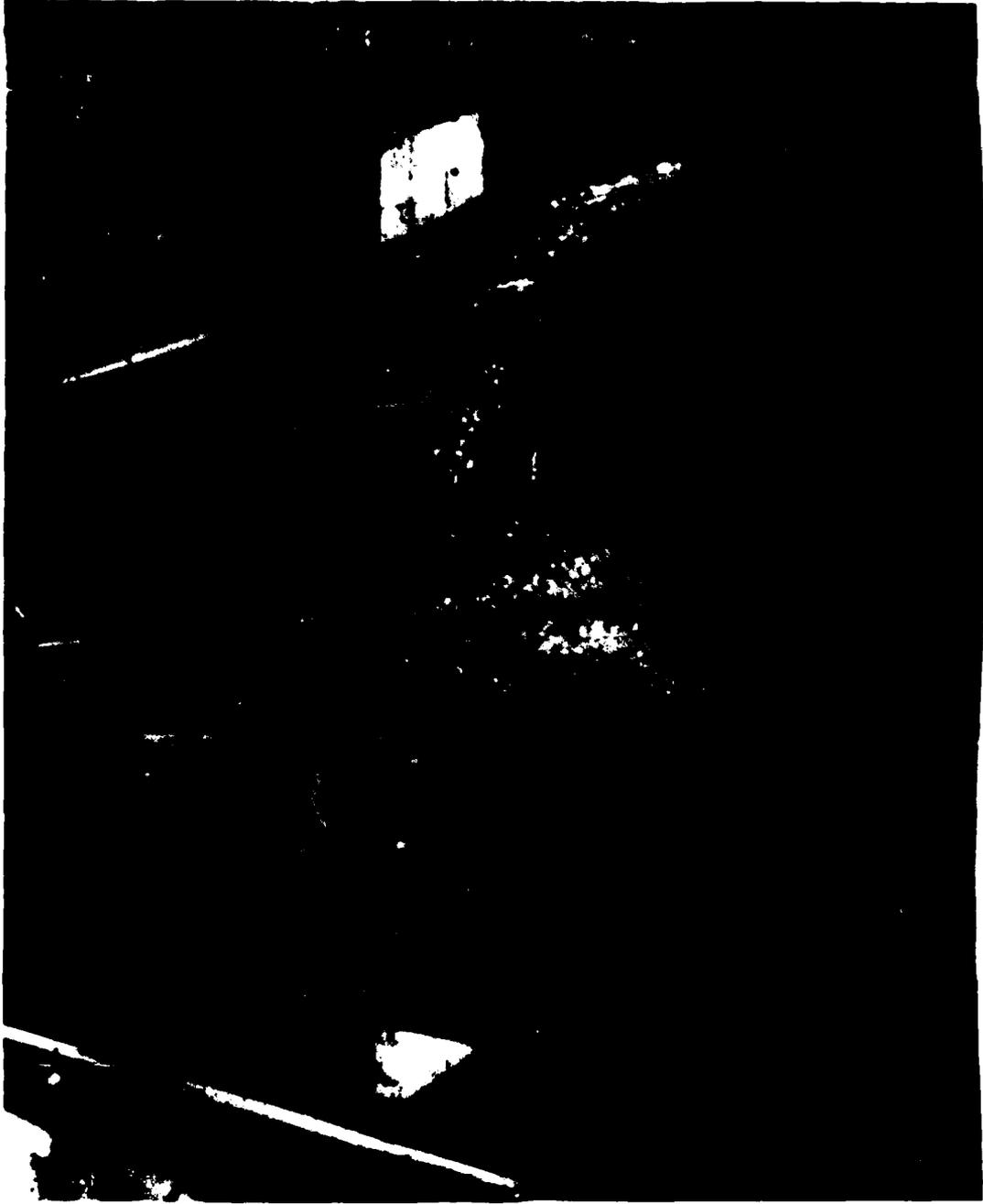


Figure 6. Aluminum vinyl coating. Algae and barnacle attachment.

