Flash Rusting: Characterization and Effect on Coating Performance

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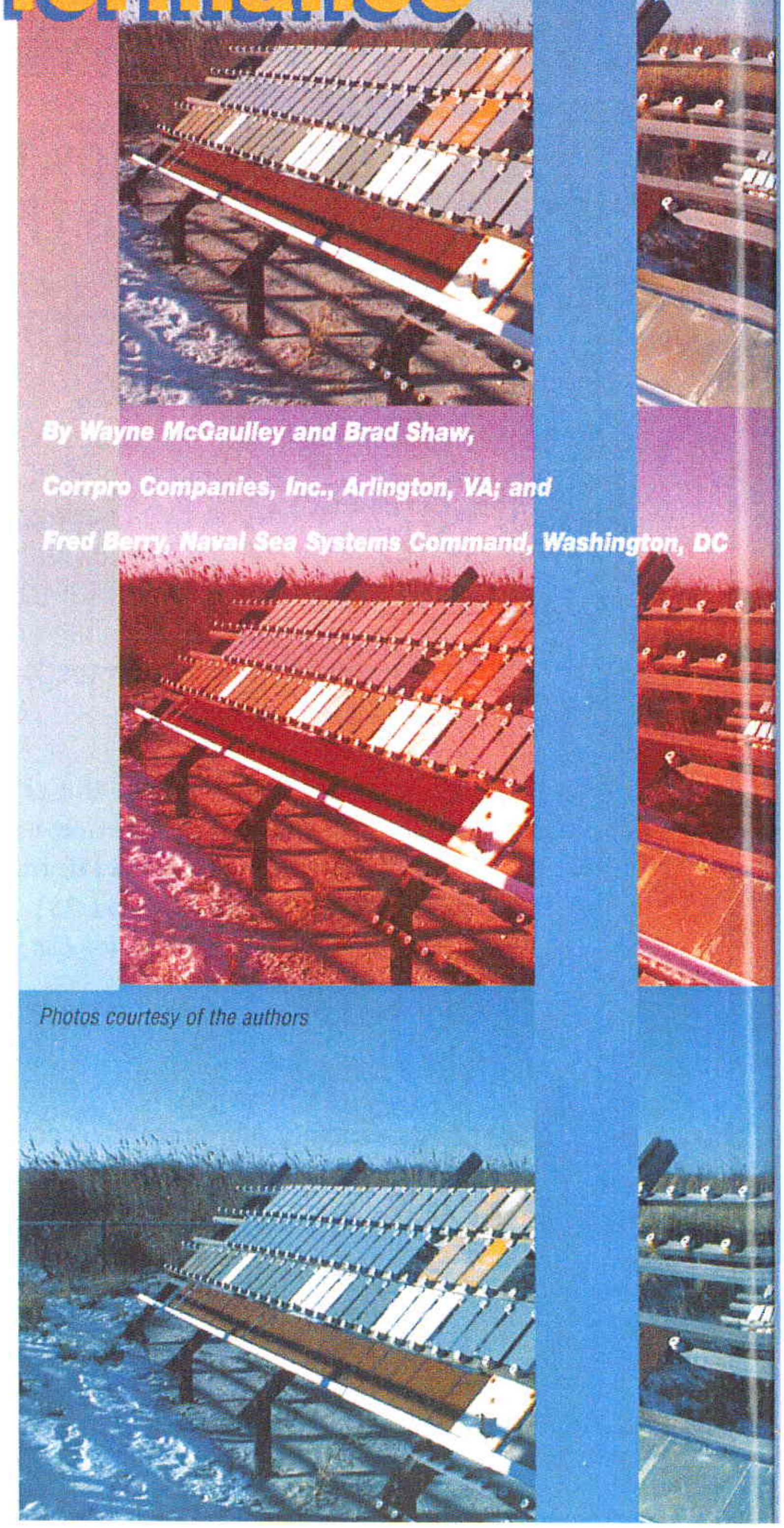

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Compared to the industry standard of abrasive blasting, waterjetting eliminates hazardous airborne pollutants, airborne dust that can damage or foul shipboard mechanical systems, and abrasive cleanup and disposal. In addition, the technology allows adjacent work by other trades.

