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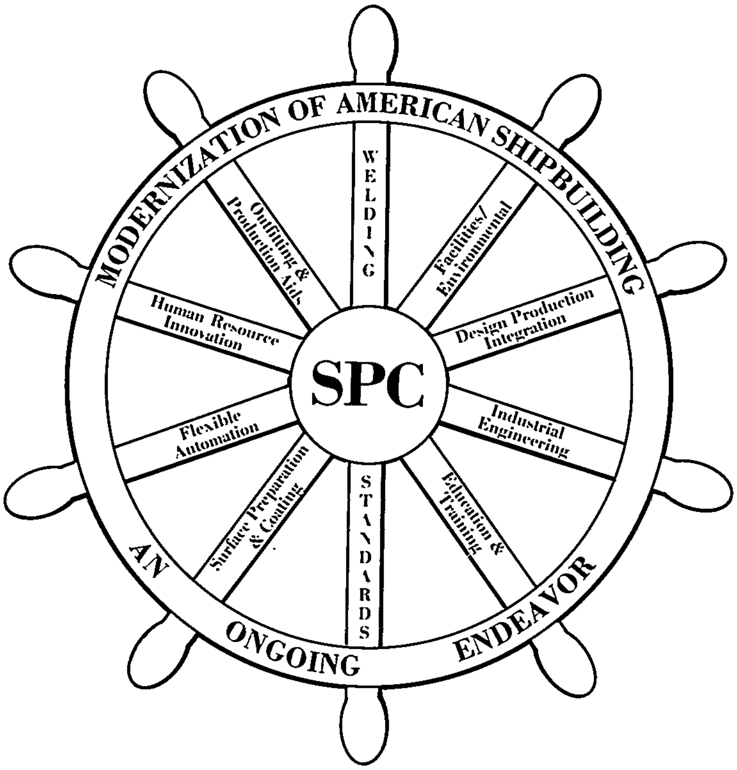

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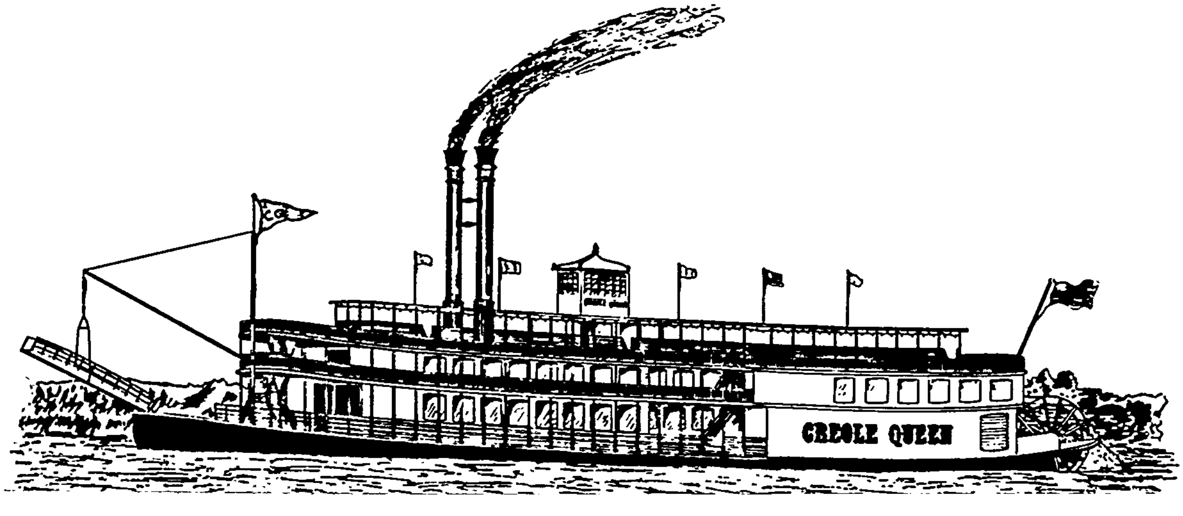

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Overcoating Inorganic Zinc Primers for Underwater Service

No. 25

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ABSTRACT

During ship construction, steel hull plate is normally protected with an inorganic zinc pre-construction primer. For the underwater portion of the hull, conventional practice is to remove the primer by abrasive blasting before final coating of the hull. If the requirement for removing the pre-construction primer could be eliminated, there would be a significant cost savings. As a result, a laboratory study was undertaken to investigate the performance of selected marine coatings when applied over inorganic zinc primers in underwater service. In general, the results of the study suggest that there are inorganic zinc pre-construction primers that can be overcoated for underwater service. The results encourage further tests to investigate the parameters affecting compatibility.

INTRODUCTION

In new ship construction, the structural steel plate used to fabricate the hull is often protected with an inorganic zinc pre-construction primer. The pre-construction primer provides corrosion protection to the steel during fabrication. After fabrication, the general practice in U.S. shipyards has been to remove the pre-construction primer on the underwater portion of the hull before application of any subsequent coats. This is done to eliminate blistering and disbondment of the topcoat which reportedly can occur when inorganic zinc coatings are overcoated in underwater service (1), (2),(3),(4).

Japanese shipyards are overcoating inorganic zinc pre-construction primers on the underwater portion of the hull. Reportedly, the Japanese are able to overcoat without problems because they are using pre-construction primers that have very low zinc levels and are less reactive, with less of a tendency to liberate hydrogen gas when contacted by water. The lower zinc levels do not provide comparable corrosion protection to those traditionally used in U.S. yards. However, the turn-around time for steel plate fabrication in the Japanese yards is supposedly lower then in U.S. yards (2-3 months vs. 6-9 months), and thus it is believed the additional corrosion protection is unnecessary.

Based on the reported practice in the Japanese shipyards, a study was undertaken whose objectives were as follows:

- To determine whether it is necessary, for underwater marine service, to remove inorganic zinc pre-construction primers by abrasive blasting prior to the application of subsequent coatings.
- To compare the propensity of different inorganic zinc primers (pre-construction vs. full-coat) to cause topcoat blistering in underwater service.
- To evaluate the effect of different inorganic zinc primer weathering periods on topcoat blistering susceptibility.
- To determine to what extent cathodic protection will affect the performance of coatings applied over inorganic zinc primers.