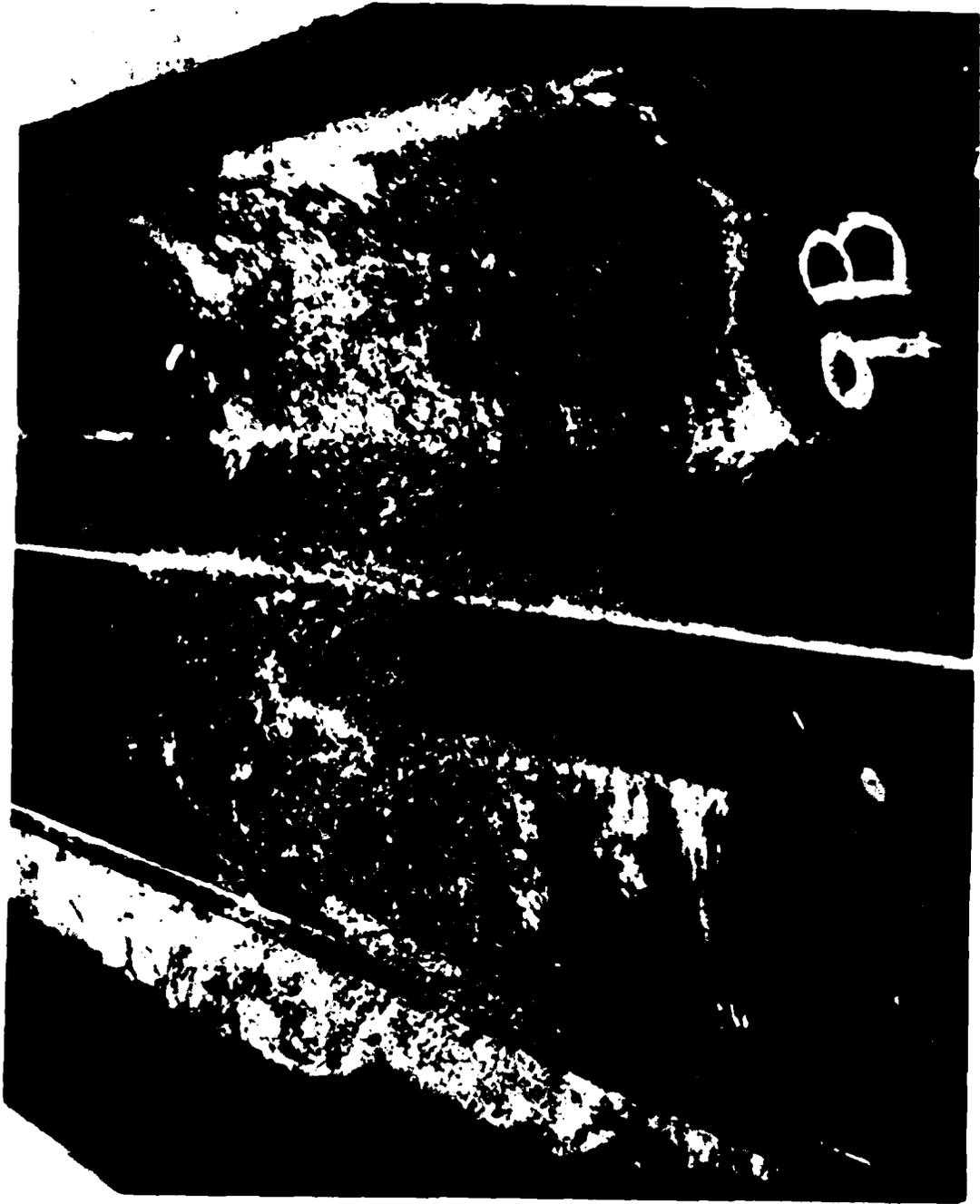


Figure 7. Neoprene coating. Heavy fouling attachment.  
No damage to coating.



Figure 8. Coal tar enamel. Heavy fouling attachment. Barnacles have damaged the coating.



Figure 9. Vinyl mastic. No appreciable abrasion.



Figure 10. Zinc dust inorganic binder-type coating.  
Some abrasion and very slight rusting.



Figure 11. Chlorinated rubber resin coating. Severe abrasion damage and rusting.



Figure 12. Hot plastic antifouling top coat removed by abrasion.  
Some areas rusted.