Despite these advantages, a potential drawback of waterjetting is flash rusting. Flash rusting of prepared surfaces frequently occurs after open-cycle waterjetting in the shipbuilding and ship repair environment. Many coating specifications require all flash rusting be removed prior to coating. This requirement involves blasting the waterjetted surface with abrasive just before coating, thus increasing job costs and delaying schedules.

One solution to this dilemma is to paint over the flash rusting, though many questions remain concerning the performance of coatings over such surface conditions. Most coatings are designed to be applied over clean, bare steel substrates equivalent to an SSPC-SP 10/NACE No. 2 (Near-White)[1] or an SSPC-SP 5/NACE No. 1 (White Metal)[2] condition, which yields a predominately shiny silver or white surface. Waterjetting, however, does not yield such a surface. Waterjetting typically leaves a dull, stained surface. Following waterjetting, the surface can begin to oxidize or flash rust. Flash rusting is typically orange, red, or brown in color, although it may take on other colors depending on the color of the underlying steel. As flash rust becomes heavier, more of the substrate will be blocked out, and the rust will dominate the color of the surface.

One major proponent of waterjetting is the U.S. Navy because of the environmental benefits and superior cleaning abilities of waterjetting. The Navy uses the technology to prepare underwater hulls and non-skid decks before painting.[3,4] To date, the Navy requires waterjetted surfaces to be cleaned to an SSPC-SP 12/NACE No. 5 WJ-2L condition.[5] As defined by SSPC, "[a] WJ-2 surface shall be cleaned to a matte finish with at least 95% of the surface area free of all previously existing visible residues and the remaining 5% containing only randomly dispersed stains of rust, coatings, and foreign matter." As defined in SSPC-VIS 4,[6] light flash rusting is "[a] surface which, when viewed without magnification, exhibits small quantities of a yellow/brown rust layer through which the steel substrate may be observed. The rust or discoloration may be evenly distributed or present in patches, but it is tightly adherent and not easily removed by light wiping with a cloth."

Due to a lack of research into the effects flash rusting has on coating performance, most paint specifications require reworking a flash-rusted surface to reveal bare steel. Additionally, most paint manufacturers will not accept liability if their products are applied over flash rusting. It may be possible, however, to determine the breakpoint where the degree of flash rusting becomes detrimental to coating performance, thus eliminating unnecessary rework and reducing costs.

This article presents data collected during a Naval Sea Systems Command (NAVSEA) study of flash rusting and its impact on coating system performance. Flash rusting is characterized by chemical make-up, adhesion to the surface, color, and degree of coverage. In this study, flash-rusted panels were coated with U.S. Navy-approved coating systems and subjected to the following: marine atmospheric exposure, immersion chamber, condensing humidity chamber, cyclic fog/dry cabinet, and cathodic disbondment testing. Coating performance is measured by adhesion to the substrate, scribe cutback, and general paint failure. Performance was correlated to the flash rust characteristics of the panels to provide general guidance to the Navy.

Technical Approach

This study investigates the effects of flash rusting on marine coating performance on pre-weathered panels that have been waterjetted to various surface conditions. After weathering, the panels were painted with the following Navy standard coating systems.

- Underwater hull paint system
- Freeboard hull system
- Tank coating system
- Non-skid deck system

Following surface preparation, application, and complete cure of the coating systems, the test panels were subjected to various accelerated and natural weathering tests as well as a battery of laboratory tests to determine their performance under typical shipboard conditions. A summary of the technical approach is outlined below.

