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FURTHER EVALUATION OF SELECTED PROTECTIVE COATINGS APPLIED UNDE--ETC(U)

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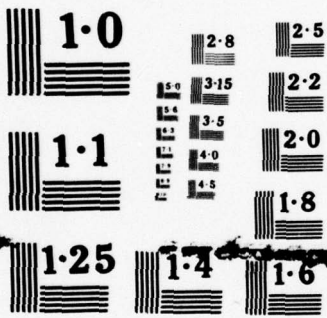
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The results of 1 year simulated exposure tests indicate that a MIL SPEC epoxy coating applied in 2 or 3 coats to achieve an 8 mil build is equal to any of the maintenance-type coatings presently available and should have an adequate service life. The results also suggest that, where complete removal of rust is not possible, a zinc chromate primer available within the Navy Supply System is equal to the proprietary "rust-stabilizing" primers currently on the market.
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I. INTRODUCTION

Effective protective coatings are required to prevent corrosion of hardware components around the launch area of aircraft carriers. The uniquely severe environment characteristic of the launch area as well as the adverse conditions under which coating maintenance must often be accomplished has made selection of an optimum coating doubtful. Work directed at rating the performance of selected coatings in a simulated flight deck environment has been in progress for the past several years under the auspices of both NAVAIRENGCEN and NAVSEC. This report presents the results of recent work evaluating the performance of protective coatings when applied under adverse conditions.

II. SUMMARY

The results of 1-year simulated exposure tests indicate that a MIL SPEC epoxy coating applied in 2 or 3 coats to achieve an 8 mil build is equal to any of the maintenance-type coatings presently available and should have an adequate service life. The results also suggest that, where complete removal of rust is not possible, a zinc chromate primer available within the Navy supply system is equal to the proprietary "rust-stabilizing" primers currently on the market. The results were mostly inconclusive regarding the relative sensitivity of various coatings to adverse application conditions. Continuation of the simulated exposure tests should yield more meaningful results.

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V. FURTHER EVALUATION OF SELECTED PROTECTIVE COATINGS APPLIED UNDER ADVERSE CONDITIONS

A. INTRODUCTION. Corrosion of hardware components in the launch area of aircraft carriers is a costly maintenance problem. Starting in 1971, NAVAIRENGCEN/NAVSEC undertook a joint corrosion control program to determine cost effective, anti-corrosive coatings that would reduce or eliminate corrosion of expensive hardware. Because of the unique and severe environment characteristic of the launch area, reliable design data on protective coatings was unavailable.

Around the launch area, a protective coating must be able to withstand the heat from jet engines and steam-powered catapults as well as a marine atmosphere/sea water spray environment. Also, the coating must be unaffected by contaminants that typically wet the flight deck such as jet fuel, lube oil, hydraulic fluid, aircraft cleaning solution, and flight deck cleaning solution. The combination of environmental factors encountered in the launch area makes it virtually impossible to sensibly select cost effective protective coatings based on manufacturers' available data. Invalid extrapolation of manufacturers' data has, in the past, led to less than satisfactory performance.

The original scope of the joint program undertaken by NAVAIRENGCEN/NAVSEC was to develop reliable performance data on commercially-available and several selected MIL-SPEC coatings under closely-simulated service conditions. To insure a realistic simulation of the marine atmosphere/ sea water spray environment, data was gathered at the laboratory site of Ocean City Research Corporation near the ocean in Ocean City, New Jersey. In the past, attempts to simulate such an environment by the use of salt spray cabinets and the like have led to misleading performance data.

Initially, performance data was gathered on protective coatings that had been applied under ideal laboratory conditions to white metal-blasted steel. However, since it is often either impossible or impractical to apply coatings under such conditions, NAVAIRENGCEN/NAVSEC conducted follow-on work to develop meaningful performance data on various protective coatings applied under more adverse conditions¹. The results of this early work demonstrated the severity of the catapult environment on protective coatings. Where a near white metal sandblast is obtainable, the test results further showed that the optimum coating was an inorganic zinc-rich coating. The tests were limited to solvent-type coatings and excluded consideration of flame-spray metallized coatings. In the event a near white metal

¹NAVAIRENGCEN/NAVSEC Report No. 7877, May, 1975.

surface was unobtainable, the test results suggested that a proprietary rust-stabilizing primer coating² would enhance the adherence and performance of selected topcoats applied over poorly prepared surfaces sufficient to insure an adequate service life. However, the test program created some uncertainties in that the results seemed to be primarily influenced by the applied thickness of the various coatings. The coatings had been evaluated as prime coats applied according to manufacturer's recommended thickness which resulted in a dry film thickness variation of 2 to 8 mils between the different coatings. It was felt that some of the coatings would have performed better if applied in multiple coats to achieve a higher build or topcoated with another coating. Therefore, further work was initiated to evaluate selected coatings at higher builds. This report presents the results of those additional tests.

B. EXPERIMENTAL APPROACH

1. SELECTION OF COATINGS FOR FURTHER TESTING.

Table I lists the ten coatings selected for further testing. Some of the coatings were selected because of performance in prior tests. Others not tested before were included to gain insight on their relative sensitivity to application over poorly prepared surfaces. In addition to the ten coatings listed in Table I, four (4) rust-stabilizing pretreatment/primer coatings (Table II) were also further evaluated. The pretreatment/primer formulations are intended to improve coating adherence on steel substrates where complete rust removal is either impossible or impractical.