Figure 13. Saran coating. Practically no rusting.

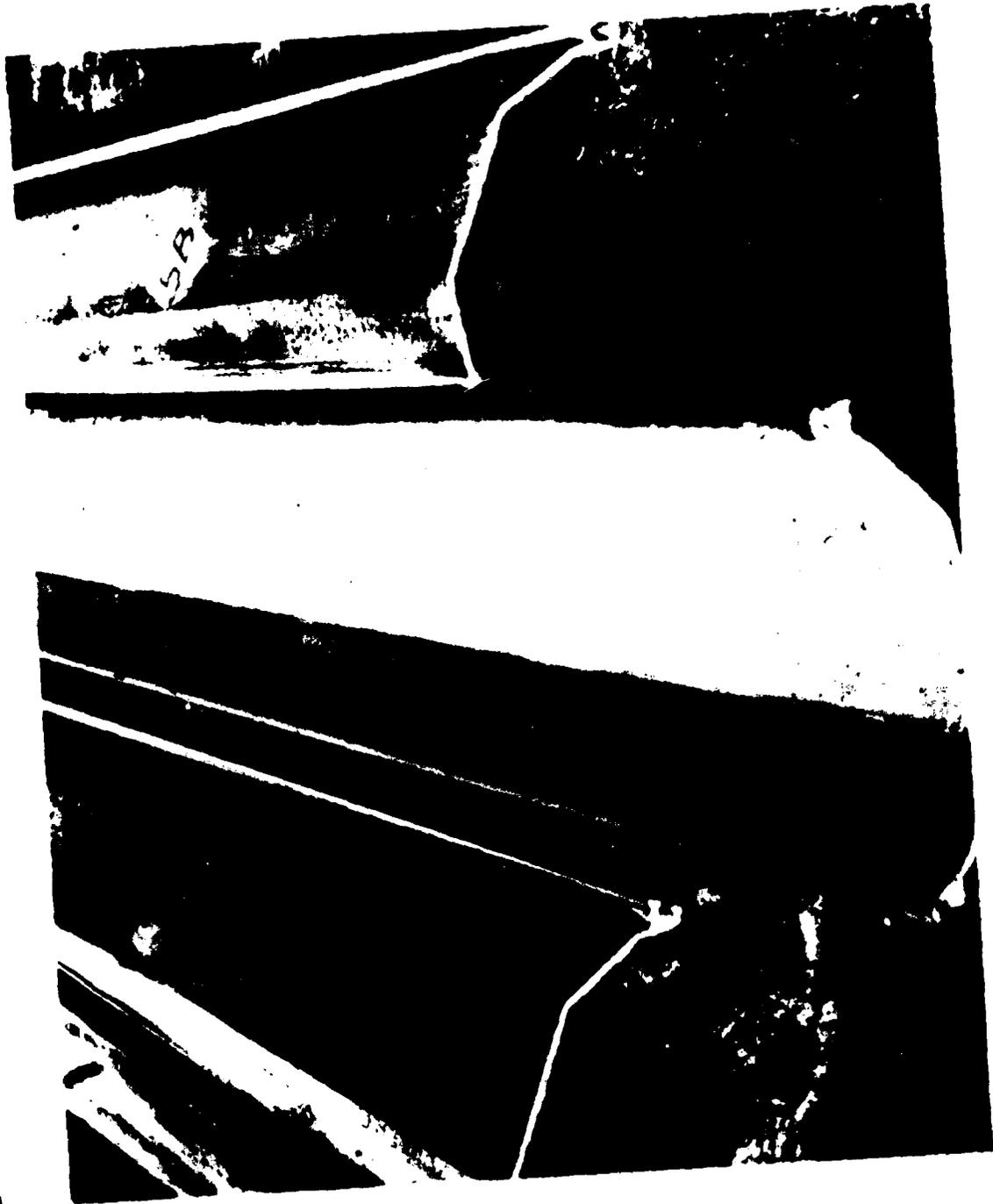


Figure 14. Vinyl resin paint (5B). Slight rusting.



Figure 15. Epoxy resin paint coating. Severe rusting in localized areas.