- Prepare profiled (blasted) steel test panels by a standardized procedure to obtain flash rusting.
- Characterize the panels with respect to the varying degrees/types of flash rusting and surface contamination prior to coating. This analysis will characterize the potential of contaminants to accelerate coating deterioration.
- Coat panels with paint systems commonly authorized by NAVSEA. (Include immersion systems, atmospheric systems, surface-tolerant systems, and decking systems.)
- Subject appropriate painted panels to natural seawater immersion and natural marine atmospheric exposure testing. Similar panels will also be exposed to simulated in-service conditions and cyclic accelerated corrosion testing.
- Conduct periodic visual inspections and numerically rate each panel for the relative coating performance for cutback, rusting, and adhesion on the various coating types.

Test Procedure

Pre-Weathering of Test Panels

Pre-weathered panels were prepared and allowed to flash rust to varying degrees, as defined by SSPC-VIS 4/NACE No. 7. This standard provided a substrate condition that was representative of what might be expected in the field during an actual coating repair job. The preparation of panels for pre-weathering is discussed below.

Initial Preparation

Laboratory personnel prepared 120 hot-rolled steel panels to an SSPC-SP 10/NACE No. 2 condition, using virgin 24-grit aluminum oxide blasting media. The surface profile was measured on several randomly selected panels using press-on tape, according to ASTM D4417, method C.[7] The average profile measurement was 2.4 mils (60 micrometers). Each panel was then stamped with a number and received one coat of epoxy polyamide, MIL-P-24441 F 150, Type III,[8] to the stamped side of each panel.

Pre-Weathering

The panels were placed at a Sea Isle City, NJ, marine atmospheric exposure site at a 45-degree angle facing south. Panels were oriented with the unpainted side facing up to allow corrosion to form on this surface. The panels were exposed for 134 days.

Surface Preparation

The panels were removed from natural marine exposure for preparation. Waterjetting was used to remove the existing coating and corrosion products on these panels. Evaluation of the panels found that the corrosion product that built up over time was thick and adhered well to the panel. Therefore, to save time, the weathered sides of the panels were only sweep blasted. The color of the corrosion product was a dark reddish-brown and almost black in some cases. Very little corrosion was observed on the painted side of the panels.

Waterjetting was completed at a corrosion laboratory facility in Ocean City, NJ, using a hand lance with two non-cavitating jewels on a rotating nozzle to prepare the panel's surface for painting. The operating pressure of the pump was 36,000 psi (2,400 bar), and the flow rate of the lance was 3 gpm. On Navy vessels, coatings are applied as a full coating system over bare substrates prepared to an SSPC-SP 10/NACE No. 2 or SSPC-VIS 4/NACE No. 7, WJ-2 condition. Coatings are also applied to spot-prepared surfaces, where a primer is applied to areas of bare metal followed by a topcoat on the remaining intact coating. To simulate these conditions, the following preparation schedule was used.

Table 1: Surface Preparation for Each Coating System

		Flash Rusting Condition*				
		Control	Less than Light	Light	Medium	Heavy
Freeboard System	Painted side	SP-7	Spot WJ 25%-50% of the surface	Spot WJ 25%-50% of the surface	Spot WJ 25%-50% of the surface	-
	Weathered side	SP-10	WJ-2	WJ-2	WJ-2	WJ-2
Underwater Hull System	Painted side	SP-10	WJ-2	WJ-2	WJ-2	WJ-2
	Weathered side	SP-10	WJ-2	WJ-2	WJ-2	WJ-2
Tank System	Painted side	SP-10	WJ-2	WJ-2	WJ-2	WJ-2
	Weathered side	SP-10	WJ-4	WJ-4	WJ-4	WJ-4
Non-Skid System	Weathered Side	SP-10	-	-	-	WJ-4
	Secondary Side	None/Still Painted	None/Still Painted	None/Still Painted	None/Still Painted	None/Still Painted

**Under each of the flash rusting categories there are ten panels for each coating system tested.*

Fig. 1: Panels waterjetted to a WJ-2 condition

- The freeboard system panels were spot blasted to a WJ-2 condition in three areas, and the remaining area was sweep blasted. The weathered side of the freeboard was sweep blasted to a WJ-4 condition.
- The underwater hull system panels were waterjetted to a WJ-2 condition on both the painted side and the weathered side, as shown in Fig. 1.
- The tank system panels were waterjetted to a WJ-2 condition on the painted side and were sweep blasted on the weathered side.
- The non-skid panels were blasted to a WJ-4 condition on the weathered side. The painted side was not blasted. Only heavy flash rusting was achieved on the non-skid panels.