EXPERIMENTAL APPROACH

General Test Plan

The general test plan comprised the evaluation of three different epoxy topcoats over each of five inorganic zinc primers. Prepared test panels were exposed to three different test environments: (1) quiescent seawater immersion at a potential of -1.0 volt vs. SCE, (2) quiescent seawater immersion at 150°F, 25 psi, and (3) flowing seawater at 18 knots.

Coatings Selected For Testing

Table I describes each of the five inorganic zinc primers selected for testing. The test matrix included three pre-construction primers and two full-coat systems, among which was a Japanese pre-construction primer.

Table II describes the topcoats included in the test program -- a coal tar epoxy, a MIL-P-23236 epoxy, and a MIL-P-24441 epoxy. The coal-tar epoxy was included as a benchmark because of its wide use on the underwater portion of ship hulls. The MIL-P-23236 coating was selected because it is recommended as a tank coating over inorganic zinc primers. The MIL-P-24441 coating system was included since it is the standard U.S. Navy underwater hull coating.

Test Panel Preparation

The inorganic zinc primers were applied to ASTM A-366 steel panels, white-metal blasted to obtain a surface profile between 1-2 mils. The nominal panel dimensions were 6" x 12" x 1/8" thick for quiescent immersion testing and 5 1/4" x 7 1/2" x 1/2" thick for flow testing.

The inorganic zinc primers were applied by airless spray using an automated application system designed to provide close control of applied film thickness. The system utilized a fixed spray gun with apparatus for moving the test panel by the spray gun nozzle at a controlled speed. After coating, the

Table I

GENERAL DESCRIPTION OF INORGANIC ZINC PRIMERS SELECTED FOR TESTING

Coating No.	Description
1	U.S. manufactured, single component, alkyl silicate type shop primer, 35% zinc in the dry film, recommended dry film thickness = 0.6 - 1.0 mil.
2	U.S. manufactured, 2-component, modified zinc silicate shop primer, 86% zinc in the dry film, recommended dry film thickness = 0.6 - 1.0 mil.
3	Japanese manufactured, 2-component shop primer, 50% zinc in the dry film, recommended dry film thickness = 0.5 - 0.7 mil.
4	U.S. manufactured, 2-component, full-coat primer, 60% zinc in the dry film, recommended dry film thickness = 3.0 mils.
5	U.S. manufactured, 2-component, full-coat primer, 85% zinc in the dry film, recommended dry film thickness = 2.0 mils.

Table II

GENERAL DESCRIPTION OF TOPCOATS SELECTED FOR TESTING

Coating No.	Description
1	Two-component, polyamide-cured high-build coal-tar epoxy, 67% volume solids, recommended application thickness = 5 mils (DFT)/coat.
2	Two-component, polyamide-cured epoxy, 56% volume solids, recommended application thickness = 5 mils (DFT)/coat. Meets MIL-P-23236, Type 1, Class 1.
3	Two-component, polyamide-cured epoxy, recommended application thickness = 2-3 mils (DFT)/coat. Standard U.S. Navy underwater hull coating meeting MIL-P-24441, Type 1.

dry film thickness on all test panels was determined using an Elcometer magnetic thickness gauge. The average dry film coating thicknesses of the respective inorganic zinc primers were as follows:

Primer #1 - 1.0 mil

Primer #2 - 0.7 mil

Primer #3 - 0.8 mil

Primer #4 - 4.2 mils

Primer #5 - 2.1 mils

After application of the zinc primers, all test panels were weathered on the test fences at the Ocean City Research Corporation marine exposure test site. This test site provides a natural marine atmosphere and is located approximately 300 feet from the ocean. In order to evaluate the effect of different weathering times, one-half of the test panels were exposed for 7 days and the other half for a period of 60 days. After weathering, all test panels were lightly sanded with 600 grit silicon carbide paper to remove any zinc corrosion product (white rust).

After sanding, the test panels were topcoated with one of the three epoxy topcoats. The topcoat systems were applied in accordance with manufacturer's directions using hand-controlled airless spray equipment. After coating, all panels were inspected for "holidays" using a wet-sponge, 67.5 volt holiday detector. All holidays were suitably repaired. The panels were allowed to cure for 10 days before being placed into test.

After topcoating, the dry film thickness of all panels was again determined using the same equipment as described previously. The average dry film coating thicknesses of the respective topcoat systems were as follows:

Coal-tar epoxy - 9.6 mils (applied in 2 coats)

MIL-P-23236 - 11.0 mils (applied in 2 coats)

MIL-P-24441 - 9.2 mils (applied in 3 coats)

During application of the topcoats, some blistering problems were encountered. Depending on the particular primer over which the topcoat was being applied, small blisters or pinholes developed almost immediately after topcoating. This problem occurred even with the application, first, of a thin mist coat (0.25 to 0.5 mil) which was allowed to tack up before applying the full coat. The problem was most evident on zinc primers #4 and #5, the two full-coat inorganic zincs included in the program. Little or no blistering was observed over the thinner pre-construction primers. Those test panels where pinholing occurred during topcoating were lightly sanded and then recoated with a thin topcoat to seal the pinholes.

As an experimental benchmark, the respective topcoats were also applied to white-metal blasted steel test panels. No application problems were encountered on these test panels.

Duplicate test panels of each coating system were prepared for each of the seawater immersion exposure tests. For the flow test, single panels were prepared. The total number of test panels prepared for exposure testing was 165.

Performance Testing

Three different types of exposure test were conducted in the study to evaluate the performance of the selected topcoats applied over the different inorganic zinc primers. These tests included: (1) quiescent seawater immersion at a potential of -1.0 volt vs. SCE (2) quiescent seawater immersion at 25 psi, 150°F and (3) seawater flow at 18 knots.