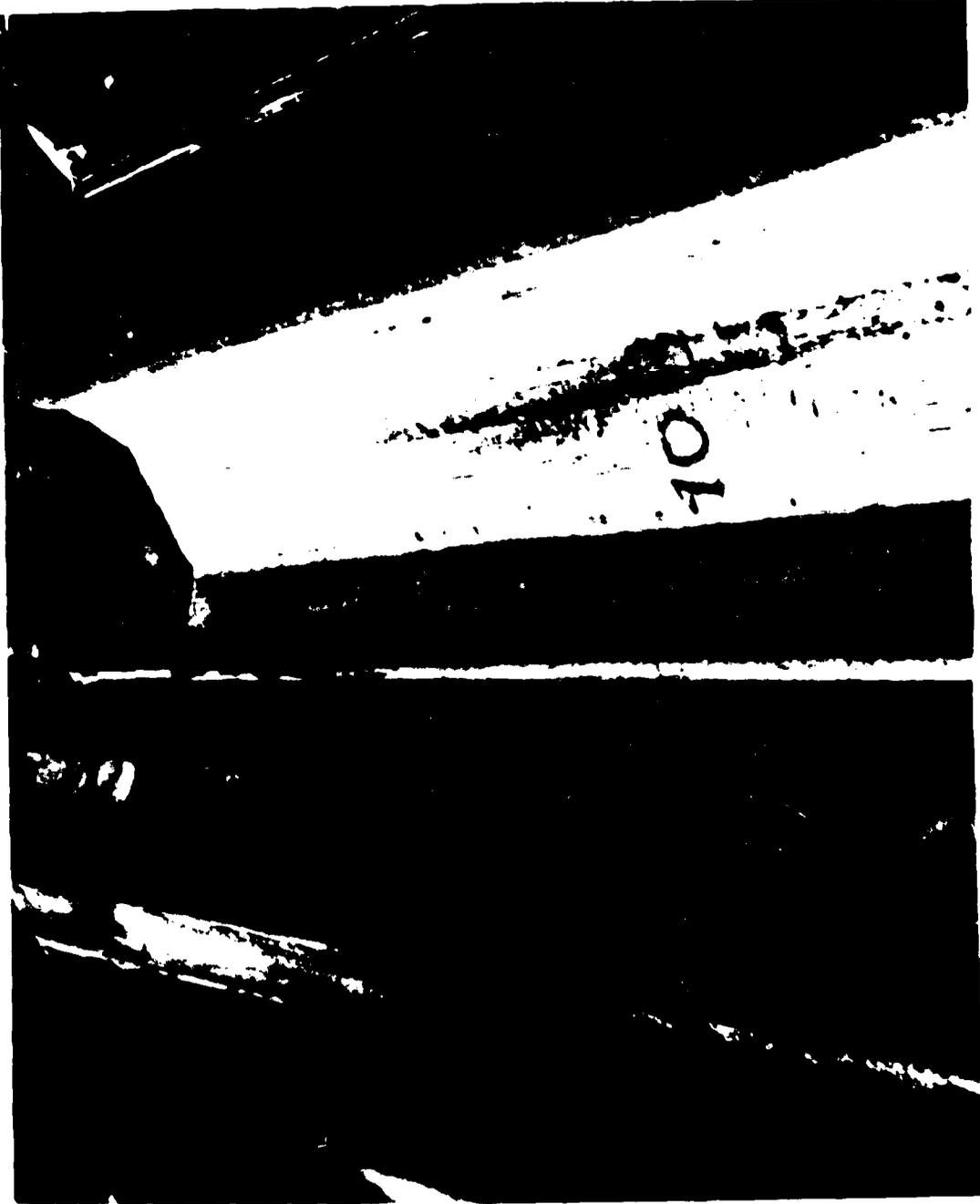


Figure 16. Alkyd resin paint. General rusting.



Figure 17. Scale deposited on an aluminum metal coating during underground exposure.



Figure 18. Close-up view of a silica scale formed on a coating containing zinc dust in an inorganic binder.



Figure 19. Failure of coal tar patching and maintenance material applied over damaged cold applied coal tar coating.