2. TESTING SCHEME. Figure I presents a test matrix showing the coatings and the various surface conditions under which they were applied. Four (4) test panels were prepared for each coating/surface condition. Two (2) panels of each coating/surface condition were exposed to a simulated flight deck environment and two (2) panels were exposed to a marine atmosphere/sea water spray environment. These different exposures and methods of surface preparation are more fully described later in this section. The time of exposure in each test was one year. The total number of test panels prepared for exposure testing was 656.

The total dry film thickness for each test panel was kept between 8 to 10 mils. For some coatings, this necessitated as many as 5 separate coats to achieve an 8 mil build. Other coatings could be applied @ 8 mils in one coat. Table III presents the average number of coats required to obtain 8 mils for each coating. A dry film

²Corroless "S", Corrovan Company.

thickness of 8 mils was selected because fleet experience indicates that, generally, this is the minimum thickness necessary to insure an adequate anti-corrosive service life. Dry film thickness measurements were made using a Mikrotest magnetic thickness gauge.

3. PREPARATION OF TEST PANELS WITH SURFACES HAVING VARYING DEGREES OF RUST REMOVAL. Test panel surfaces were prepared as follows:

- a. Pre-rusted, sandblasted to near white metal (95% rust removal)
- b. Pre-rusted, wire brushed and power disc-sanded
- c. Pre-rusted, rust removed with pneumatic needle gun
- d. Pre-rusted, wire brushed
- e. Sandblasted to near white metal and surface contaminated

The test panels were 3" x 6" x 16 gauge, hot-rolled steel (SAE1010). All test panels were pre-rusted by exposing the as-received panels to a marine atmosphere/sea water spray environment for two (2) months. The panels were exposed near the ocean in Ocean City, New Jersey and sprayed three times daily with sea water.

The wire brush surface finish was achieved by hand brushing individual test panels with a stiff wire brush to remove loose scale. In preparing the wire brushed disc-sanded surface, additional rust was removed by disc sanding with extra coarse #20 grit silicon carbide paper.

To simulate a contaminated surface, near white metal blasted panels were wetted with a soiling medium consisting of 35 gm raw umber, 6 gm petrolatum and 40 ml of JP-5 jet fuel. The mixture was brushed onto the panels at a uniform thickness and allowed to air dry for 1/2 hour at room temperature. The contaminated test panels were then baked in an oven at 220°F for about 45 minutes. The panels were then cooled to room temperature and excess residue brushed off prior to coating.

4. PREPARATION OF TEST PANELS UNDER CONDITIONS OF EXTREME TEMPERATURE AND HIGH HUMIDITY. The program included application of the selected coatings to near white metal surfaces under conditions of extreme temperature and high humidity.

For application at high humidity, test panels were coated and cured in a 100% relative humidity environment (water vapor created by boiling water) sufficient to cause moisture condensation on the surface of the panels. The relative humidity was monitored throughout with a wet/dry bulb sling psychrometer.

For application under conditions of extreme temperature, test panels were coated at 25°F and 120°F. Coating application at 120°F was accomplished using a thermostatically controlled ($\pm 2^\circ\text{F}$) laboratory oven. Prior to application, both the coating systems and the test panels were heated to 120°F. The panels were then coated and subsequently cured at 120°F. To simulate low temperature application, the test panels were cooled at 25°F and the coatings at 40°F in a refrigerator prior to application. Subsequently, the panels were coated and then cured at 40°F.

5. SIMULATED FLIGHT DECK EXPOSURE TESTS.

The test panels were exposed in a test rig designed to simulate the catapult/flight deck area of aircraft carriers. The exposure cycle over 24 hours was as follows:

- a. Marine Atmosphere - approximately 20 hours/daily
- b. Sea Water Immersion - two hours/daily
- c. Simulated deck scrub down with a 3% sodium metasilicate/ $\approx 3\%$ water soluble detergent (MIL-D-16791E, Type I) solution, followed by sea water washing - twice/week. Procedures were simulated as described in NAVSHIPSNOTE 9140, Service Bullentin 6634A-363 dated June 2, 1966.
- d. Wetting with aircraft cleaning solution (a 1:1 mixture of MIL-C-43616 and MIL-C-25679) - twice/week.
- e. Intermittent hot air blast - 2 hours daily. Each panel received a hot air blast averaging 100°F for about 12 seconds duration every 12 minutes over a two hour period. This intermittent heat cycle is sufficient to raise the surface temperature of an uncoated panel to between 200°F and 250°F (air temperature $\approx 60^\circ\text{F}$) after two hours.

Figures 2 and 3 show the test rig. The test rig provided an aluminum trough for placement of the test panels. The test panels were insulated from the aluminum trough using phenolic spacers. Events b. and e. in the above cycle were automatically controlled using a timer circuit, appropriate switches, and solenoid valves. The heat was supplied from heat guns mounted on a rotating arm attached to a fractional horsepower motor in the center of the rig.

6. MARINE ATMOSPHERE/SEA WATER SPRAY EXPOSURE TESTS. In addition to simulated flight deck exposure tests, concurrent exposure tests were conducted on the test fences at the OCRC site. Replicate test panels were mounted on a 45° angle facing directly south and sprayed with sea water 3x daily. The panels were mounted using porcelain knobs. Figure 4 shows the test set-up.