Seawater Flow at 18 Knots. The natural seawater flow channel permits velocity testing under flow conditions that are reasonably representative of the flow conditions that would exist over a major portion of a ship's hull--fully developed parallel, turbulent, high Reynolds Number, seawater flow. The flow channel accommodates test panels large enough to minimize edge and/or boundary effects. The width of the channel cross section varies along the length permitting testing at different flow velocities simultaneously. Figure 1 shows the flow channel while Figure 2 shows the method by which test panels are typically mounted in the flow channel.

Seawater flow through the channel is accomplished using a double-suction centrifugal pump powered by a 100 HP motor. The flow rate exceeds 5,000 gpm and is measured using a calibrated 316 stainless steel orifice plate/differential pressure gauge set-up. The rate of seawater make-up into the channel can be adjusted to control seawater temperature to within ± 4.5°F and is maintained sufficiently high to avoid stagnation or concentration effects.

A single test panel (5 1/4" x 7 1/2" x 1/2" thick) for each weathering/primer/topcoat condition was exposed in

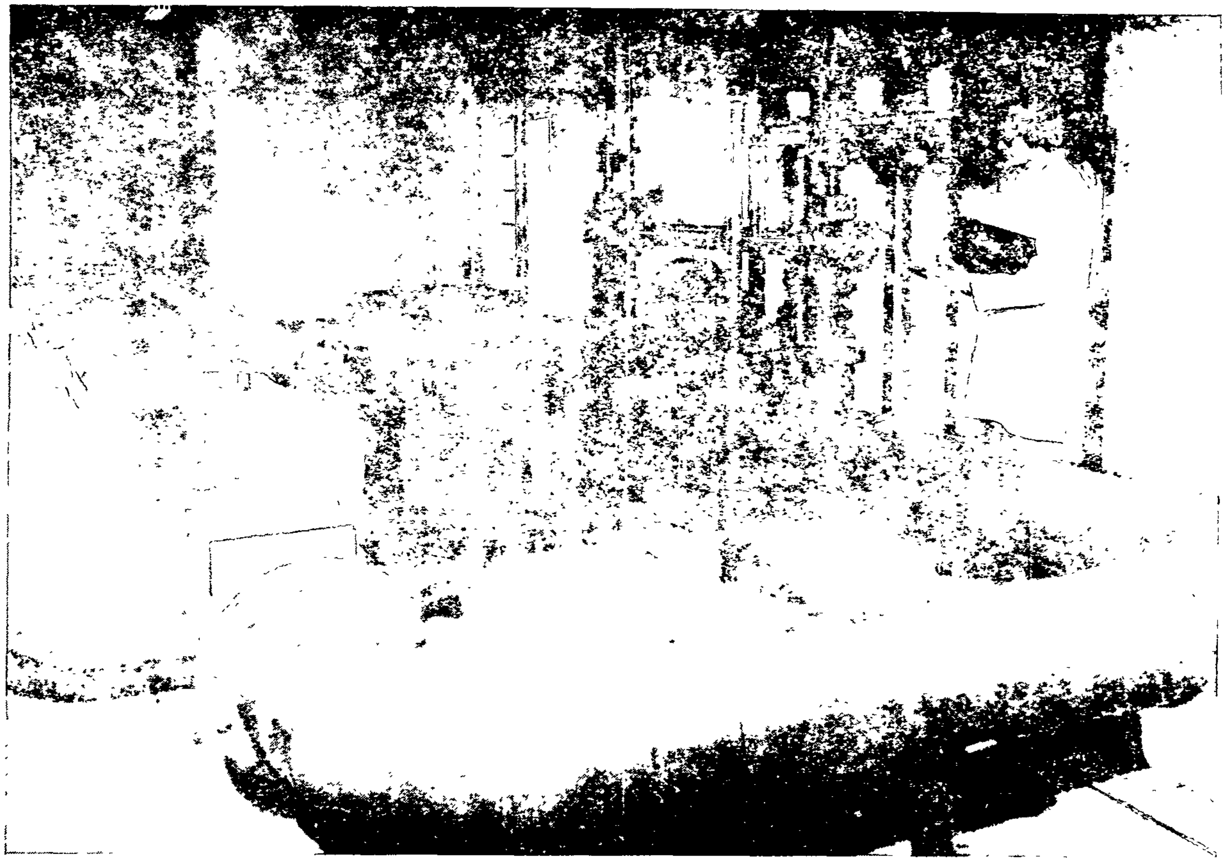

Figure 1 - Flow Channel

a natural seawater flow channel for a period of 60 days at a velocity of 18 knots. Both sides of each panel were scribed at the center (1" vertical scribe) with a razor knife. In this way, each side of the panel represented a duplicate exposure.

After the first 30 days of test, the intentional scribe on those panels not evidencing any significant failure (disbondment area ≤ 1 in^2) was modified. The original 1" vertical razor scribe was widened to 1" x 1/4" rectangular holiday. All zinc primer within the holiday area was removed to expose bare steel. Coatings which had disbonded over 1 in^2 were recoated with a MIL-P-24441 epoxy and left in test without a scribe.

<u>Quiescent Seawater Immersion @-1.0 volt.</u> Duplicate test panels (6" x 12" x 1/8" thick) for each weathering/primer/topcoat condition were suspended in 100-gallon plastic tanks filled with fresh seawater. The seawater tanks were continually refreshed at a rate sufficient to effect a complete changeover 3 times a day. The seawater temperature was maintained at 70°F.

A lead wire was attached to each test panel facilitating electrical connection to a zinc anode. Electrical coupling to a zinc anode maintained the test panels at a potential of -1.0 volt versus a saturated calomel electrode. Prior to the start of test, each test panel received a 1/4" radial holiday directly in the center of one side. The test duration was 6 months.