Laboratory personnel blasted the freeboard control panels to an SSPC-SP 10 on the weathered side and to an SSPC-SP 7/NACE No. 4, Brush-Off Blast[9] on the painted side of the panels. For the tank and underwater hull systems, the control panels were blasted to an SSPC-SP 10/NACE No. 2 on both sides. The surface preparation matrix is shown in Table 1.

Flash Rusting Evaluation

After waterjetting, the panels were allowed to flash rust to varying degrees before painting (Fig. 2). The following four categories of flash rusting were identified for this study.

- Less Than Light Flash Rusting: Two distinct levels of Light Flash Rusting were observed. Less Than Light Flash Rusting did not have as much flash rusting as the level, Light Flash Rusting.
- Light Flash Rusting (SSPC-VIS 4/NACE No. 7, Light Flash Rust): The surface is partially discolored by small quantities of light tan-brown, tightly adherent rust that will not mark objects that are brushed against it.
- Medium Flash Rusting (SSPC-VIS 4/NACE No. 7, Moderate Flash Rust): The surface is covered by a layer of

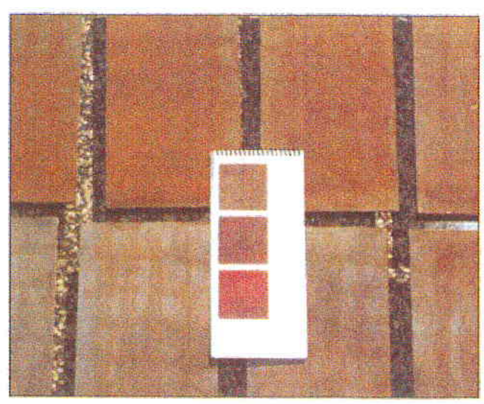

Fig. 2: Panels with less than light, light, and medium flash rust

Table 2: Coating Systems Applied to Panels

Type	Coating System
Free-board	1 coat of MIL-P-24441 epoxy (F150), 4-5 mils DFT 1 coat of MIL-P-24441 epoxy (F151), 4-5 mils DFT 2 coats alkyd topcoat , 3-4 mils DFT each
Under-water Hull	1 coat DOD-PRF-24647 epoxy, 4-6 mils DFT 1 coat DOD-PRF-24647 epoxy, 4-6 mils DFT
Tanks	1 coat MIL-P-23236 epoxy, 6-8 mils DFT 1 coat MIL-P-23236 epoxy, 6-8 mils DFT
Non-Skid	1-2 coats inhibited epoxy primer, 4-6 mils DFT 1 coat MIL-P-24667A Type I, Comp G epoxy Non-Skid

light tan-brown rust that will mark objects brushed against it.

• Heavy Flash Rusting (SSPC-VIS 4/NACE No. 7, Heavy Flash Rust): The surface is completely covered by dark tan-brown rust that is loosely adherent and will mark objects brushed against it.

Coating Systems

The coating systems in Table 2 were applied to both sides of the panels after waterjetting.

The non-skid coating system was applied to the 12-inch x 12-inch (30-centimeter x 30-centimeter) panels: 1 control and 3 heavy flash rusting. The other 3 coating systems were each applied to 50, 6-inch x 12-inch (15-centimeter x 30-centimeter) panels: 10 control, 10 less than light flash rusted, 10 light flash rusted, 10 medium flash rusted, and 10 heavy flash rusted.