The test fence exposure was included to evaluate relative coating performance under a less severe exposure. The test fence exposure with sea water spray is fairly typical of many areas of the flight deck.

C. RESULTS

1. COATING PERFORMANCE IN GENERAL

After 1 year simulated flight deck and marine atmosphere/sea water spray exposure, the overall performance ratings of the ten selected coatings were as follows:

- Polyamide Epoxy (MIL-P-24441) - excellent
- Polyamide Epoxy (Dupont Corlar) - excellent
- Urethane (CFI Urethabond 104) - excellent
- Urethane (International Paint Interthane 2220) - excellent
- Epoxy Non-Skid (Type 1) - excellent
- Epoxy Non-Skid (Type 2) - excellent
- Zinc-rich Epoxy - fair
- Zinc-rich Urethane - poor
- Aluminum-rich Epoxy - poor
- Coal Tar Epoxy - failed

The criteria for the ratings were as follows:

- Excellent - no visible coating deterioration on 90% of the exposed test panels
- Good - less than 5% coating deterioration per panel on 90% of the exposed test panels
- Fair - less than 10% coating deterioration per panel on 90% of the exposed test panels
- Poor - less than 10% coating deterioration per panel on 60% of the exposed test panels
- Failed - greater than 25% coating deterioration per panel on 60% of the exposed test panels

The forms of deterioration considered include rusting, cracking, blistering, checking, and flaking. Tables IV thru VI summarize the performance ratings for the different test conditions.

As expected, the simulated flight deck exposure was much worse than the marine atmosphere/sea water spray exposure. With very few exceptions, all test panels exposed to marine atmosphere/sea water spray still rate good to excellent.

2. PERFORMANCE OF COATINGS APPLIED OVER SURFACES WITH RUST REMOVED TO VARYING DEGREES

The zinc-rich urethane coating was the only coating which evidenced sensitivity to various degrees of rust removal. Applied over near white metal, the zinc-rich urethane is still in excellent condition. Applied over the other surfaces, the zinc-rich urethane has failed. Figure 5 shows the test panels after 1 year.

The other coatings evaluated did not show distinguishable differences in performance related to the different methods of surface preparation. The six coatings rated excellent above showed no deterioration for any of the different surface conditions. The zinc-rich epoxy rated good to excellent over all four surfaces. The coal-tar epoxy and aluminum-rich epoxy performed poorly over all four surfaces including near white metal.

3. PERFORMANCE OF SELECTED COATINGS APPLIED UNDER CONDITIONS OF HIGH HUMIDITY, EXTREME TEMPERATURE, AND SURFACE CONTAMINATION

Only the aluminum-rich epoxy, zinc-rich epoxy and zinc-rich urethane exhibited sensitivity to application under the subject conditions. The zinc-rich urethane blistered when applied at both low and high temperatures (Figure 6) but showed no detectable sensitivity to high humidity or surface contamination. The zinc-rich epoxy blistered on application at high temperature, high humidity, and a contaminated surface (Figure 7). The aluminum-rich epoxy rusted more rapidly when applied at both temperature extremes, at high humidity, and with surface contamination. Detectable differences in performance as a function of the subject application conditions were not apparent for the remainder of the coatings evaluated.

4. EVALUATION OF RUST-STABILIZING PRIMER FORMULATIONS

The rust-stabilizing primer coatings were evaluated on their relative ability to improve coating performance on surfaces with incomplete rust removal (rusted steel cleaned with either needle gun, disc sander, or wire brush). All four of the primer formulations were tested with the coal-tar epoxy, aluminum-rich epoxy, urethane (Urethabond 104), and the polyamide epoxy (MIL-P-24441). The Corroless "S" primer and the zinc chromate alkyd primer were also

evaluated with the other six coatings. Previous testing tended to indicate that Corroless "S" improved coating performance over surfaces with incomplete rust removal, therefore, it was decided to conduct a more in-depth evaluation using the zinc chromate alkyd primer as a benchmark.

The performance results for the coal-tar epoxy and aluminum-rich epoxy permit the only comparison of all four primer formulations because the other two top coatings for which all four primers were used showed no deterioration. Figures 8 and 9 show the results for the aluminum-rich epoxy and coal-tar epoxy applied over a wire brush surface. The Lox Rust and Actan primers were of little benefit. Both the coal-tar epoxy and aluminum-rich epoxy failed when applied over the different surfaces primed with Lox Rust and Actan. In fact, the aluminum-rich epoxy performed better, by itself, then it did with a prime coat of Lox Rust or Actan.

The Corroless "S" and the zinc chromate alkyd primers did improve significantly the performance of the aluminum-rich epoxy. All test panels having these two primers were rated excellent. The aluminum-rich epoxy blistered and rusted when applied, by itself, to a wire brushed surface.

The Corroless "S" primer did not improve the performance of the coal-tar epoxy coating, whereas the zinc chromate alkyd primer did. With and without the Corroless "S" primer, the coal-tar epoxy performed poorly (rusting, blistering, disbondment) even over a near white metal surface. When applied over the zinc chromate-alkyd primer, the coal-tar epoxy looked good after a year's exposure.