<u>Quiescent Seawater Immersion @ 25 psi, 150°F.</u> Duplicate test panels were immersed in seawater maintained at 25 psi, 150°F. Each test panel had a 1" vertical scribe centered on one side. The panels were mounted in PVC racks. The racks were then inserted into a 12-inch diameter PVC pipe which served as the test chamber. A pump provided seawater make-up while maintaining a positive pressure of 25 psi inside the pipe . The make-up flow was sufficient to effect a complete changeover once a day. The temperature was controlled at 150°F with two thermosensors immersed in the test chamber which were electrically coupled through an appropriate temperature controller to a nichrome heating element wrapped around a titanium tube in the seawater supply line. The seawater was constantly circulated through the heating tube to maintain temperature. The test duration was 6

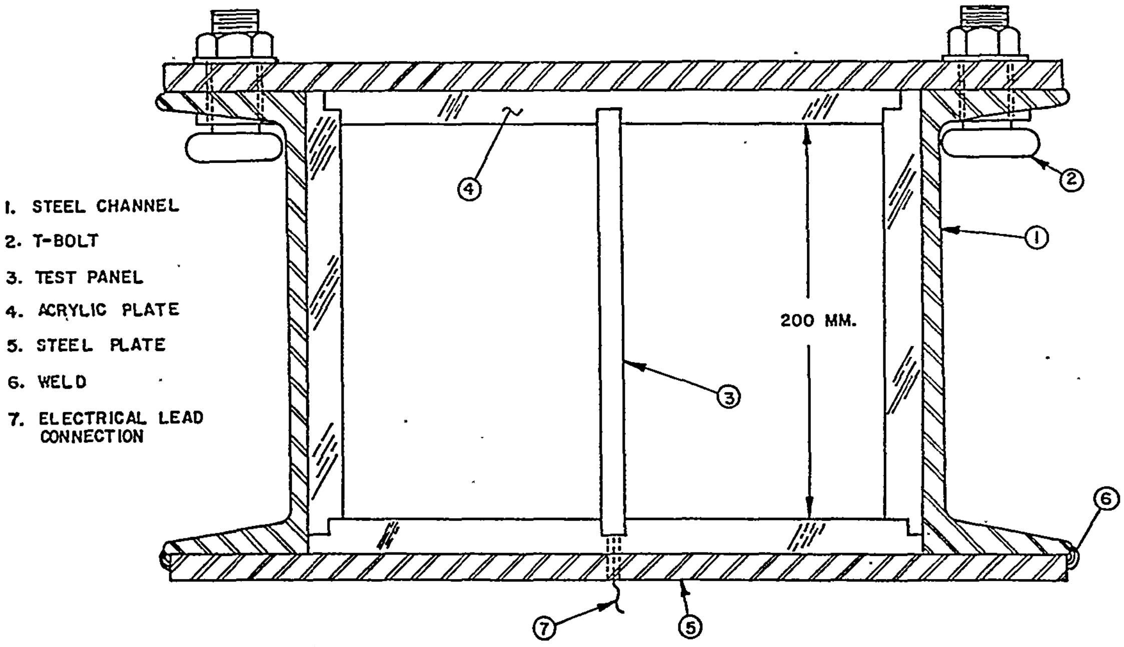

Figure 2 - Typical Test Panel Arrangement in the Flow Channel

months.

Inspection/Evaluation Procedures

During the course of each of the three exposure tests, the test panels were periodically removed, visually inspected, and rated for blistering, disbondment, and/or other forms of deterioration. At the conclusion of each test, the total extent of coating disbondment was determined by lifting all loose or disbonded coating with the point of a knife.

RESULTS AND DISCUSSION

Weathering of Inorganic Zinc Primers Before Topcoating

Visual inspection of the inorganic zinc primed panels after the two different weathering exposures (7 days, 60 days) showed significant differences on only one primer (#1). For system #1, the panels exposed for 60 days exhibited extensive rust-through while those exposed for only 7 days showed no evidence of rust-through. Of the three pre-construction primers, primer #1 had the lowest zinc loading in the dry film based on the manufacturers' specifications.

For the other four inorganic zinc primers, there were only slight, visually detectable differences between the 7-day and 60-day panels, with the 60-day panels exhibiting slightly more corrosion product (white rust).

Seawater Flow Test

There were 16 separate instances where significant disbondment (greater than 1 in^2) occurred during the 60-day test. Of these, 6 occurred within the first 24 hours after start-up and 15 occurred within the first 30 days. Of the 13 test panels that exhibited disbondment failure during the test, failure on both sides occurred on only 3 test panels. Analysis of these results at 30 days raised concern about the seemingly poor replication. It was felt at this time that there might have been differences traceable to the knife-cut scribe initially made at the center on each side of each panel. All disbondment failures had initiated at the scribe. Thus, at this point, the intentional holiday was expanded from a knife-cut scribe to a 1" x 1/4" rectangular window which was felt would provide more uniformity. However, the lack of further failures (excepting the control) during the latter 30 days of the test precluded obtaining any further insight regarding this concern.

Where the topcoats did disbond, there was extensive rusting of the substrate (Figure 3). This observation suggests that the zinc primers tend to sacrifice rapidly once exposed to flowing seawater. Furthermore, it suggests that, at scribes or holidays, topcoats may be prone to underfilm lifting as the zinc coating dissolves. Topcoat disbondment due to dissolution of the zinc primer exposed at a holiday may decrease with time as the zinc corrosion products build up and plug the underfilm paths. The occurrence of such a phenomenon might account for the lack of further disbondment over the latter 30 days of the test.

Table III lists the total area of disbondment which occurred over each inorganic zinc primer. The data in Table III show that the least amount of topcoat disbondment occurred over primer #1 while the most disbondment occurred over primer #4. There was clearly a marked propensity for topcoat disbonding over primer #4 compared to other primers. Primer #4 is a 2-component, full-coat system which was applied at an average thickness of 4.2 mils (the heaviest applied thickness included in the study).

Of special interest was the comparative topcoat performance over primer #3, a Japanese pre-construction primer whose manufacturer suggests can be topcoated (without need of washdown or sandsweep) for underwater service. As is evident, significant disbondment occurred on two of the six test panels within 30 days. On both panels, some degree of disbondment was observed within 24 hours after start of the test.

Comparison of the disbondment results by topcoat shows that topcoat #3, the standard Navy hull coating (MIL-P-24441, Type I), exhibited the least amount of disbondment over 60 days. For this topcoat, disbondment occurred only on those panels primed with primer #4.