Five dry film thickness (DFT) readings were made on each panel after coating application and cure. DFTs were found to be within the specified range.

Testing

Following application and cure of the coating systems, the panels were placed into performance testing. The tests selected were intended to simulate the in-service conditions experienced by each of the coating systems.

Condensing Humidity Cabinet

Condensing humidity testing was performed in accordance with ASTM D4585, Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation.[10] This test was used to simulate the effects of the atmospheric zone of a ballast tank (Fig. 3). Twenty panels of the tank system were exposed in the condensing humidity test. The panels were evaluated for general rusting and coating blistering.

Prior to testing, the adhesion of the coating systems was measured on four panels (ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers). The damaged areas of the panels were repaired with MIL-P-23236 epoxy.[12]

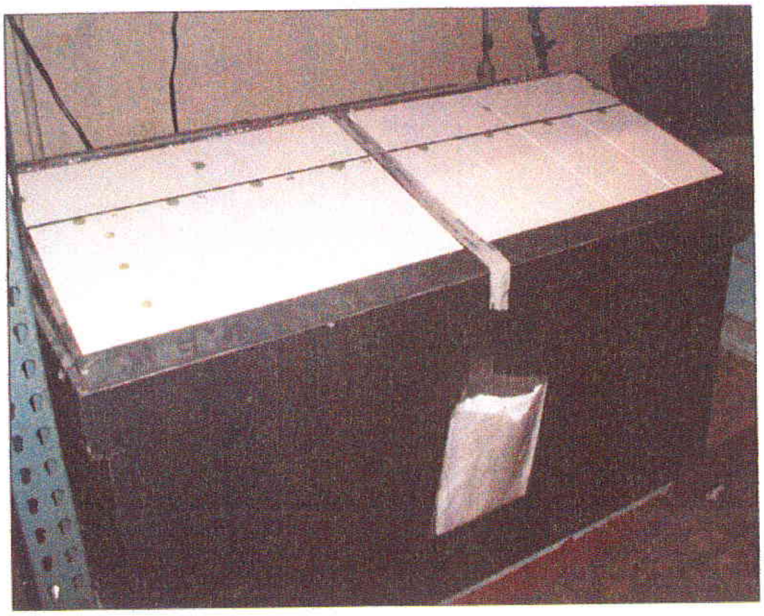

Fig. 3: Condensing humidity cabinet, ASTM D4585

Atmospheric Exposure

Twenty panels from the freeboard coating system were chosen for atmospheric exposure. Testing included an equal number of panels with each rust condition. These panels were placed in the atmospheric test site in Sea Isle City, NJ, on June 13, 2000. The panels were mounted at 45 degrees south with the spot-prepared sides up. The panels received daily natural seawater spray and were evaluated every two weeks. Before being placed at the atmospheric exposure test site, adhesion values were measured on four of the panels for each system, in accordance with ASTM D4541.[11]

Immersion Testing

Immersion testing is used to simulate the actual service conditions seen by underwater hull and tank coating systems. During this test, panels coated with the underwater hull system were placed in natural seawater that was continually refreshed to avoid stagnation. Daily seawater temperature readings were made throughout testing to monitor the local environment. The panels remained immersed for four months, with weekly evaluations during the first month and monthly evaluations thereafter.

Forty panels were placed in immersion testing: twenty with the underwater hull system, and twenty with the tank system. Prior to immersion, the adhesion of the coating systems was measured (ASTM D4541) on four panels from each system. The damaged areas of the panels were repaired with DOD-PRF-24647 epoxy.[13]

Accelerated Corrosion Chamber

Accelerated corrosion testing was performed in general accordance with ASTM G85,[14] Standard Practice for Modified Salt Spray (Fog) Testing. Here, test samples were subjected to a standard salt fog exposure, using a