D. DISCUSSION OF RESULTS

1. COMPARISON WITH PREVIOUS RESULTS

Based on the previous test results, the excellent appearance of six of the selected coatings after 1 year's simulated flight deck exposure was surprising. All of these coatings had exhibited varying degrees of deterioration in previous tests and none performed favorably over a pre-rusted, wire-brushed surface. Because of observed failures in earlier tests, a tentative conclusion had been reached that application over a wire-brushed surface, or the like, required the use of a rust-stabilizing primer. Corroless "S" had performed well in previous testing and was considered a likely candidate. However, the results of the subject program do not support this conclusion.

The significant improvement in coating performance appears traceable to the heavier applied coating thickness obtained in the current program. All coatings were applied at a dry film thickness of between 8 to 10 mils. In the

previous program, the coatings were evaluated only as primers and applied in a single coat according to military specifications or manufacturer's recommendations. The dry film thickness ranged between 2 and 8 mils.

2. PRACTICAL CONSIDERATIONS

Although the performance of six of the coatings evaluated seems acceptable, the practicality of applying some of these coatings at high builds is questionable. To achieve a minimum 8 mil build, some coatings required as many as 5 separate coats. This would be impractical under service conditions and prohibitive from a cost standpoint.

On the other hand, the two coating systems (coal-tar epoxy and aluminum-rich epoxy) where an 8 mil build was obtainable in one coat performed poorly. These coatings are relatively thick, viscous coatings specifically designed to yield a high build (6-8 mils) in one application. Brush application left distinct brush marks resulting in uneven coverage and significant thickness variation. The other coating systems applied in multiple, thinner coats were much more uniform in thickness. The predominant form of deterioration for the two high build coatings was rusting initiating at points of low coating thickness. The rusting followed a brush mark pattern occurring primarily in the "valleys" created from brush application. Figure 10 shows the typical pattern.

The results suggest that a multiple coat system approaching 8 mils thickness will provide adequate corrosion protection in the flight deck environment. Three coats would appear to be the practical limit with a two coat system preferable. Considering the results of the exposure tests and the constraints on the practical number of coats necessary to achieve an 8 mil build, the MIL-P-24441 polyamide epoxy coating appears to be the best choice of those included in the program. The tests demonstrated that this coating system as well as several others can tolerate adverse application conditions.

3. RUST STABILIZING PRIMERS

The dominating influence of the dry film thickness on the test results tends to also explain the heretofore apparent superiority of the Corroless "S" primer over the other rust-stabilizing primers. The Corroless "S" primer is thicker than the others that were evaluated (4 mils versus 1-2 mils). However, the limited test results where meaningful differences were distinguishable does suggest that a 2-mil zinc chromate alkyd prime coat is comparable to, if not better than, the Corroless "S" formulation. The zinc chromate alkyd provided additional corrosion protection as well as enhanced a less-than-ideal surface for subsequent top

coating. The zinc chromate primer is currently in use and available through the Navy supply system.

4. FUTURE WORK

The relative sensitivity of several coatings included in the program to different application conditions could not be established because meaningful differences in the degree of deterioration were not evident after one year's simulated exposure. Extension of the simulated exposure tests is required to make a relative comparison. Considering that the major cost of the program involved the preparation and coating of the test panels, further testing seems appropriate. Continuation of the exposure tests will establish:

- a. The relative service life of each coating system.
- b. The relative sensitivity to extreme application conditions.
- c. The best alternative method of preparing a steel surface prior to coating if sandblasting is not possible.

The test results after 1 year have yielded only limited information on these three items.

E. CONCLUSIONS

1. The better performance of several of the selected coatings compared to previous exposure tests is traceable to the heavier coating thickness used in these later tests.
2. A minimum dry film thickness of 8 mils is required to protect structural steel exposed to the typical flight deck environment.
3. Uniform coating coverage at 8 mils is best obtained in multiple coats as opposed to a single coat of a high build coating.
4. The MIL-P-24441 polyamide epoxy coating system appears to be equal to or better than any of the other coatings included in the simulated exposure tests.
5. The MIL-P-24441 polyamide epoxy is available through the Navy supply system. It appears suitable for protecting structured steel when confronted with the application and environmental conditions simulated in this study.
6. The results of this program do not support the tentative conclusion reached in earlier tests that Corroless

"S", a proprietary rust-stabilizing primer, is better than the primer now available in the Navy supply system for use over less-than-ideal surfaces.

7. Because of the lack of detectable deterioration for several coatings after 1 year exposure, the results do not permit a meaningful comparison of the relative sensitivity to adverse application conditions. The relative service life of most of the coatings included in the study is also indeterminate.

8. Extension of the simulated exposure tests would probably enable a more meaningful comparison of relative sensitivity to adverse application conditions and relative service life.