For three out of five primers, the total area of topcoat disbondment was greater on the panels weathered for 60 days versus 7 days. This observation is somewhat surprising -- in planning the study it had been felt that aging or weathering of the inorganic zinc primers would tend to reduce their inherent porosity (due to plugging of the pores with corrosion products) thereby reducing the tendency to blister and disbond. Additional data would be required however to establish that this observation is statistically significant.

Comparison of the results for all inorganic zinc primers versus the results obtained for the control panels indicates the only primer for which there is a clear-cut evidence of increased susceptibility to disbondment is primer #4.

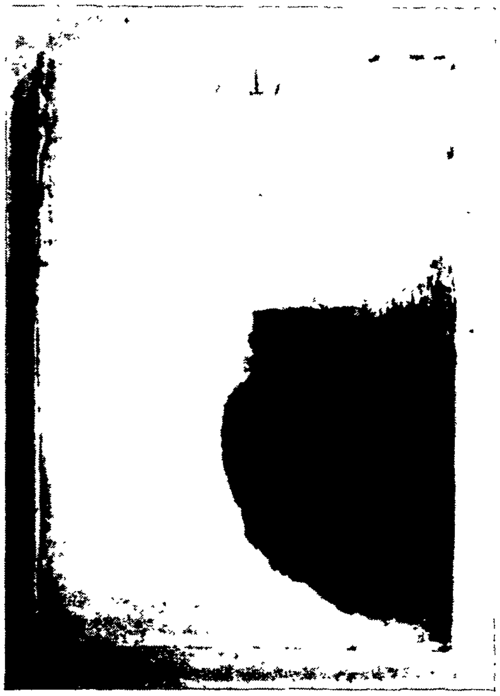

Figure 3 - Topcoat #2 over Primer #4 after 30 Days Exposure to Flowing Seawater at 18 Knots

Quiescent Seawater Immersion @-1.0 Volt

Of the 66 panels exposed in this phase of the test program, only four test panels exhibited blistering (excluding the area immediately around the holiday). Table IV summarizes the observed blistering after 6 months. The blistering was first detected after 3 months exposure. Figure 4 shows the blistering observed for topcoat #2/primer #4 after 6 months of testing. The blistering occurred at the zinc/topcoat interface.

Table V summarizes the blistering observed immediately around the holiday after 6 months exposure. Blister formation at the holidays was first detected as early as one month into test. None of the panels which exhibited blistering at the holiday showed blistering elsewhere on the surface. This observation suggests that blistering outside the holiday area occurs by a different mechanism than that at the holiday.

Table VI summarizes the extent of

disbondment which occurred about the holidays over the 6-month test. There was only one case (topcoat #1/primer #3) where disbondment over an inorganic zinc primed panel was outside the disbondment range exhibited by the control panels. Comparing just the inorganic primers, there appeared to be more of a tendency for cathodic disbondment with primers #1, #2, and #3 than with primers #4 and #5 (the full-coat primers). As in the flow tests, the MIL-P-24441 epoxy topcoat system (topcoat #3) exhibited the least susceptibility to blistering and disbondment.

Quiescent Seawater Immersion @ 25 psi, 150°F

Table VII presents the results of the quiescent seawater immersion tests at 25 psi and 150°F. The data in Table 6 show that topcoats applied over primer #4 were especially susceptible to rapid and extensive blistering. The results appeared to be insensitive to the length of weathering period. Figure 5 shows the appearance of topcoat #3 over primer #4 after a month in test.

Table III

TOTAL AREA OF DISBONDMENT
AFTER 60-DAY SEAWATER FLOW TESTS

Inorganic Zinc Primer	Weathering Period	Area of Disbondment, in^2 Topcoat #1	Topcoat #2	Topcoat #3	Total
#1	7-day	0.00	0.59	0.00	0.59
#1	60-day	0.16	0.41	0.22	0.79
#2	7-day	7.62	0.02	1.08	8.72
#2	60-day	0.00	8.59	0.12	8.71
#3	7-day	0.09	21.0	0.08	21.17
#3	60-day	5.00	0.12	0.15	5.27
#4	7-day	8.00	12.13	4.30	24.43
#4	60-day	24.00	1.36	13.69	39.05
#5	7-day	0.91	0.16	0.00	1.07
#5	60-day	0.06	20.00	0.11	20.17
Control	-	50.53	7.34	0.16	58.03
	Total	96.37	71.72	19.91	

Table IV

BLISTERING OBSERVED AFTER 6 MONTH QUIESCENT
SEAWATER IMMERSION @ -1.0 VOLT

Inorganic Zinc Primer	Weathering Period	Topcoat	Description
#3	60-Day	#2	Few 1/32" blisters were observed on both of the replicate test panels
#4	7-Day	#2	Medium 1/16"-1/8" blistering on single test panels
#4	60-Day	#2	Medium 1/32"-1/16" blistering on single test panel

Table V

BLISTERING OBSERVED IMMEDIATELY AROUND HOLIDAY AFTER 6 MONTH QUIESCENT SEAWATER IMMERSION @ -1.0 VOLT

Inorganic Zinc Primer	Weathering Period	Topcoat	Description
#1	7-Day	#1	Medium 1/64"-1/32" blistering
#1	7-Day	#2	Medium 1/64"-1/32" blistering
#1	60-Day	#1	Medium 1/64"-1/32" blistering
#1	60-Day	#2	Few 1/64"-1/32" blisters
#1	60-Day	#3	Few 1/32"-1/16" blisters
#2	7-Day	#1	Few 1/16" blisters
#2	7-Day	#2	Few 1/4" blisters
#2	60-Day	#1	Few 1/64"-1/32" blisters
#2	60-Day	#2	Few 1/32" blisters
#3	7-Day	#1	Few 1/64"-1/32" blisters
#3	7-Day	#2	Few 1/64"-1/32" blisters
Control	-	#2	Medium 1/64"-1/32" blistering

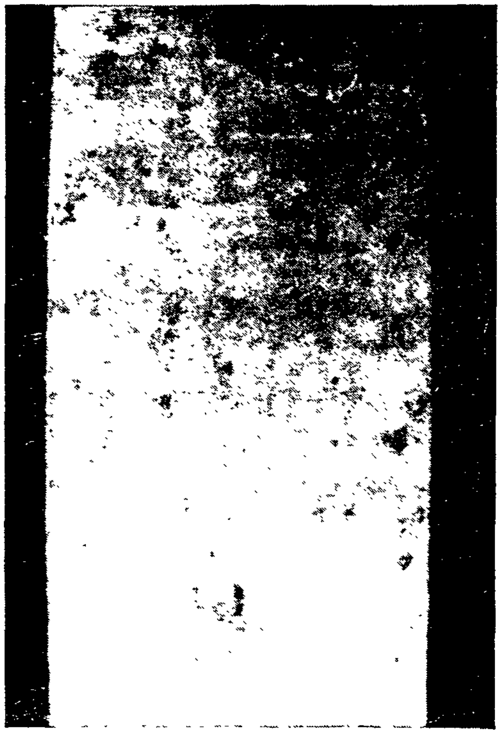

Figure 4 - Topcoat #2 over Primer #4 Weathered for 7 Days after 6 Months Exposure in Quiescent Seawater at -1.0 Volt

Blistering also occurred quickly and extensively over primer #3 but only on those test panels where the primer was weathered for 60 days. A further examination of the data reveals that the topcoats applied on test panels weathered for 60 days were far more likely to blister than those applied on panels weathered for just 7 days. Eighty percent of the test panels weathered for 60 days exhibited blistering of the topcoat compared to forty percent of the panels weathered for 7 days.

Table VIII summarizes the extent of blistering observed within 1 inch of the intentional scribe. These results are consistent with the results for the general surface area. The heaviest topcoat blistering near the scribe was detected on those panels primed with primer #4 (both weathering periods) and primer #3 (60-day weathering period). Again, there was a greater tendency for blistering on those panels weathered for 60 days versus 7 days.

Table IX lists the total area of topcoat disbondment adjacent to the scribe. As with the blistering observations, the worst topcoat disbondment occurred over primer #4 and primer #3 weathered for 60 days. The remainder of the test panels exhibited disbondment that was not significantly differ-

Table VI

AVERAGE AREA OF DISBONDMENT AFTER 6 MONTH QUIESCENT SEAWATER IMMERSION @ – 1.0 VOLT

Inorganic Zinc Primer	Weathering Period	Average Area Of Disbondment, in^2 Topcoat #1	Topcoat #2	Topcoat #3	Total
#1	7-Day	0.47	0.31	0.23	1.01
#1	60-Day	1.05	0.42	0.16	1.63
#2	7-Day	0	1.98	0	1.98
#2	60-Day	0.56	0.34	0.03	0.93
#3	7-Day	0.20	0.74	0	0.94
#3	60-Day	4.82	0.37	0.26	5.45
#4	7-Day	0	0	0	
#4	60-Day	0	0	0	
#5	7-Day	0	0	0	
#5	60-Day	0	0	0	
Control	-	0.53	2.17	0	2.70
	Total	7.63	6.33	0.68	

Table VII

RESULTS OF QUIESCENT SEAWATER IMMERSION TESTING @ 25 psi, 150°F

Primer #	Topcoat #	Weathering Period	Panel #	Comments
#1	#1	7-day	#1	Few 1/4" blisters after 6 months
#1	#1	7-day	#2	Few 1/16"-1/8" blisters after 6 months
#1	#2	7-day	#1	No blistering after 6 months
#1	#2	7-day	#2	No blistering after 6 months
#1	#3	7-day	#1	No blistering after 6 months
#1	#3	7-day	#2	No blistering after 6 months
#1	#1	60-day	#1	Few 1/16" blisters after 6 months
#1	#1	60-day	#2	Few 1/64" blisters after 1 month; few 1/8" blisters after 6 months
#1	#2	60-day	#1	Medium 1/32" blistering after 2 weeks; dense 1/32" blistering after 6 months
#1	#2	60-day	#2	Few 1/64" blisters after 3 months; dense 1/32"-1/16" blistering after 6 months
#1	#3	60-day	#1	Few 1/8" blisters after 6 month
#1	#3	60-day	#2	Few 1/32" blisters after 1 week; few 1/16"-1/8" blisters after 6 months
#2	#1	7-day	#1	Medium dense 1/64" blistering after 4 months; dense 1/64" and few 1/16" blisters after 6 months
#2	#1	7-day	#2	Medium dense 1/64" blistering after 4 months; dense 1/64" and few 1/8" blisters after 6 months
#2	#2	7-day	#1	No blistering after 6 months
#2	#2	7-day	#2	No blistering after 6 months
#2	#3	7-day	#1	Few 1/64"-1/32" blisters after 4 months; medium 1/32"-1/16" blisters after 6 months
#2	#3	7-day	#2	Few 1/64"-1/32" blistering after 1 month; medium dense 1/16" blistering after 6 months

Table VII

RESULTS OF QUIESCENT SEAWATER IMMERSION TESTING @ 25 psi, 150°F

(Continued)