F. RECOMMENDATIONS

1. Extend the simulated exposure tests for another year.

TABLE I - COATINGS SELECTED FOR FURTHER TESTING

<u>Generic Type</u>	<u>Manufacturer/Trade Name</u>
1. Polyamide Epoxy*	Seaguard Company
2. Polyamide Epoxy, Zinc Chromate pigment	Dupont Company/Corlar
3. Aluminum-rich Epoxy	Carboline Co./Carbomastic 15
4. Zinc-rich Epoxy**	-
5. Coal-Tar Epoxy	Carboline Co./Carbomastic 3
6. Urethane	CFI Co./Urethabond 104
7. Urethane	International Paint/Interthane 2220
8. Zinc-rich Urethane	CFI Co./Urethabond 102
9. Epoxy Non-Skid***	Palmer Products Co./Epoxit
10. Epoxy Non-Skid****	Palmer Products Co./Epoxit

* MIL-P-24441

** Experimental formulation developed by U.S. Navy Mare Island Paint Laboratory - Formula 1025

*** MIL-D-24483 Type 1 (Non-Landing Areas)

**** MIL-D-24483 Type 2 (Landing Areas)

TABLE II - RUST-STABILIZING PRETREATMENT/PRIMER COATINGS
SELECTED FOR FURTHER TESTING

<u>Generic Type</u>	<u>Manufacturer/Trade Name</u>
1. Tannic Acid	Troy Chemical Corp./Actan
2. Tannic Acid	Steelcote Co./Lox Rust
3. Alkyd Resin with high iron oxide content	Corrovan Co./Corroless "S"
4. Zinc Chromate Alkyd*	

* Fed. Spec. TT-P-645, Formula 84 - Standard U.S. Navy primer included as a control

TABLE III - AVERAGE NUMBER OF COATS REQUIRED TO
OBTAIN 8 MIL DRY FILM THICKNESS

<u>Coating</u>	<u>Average No. of Coats</u>
1. Polyamide Epoxy (MIL-P-24441)	3
2. Polyamide Epoxy (Corlar)	4
3. Aluminum-rich Epoxy	1
4. Zinc-rich Epoxy	3
5. Coal-tar Epoxy	1
6. Urethane (Urethabond 104)	5
7. Urethane (Interthane 2220)	5
8. Zinc-rich Urethane	3
9. Epoxy Non-Skid (Type I)	3
10. Epoxy Non-Skid (Type II)	3

TABLE IV - PERFORMANCE OF COATINGS WHEN APPLIED OVER SURFACES,
WITH RUST REMOVED TO VARYING DEGREES

Coating	Near White Metal	Wire Brush-Disc Sanded	Needle Gun	Wire Brush	Near White Metal, Contaminant
1. Polyamide Epoxy (MIL-P-24441)	E	E	E	E	E
2. Polyamide Epoxy (DuPont Corlar)	E	E	E	E	E
3. Urethane (CFI Urethabond 104)	E	E	E	E	E
4. Urethane (International Paint Interthane 2220)	E	E	E	E	E
5. Epoxy Non-skid (Type 1)	E	E	E	E	E
6. Epoxy Non-skid (Type 2)	E	E	E	E	E
7. Zinc-rich Epoxy	G/E	G/E	G/E	G/E	P
8. Zinc-rich Urethane	E	X	X	X	X
9. Aluminum-rich Epoxy	X	X	X	X	X
10. Coal Tar Epoxy	X	X	X	X	X

E = Excellent
 G = Good
 F = Fair
 P = Poor
 X = Failed

TABLE V - PERFORMANCE OF COATINGS APPLIED UNDER CONDITIONS OF
HIGH HUMIDITY AND EXTREME TEMPERATURE

Coating	50% R.H., 70°F	100% R.H.	25°-40°F	120°F
1. Polyamide Epoxy (MIL-P-24441)	E	E	E	E
2. Polyamide Epoxy (DuPont Corlar)	E	E	E	E
3. Urethane (CFI Urethabond 104)	E	E	E	E
4. Urethane (International Paint Interthane 2220)	E	E	E	E
5. Epoxy Non-skid (Type 1)	E	E	E	E
6. Epoxy Non-skid (Type 2)	E	E	E	E
7. Zinc-rich Epoxy	G/E	P	G/E	P
8. Zinc-rich Urethane	E	E	P	P
9. Aluminum-rich Epoxy	X	X	X	X
10. Coal Tar Epoxy	X	X	X	X

E = Excellent
 G = Good
 F = Fair
 P = Poor
 X = Failed

TABLE VI - PERFORMANCE OF SELECTED COATINGS APPLIED OVER RUST-STABILIZING PRIMER FORMULATIONS

Coating	Wire Brush	Wire Brush-Disc Sanded	Needle Gun
Actan			
Polyamide Epoxy (MIL-P-24441)	E	E	E
Urethane (CFI Urethabond 104)	E	E	E
Aluminum-rich Epoxy	X	X	X
Coal Tar Epoxy	X	X	X
Lox Rust			
Polyamide Epoxy (MIL-P-24441)	E	E	E
Urethane (CFI Urethabond 104)	E	E	E
Aluminum-rich Epoxy	X	X	X
Coal Tar Epoxy	X	X	X
Corroless "S"			
Polyamide Epoxy (MIL-P-24441)	E	E	E
Polyamide Epoxy (DuPont Colar)	E	E	E
Urethane (CFI Urethabond 104)	E	E	E
Urethane (International Paint Interthane 2220)	E	E	E
Epoxy Non-skid (Type 1)	E	E	E
Epoxy Non-skid (Type 2)	E	E	E
Zinc-rich Epoxy	E	E	E
Zinc-rich Urethane	E	E	E
Aluminum-rich Epoxy	E	E	E
Coal Tar Epoxy	P	P	P

TABLE VI CONT'D

<u>Coating</u>	<u>Wire Brush</u>	<u>Wire Brush-Disc Sanded</u>	<u>Needle Gun</u>
Zinc Chromate Alkyd (TT-P-645)			
Polyamide Epoxy (MIL-P-24441)	E	E	E
Polyamide Epoxy (DuPont Colar)	E	E	E
Urethane (CFI Urethabond 104)	E	E	E
Urethane (International Paint Interthane 2220)	E	E	E
Epoxy Non-skid (Type 1)	E	E	E
Epoxy Non-skid (Type 2)	E	E	E
Zinc-rich Epoxy	E	E	E
Zinc-rich Urethane	E	E	E
Aluminum-rich Epoxy	E	E	E
Coal Tar Epoxy	G	G	G

E = Excellent
 G = Good
 F = Fair
 P = Poor
 X = Failed

SURFACE & APPLICATION CONDITIONS	COATING											
	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441	ML-P-2441
NEAR WHITE METAL (NWM)	X	X	X	X	X	X	X	X	X	X	X	X
NEEDLE GUN (NG)	X	X	X	X	X	X	X	X	X	X	X	X
DISC-SANDED (DS)	X	X	X	X	X	X	X	X	X	X	X	X
WIRE BRUSHED (WB)	X	X	X	X	X	X	X	X	X	X	X	X
NG + ACTAN PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
DS + ACTAN PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
WB + ACTAN PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
NG + LOX RUST PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
DS + LOX RUST PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
WB + LOX RUST PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
NG + CORROLESS "S" PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
DS + CORROLESS "S" PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
WB + CORROLESS "S" PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
NG + TT-P-645 PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
DS + TT-P-645 PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
WB + TT-P-645 PRIMER	X	X	X	X	X	X	X	X	X	X	X	X
NWM + CONTAMINANT	X	X	X	X	X	X	X	X	X	X	X	X
NWM + HIGH HUMIDITY	X	X	X	X	X	X	X	X	X	X	X	X
NWM + LOW TEMP.	X	X	X	X	X	X	X	X	X	X	X	X
NWM + HIGH TEMP.	X	X	X	X	X	X	X	X	X	X	X	X

NOTE: 4 TEST PANELS WERE PREPARED FOR EACH COATING/S&A CONDITION COMBINATION. TOTAL NO. OF PANELS = 656

FIGURE 1 - TEST MATRIX FOR EVALUATING THE PERFORMANCE OF SELECTED COATINGS AS A FUNCTION OF ADVERSE APPLICATION CONDITIONS