Primer #	Topcoat #	Weathering Period	Panel #	Comments
#2	#1	60-day	#1	Medium dense 1/64" blistering after 3 weeks; dense 1/64"-1/32" blistering after 6 months
#2	#1	60-day	#2	Few 1/64" blisters after 2 months; dense 1/64"-1/32" blistering after 6 months
#2	#2	60-day	#1	No blistering after 6 months
#2	#2	60-day	#2	No blistering after 6 months
#2	#3	60-day	#1	Few 1/32"-1/16" blisters after 4 months; dense 1/32"-1/16" blistering after 6 months
#2	#3	60-day	#2	Few 1/32"-1/16" blisters after 3 weeks; dense 1/32"-1/16" blistering after 6 months
#3	#1	7-day	#1	No blistering after 6 months
#3	#1	7-day	#2	No blistering after 6 months
#3	#2	7-day	#1	No blistering after 6 months
#3	#2	7-day	#2	No blistering after 6 months
#3	#3	7-day	#1	No blistering after 6 months
#3	#3	7-day	#2	No blistering after 6 months
#3	#1	60-day	#1	Medium dense 1/32" blistering after 2 weeks; dense 1/32" blistering after 6 months
#3	#1	60-day	#2	Medium dense 1/64"-1/32" blistering after 3 weeks; dense 1/32" blistering after 6 months
#3	#2	60-day	#1	Medium 1/16" blistering after 1 week; dense 1/16"-1/8" blistering after 6 months
#3	#2	60-day	#2	Medium 1/16" blistering after 1 week; dense 1/16"-1/8" blistering after 6 months
#3	#3	60-day	#1	Medium dense 1/32"-1/16" blistering after 3 weeks; medium 1/16" blistering after 6 months
#3	#3	60-day	#2	Few 1/32"- 1/16" blistering after 2 months; medium 1/16"-1/8" blistering after 6 months
#4	#1	7-day	#1	Coating 20% disbonded after 2 weeks; coating 20% disbonded with few 1/16"-1/8" blisters after 6 months
#4	#1	7-day	#2	Few 1/64"-1/32" blisters after 1 month; few 1/32"-1/16" blisters after 6 months
#4	#2	7-day	#1	Medium 1/8"-1/4" blistering after 1 week; medium 1/4" blistering after 6 months
#4	#2	7-day	#2	Medium 1/8"-1/4" blistering after 1 week; medium 1/4" blistering after 6 months
#4	#3	7-day	#1	Coating 75% disbonded after 1 week; coating 100% disbonded after 6 months
#4	#3	7-day	#2	Coating 40% disbonded after 1 week and 6 months
#4	#1	60-day	#1	Few 1/8" blisters after 2 weeks; few 1/4" blisters after 6 months
#4	#1	60-day	#2	Few 1/8" blisters after 3 months; few 1/8" blisters and medium 1/64" blistering after 6 months
#4	#2	60-day	#1	Few 1/16"-1/8" blisters after 1 week; dense 1/8"-1/4" blistering after 6 months
#4	#2	60-day	#2	Few 1/16"-1/8" blisters after 3 weeks; medium dense 1/16"-1/8" blistering after 6 months
#4	#3	60-day	#1	Few 1/16"-1/8" blisters after 1 week; few 1/8" blisters after 6 months
#4	#3	60-day	#2	Coating 70% disbonded after 1 week; coating 75% disbonded after 6 months

Table VII

RESULTS OF QUIESCENT SEAWATER
IMMERSION TESTING @ 25 psi, 150°F

(Continued)

Primer #	Topcoat #	Weathering Period	Panel #	Comments
#5	#1	7-day	#1	No blistering after 6 months
#5	#1	7-day	#2	No blistering after 6 months
#5	#2	7-day	#1	No blistering after 6 months
#5	#2	7-day	#2	No blistering after 6 months
#5	#3	7-day	#1	No blistering after 6 months
#5	#3	7-day	#2	No blistering after 6 months
#5	#1	60-day	#1	Few 1/32" blisters after 1 and 6 months
#5	#1	60-day	#2	Medium 1/32" blistering after 1 and 6 months
#5	#2	60-day	#1	No blistering after 6 months
#5	#2	60-day	#2	Dense 1/32" blistering after 1 week; dense 1/32"-1/16" blistering after 6 months
#5	#3	60-day	#1	Few 1/64"-1/32" blisters after 1 week; dense 1/32"-1/16" blistering after 6 months
#5	#3	60-day	#2	Few 1/64" blisters after 5 months; few 1/32"-1/16" blisters after 6 months
Control	#1	-	#1	Few 1/16" - 1/8" blisters after 6 months
Control	#1	-	#2	Few 1/8" blisters after 6 months
Control	#2	-	#1	Few 1/36" - 1/16" blisters after 6 months
Control	#2	-	#2	No blistering after 6 months
Control	#3	-	#1	No blistering after 6 months
Control	#3	-	#2	No blistering after 6 months

Figure 5 - Topcoat #3 over Primer #4 Weathered for 60 Days after 1 Month Exposure in Quiescent Seawater at 25 psi, 150°F

ent than that of the control panels. Qualitatively, however, considering the disbonded area due to blistering, the only test panels where the topcoats performed as well as on the control panels were the panels primed with primers #1, #3, and #5 and weathered for 7 days.

All of the blistering/disbondment observed on the test panels originated at the zinc/topcoat interface. This is consistent with the results obtained in the other tests.

CONCLUSIONS

1. The results of the tests suggest that, depending on the degree of weathering prior to topcoating, there may be inorganic zinc pre-construction primers that can be overcoated for underwater service. After a weathering exposure of 7 days, three of the primers tested in this program (primers #1, #2 and #5 in Table 1) did not appear to increase the tendency for topcoat blistering or disbondment when compared to white-metal blasted control panels.
2. The Japanese-manufactured inorganic zinc pre-construction primer tested in the subject program showed a propensity to cause top-