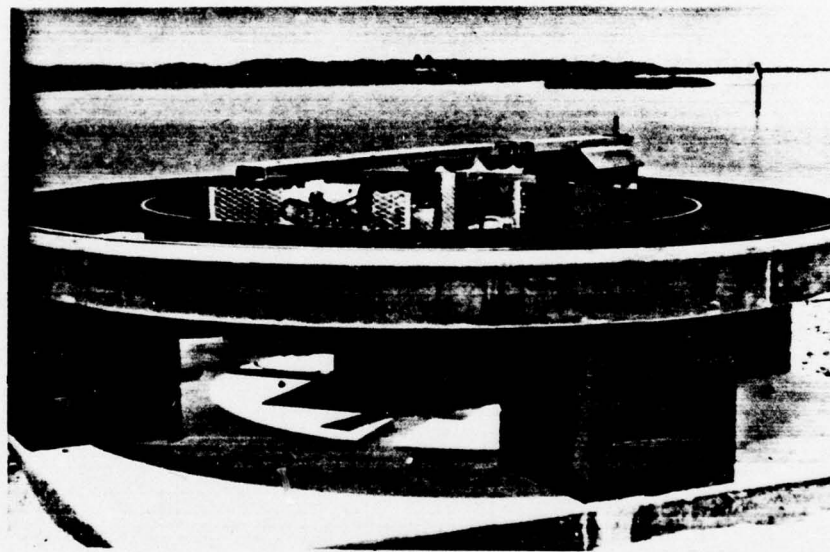


FIGURE 2 - General View of Test Rig

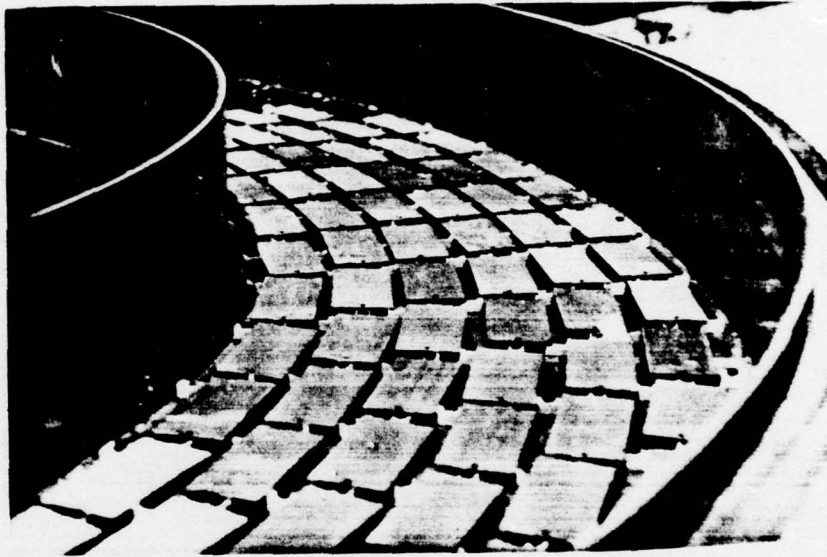


FIGURE 3 - Close-up View of Panels Mounted
in Test Rig

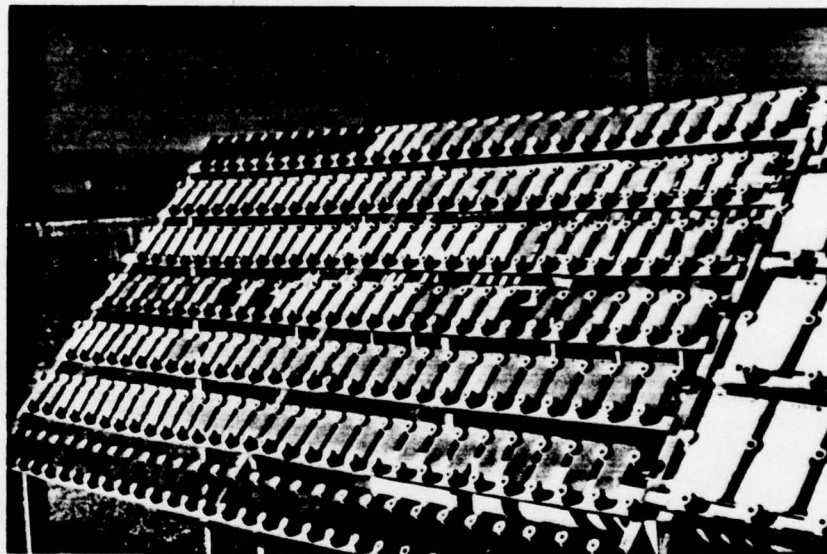
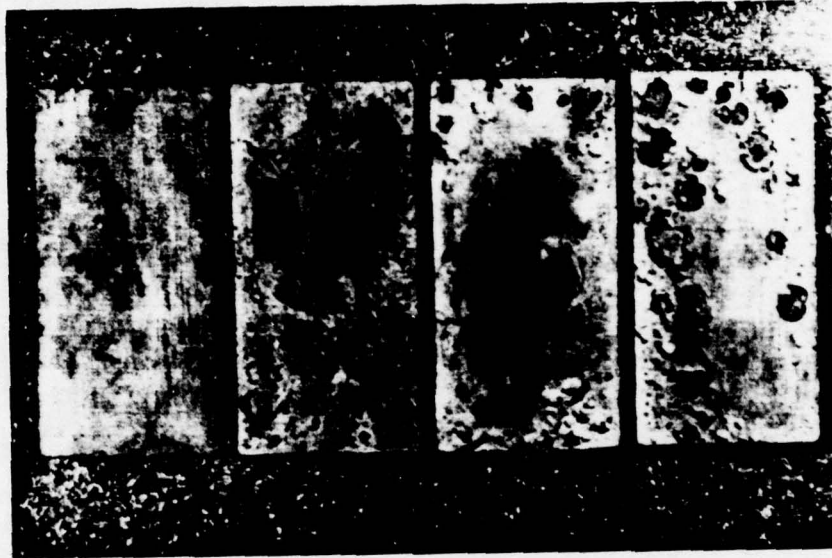


FIGURE 4 - Marine Atmosphere Exposure at OCRC Site



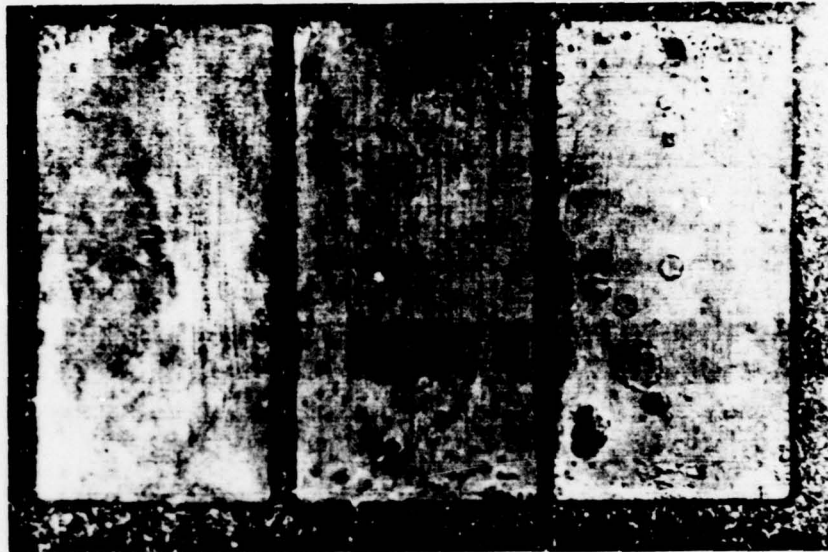
Near
White
Metal

Needle
Gun

Disc
Sanded

Wire
Brush

FIGURE 5 - Test Panels Coated with Zinc-Rich Urethane (1 year exposure)

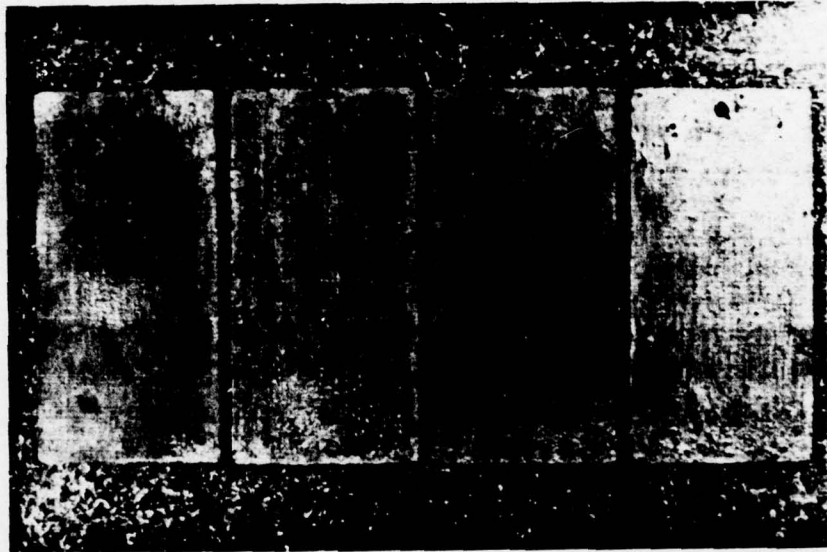


Near White
Metal

Low
Temperature

High
Temperature

FIGURE 6 - Test Panels Coated with Zinc-Rich Urethane (1 year exposure)



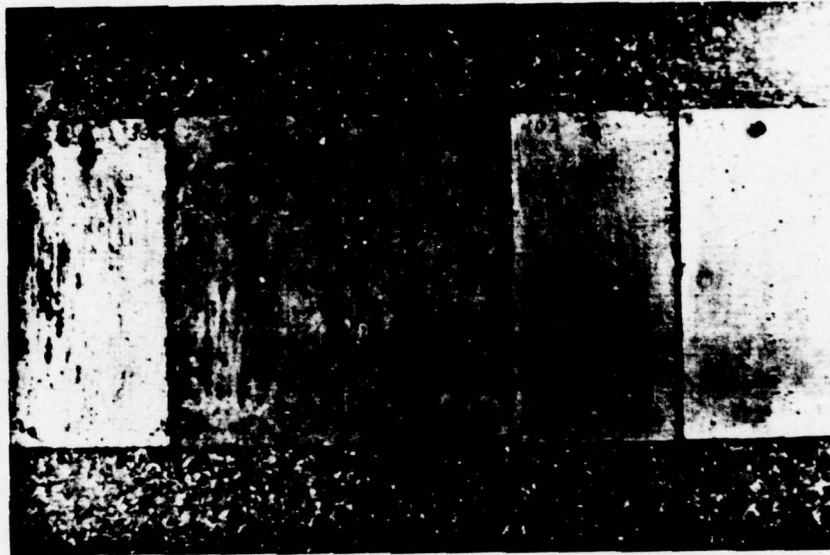
Near White
Metal

High
Humidity

High
Temperature

Surface
Contaminant

FIGURE 7 - Test Panels Coated with Zinc-Rich Epoxy (1 year exposure)



No Primer

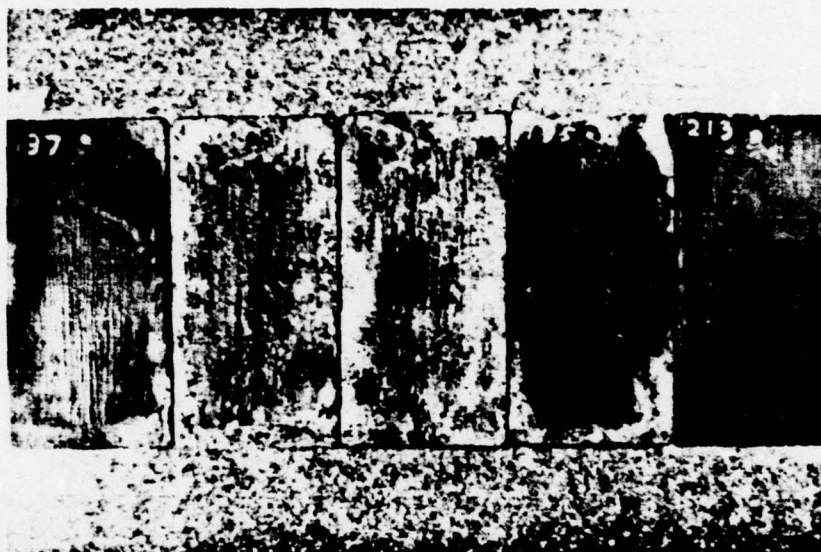
Actan
Primer

Lox Rust
Primer

Corroless
"S" Primer

TT-P-645
Primer

FIGURE 8 - Test Panels Top-Coated with Aluminum-Rich Epoxy Over Different Primers



No Primer Actan
Primer Lox Rust
Primer Corroless
"S" Primer TT-P-645
Primer

FIGURE 9 - Test Panels Top-Coated with Coal-Tar Epoxy Over Different Primers



FIGURE 10 - Test Panels of Aluminum-Rich Epoxy
Showing Rusting Following a Brush
Mark Pattern