Table VIII

EXTENT OF BLISTERING AT INTENTIONAL SCRIBE AFTER 6 MONTHS QUIESCENT SEAWATER IMMERSION @ 25psi, 150°F

Primer #	Topcoat #	Weathering #1	Panel #	Comments
#1	#1	7-Day	#1	Few 1/8" blisters
#1	#1	7-Day	#2	Few 1/16" - 1/8" blisters
#1	#2	7-Day	#1	Medium dense 1/32" blistering
#1	#2	7-Day	#2	Few 1/8" blisters
#1	#3	7-Day	#1	No blistering
#1	#3	7-Day	#2	No blistering
#1	#1	60-Day	#1	No blistering
#1	#1	60-Day	#2	Medium 1/16" - 1/8" blistering
#1	#2	60-Day	#1	Medium dense 1/32" blistering
#1	#2	60-Day	#2	No blistering
#1	#3	60-Day	#1	Few 1/8" - 1/4" blisters
#1	#3	60-Day	#2	Medium dense 1/8" - 1/4" blistering
#2	#1	7-Day	#1	No blistering
#2	#1	7-Day	#2	No blistering
#2	#2	7-Day	#1	No blistering
#2	#2	7-Day	#2	No blistering
#2	#3	7-Day	#1	Medium 1/8" - 1/4" blistering
#2	#3	7-Day	#2	Medium dense 1/8" blistering
#2	#1	60-Day	#1	Dense 1/32" - 1/16" blistering
#2	#1	60-Day	#2	Medium dense 1/8" blistering
#2	#2	60-Day	#1	No blistering
#2	#2	60-Day	#2	No blistering
#2	#3	60-Day	#1	Few 1/16" - 1/8" blisters
#2	#3	60-Day	#2	Medium dense 1/8" - 1/4" blistering
#3	#1	7-Day	#1	No blistering
#3	#1	7-Day	#2	No blistering
#3	#2	7-Day	#1	Few 1/32" blisters
#3	#2	7-Day	#2	No blistering
#3	#3	7-Day	#1	No blistering
#3	#3	7-Day	#2	No blistering
#3	#1	60-Day	#1	Medium dense 1/32"-1/16" blistering
#3	#1	60-Day	#2	Few 1/16" blisters
#3	#2	60-Day	#1	Dense 1/32" blistering
#3	#2	60-Day	#2	Dense 1/8" - 1/4" blistering
#3	#3	60-Day	#1	Medium 1/16" - 1/8" blistering
#3	#3	60-Day	#2	Few 1/16" - 1/8" blisters
#4	#1	7-Day	#1	Medium dense 1/8"-1/4" blistering
#4	#1	7-Day	#2	Medium dense 1/8"-1/4" blistering
#4	#2	7-Day	#1	Medium 1/4" - 1/2" blistering
#4	#2	7-Day	#2	Few 1/4" - 1/2" blisters
#4	#3	7-Day	#1	Coating disbonded
#4	#3	7-Day	#2	Coating disbonded
#4	#1	60-Day	#1	Dense 1/4" - 1/2" blistering
#4	#1	60-Day	#2	Medium Dense 1/2" blistering
#4	#2	60-Day	#1	No blistering
#4	#2	60-Day	#2	Few 1/4" blisters
#4	#3	60-Day	#1	Coating disbonded
#4	#3	60-Day	#2	Medium Dense 1/4"-1/2" blistering
#5	#1	7-Day	#1	Medium 1/8" - 1/4" blistering
#5	#1	7-Day	#2	Few 1/8" - 1/4" blisters
#5	#2	7-Day	#1	No blistering
#5	#2	7-Day	#2	No blistering
#5	#3	7-Day	#1	Medium 1/4" blistering
#5	#3	7-Day	#2	Medium 1/4" blistering

Table VIII

EXTENT OF BLISTERING AT INTENTIONAL SCRIBE AFTER 6 MONTHS QUIESCENT SEAWATER IMMERSION @ 25psi, 150°F

(Continued)

Primer #	Topcoat #	Weathering #1	Panel #	Comments
#5	#1	60-Day	#1	Few 1/8" - 1/4" blisters
#5	#1	60-Day	#2	Medium 1/8" blistering
#5	#2	60-Day	#1	No blistering
#5	#2	60-Day	#2	No blistering
#5	#3	60-Day	#1	No blistering
#5	#3	60-Day	#2	No blistering
Control	#1	-	#1	Few 1/8" - 1/4" blisters
Control	#1	-	#2	Medium 1/8" blistering
Control	#2	-	#1	No blistering
Control	#2	-	#2	No blistering
Control	#3	-	#1	No blistering
Control	#3	-	#2	No blistering

Table IX

AVERAGE AREA OF DISBONDMENT AT THE INTENTIONAL SCRIBE AFTER 6 MONTHS QUIESCENT SEAWATER IMMERSION @ 25 psi, 150°F

Inorganic Zinc Primer	Weathering Period	Disbonded Area, in² Topcoat #1	Topcoat #2	Topcoat #3	Total
#1	7-Day	1.55	0.78	0	2.33
#1	60-Day	0.62	0.78	0.31	1.71
#2	7-Day	0	0.31	0	0.31
#2	60-Day	0.16	0	0	0.16
#3	7-Day	0.16	0.31	0	0.47
#3	60-Day	0.62	36.43	0.31	37.36
#4	7-Day	0.31	0.16	70.68	71.15
#4	60-Day	0	0	35.34	35.34
#5	7-Day	0.31	0	0.31	0.62
#5	60-Day	0.78	0	0.16	0.94
Control	-	2.17	0	1.40	3.57
	Total	6.68	38.77	108.51	

coat blistering. This is contrary to the manufacturer's claims.

3. Of the primers tested, the greatest tendency for topcoat blistering occurred over the 2-component full-coat inorganic zinc primer applied at the heaviest thickness (approximately 4 mils).

4. The results of the tests suggest that a longer weathering period (60 days versus 7 days) increases the susceptibility of the inorganic zinc primers to topcoat disbondment. This is contrary to the generally accepted notion.

5. Of the topcoats included in the test program, the MIL-P-24441 epoxy showed the least tendency toward blistering and disbondment.

REFERENCES

1. C. G. Munger, "Inorganic Zinc Coatings, Past, Present and Future," paper No. 70 presented at CORROSION/75, Toronto, ON, Apr. 14-18, 1975.

2 M. J. Masciale, "Use Zinc Rich Coatings - But Use Them Wisely", paper No. 80 presented at CORROSION/75, Toronto, ON, Apr. 14-18, 1975.

3. A. H. Roebuck, "Inorganic Zinc Coatings, Some Disadvantages and Remedies", paper No. 112 presented at CORROSION/80, Chicago, IL, Mar. 3-6, 1980.

4. K. B. Tator, "Top Coating Zinc Rich Primers", paper No. 82 presented at CORROSION/75, Toronto, ON, Apr. 14-18, 1975.

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