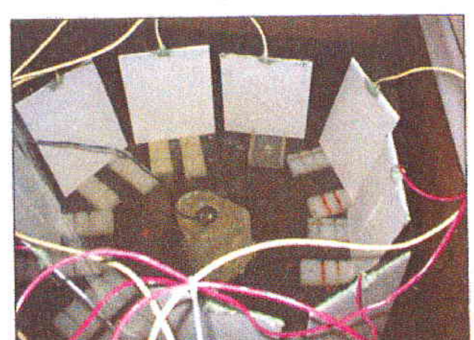

Fig. 4: Cathodic disbondment testing

5% NaCl solution, for a period of one hour. The test samples were then subjected to a one-hour dry-off period, where the exposure chamber was purged of the salt air and heated to 35 C (95 F). This cycle was repeated for one month.

Twenty of the panels coated with the freeboard system were placed in the accelerated corrosion test chamber. Before being placed in the chamber, adhesion values were determined on four of the panels. The areas damaged during the test were repaired with the alkyd topcoat.

Evaluation for Each of the Tests

Two intentional, circular holidays were made in the coating down to the substrate on two panels of each rust condition. The panels were evaluated for general rusting, cutback at the holiday, and general paint failure.

Cathodic Disbondment Testing

To simulate the cathodic protection on Navy vessels, cathodic disbondment testing was conducted in general accordance with ASTM G8,[15] Test Method for Cathodic Disbondment of Pipeline Coatings. Duplicate-coated 6-inch by 12-inch by ⅛-inch (15-centimeter by 30-centimeter by 3-millimeter) test panels had a 6-inch scribe made parallel to and centered along the 12-inch panel edge. The test panels were placed in a non-metallic tank and exposed to natural seawater (Fig. 4). Seawater flow into the tank was maintained to avoid stagnation.

The test panels were electrically coupled to a centrally located magnesium anode. These panels remained in testing for a minimum of 45 days, with electrical data (galvanic current and on/off potentials) taken weekly. After exposure, the panels were removed from the tank and inspected for blistering and cutback from the scribe. Blistering was rated in accordance with ASTM D 714,[16] and scribe cutback was recorded as the maximum distance from the scribe that the complete coating system can be easily removed using a razor knife. Cathodic disbondment testing can therefore be used as an indicator of coating adhesion to the substrate.

Twenty of the panels coated with the underwater hull system were placed in cathodic disbondment testing. Prior to being placed in testing, adhesion values were determined on four of the panels. The areas damaged during the test were repaired with DOD-PRF-24647 epoxy.

Table 3 shows a summary of the testing with each coating system.

Table 3: Summary of Test Matrix

Coating System	Free-Board	Underwater Hull	Non-Skid	Tank
Cathodic disbondment		√		
Accelerated corrosion	√			
Chamber immersion		√		√
Atmospheric exposure	√		√	
Condensing humidity				√

Results and Discussion

Testing was conducted on the four test systems using the methods described above. The results of these tests are discussed below.

Condensing Humidity Testing

Panels from the tank system were evaluated in condensing humidity cabinet testing. Testing was performed for eight months, with evaluations of the samples every four months. After eight months of testing, no visible deterioration of the test samples was observed.

Table 4 shows the average adhesion results of these samples during testing.

Although the strengths at which these samples failed varied throughout testing, the location of the adhesion failures did typically worsen with extended exposure. The samples applied over light and medium flash rust conditions experienced failures at the panel substrate after eight months of exposure. During previous tests of these samples, failures were observed to be intra- or intercoat failures (within the coating or between coating materials). The samples applied over heavy flash rusting experienced this failure after only four months of exposure. Since only the final adhesion measurements show any actual adhesion to the substrate (with values higher than previously measured on those panels), no inferences can be made as to which systems performed better based on adhesion only.

Table 4: Adhesion Test Results during Condensing Humidity Testing*

Condition	Pre-Test Strength (psi) / Failure Mode **	4-months Strength (psi) / Failure Mode **	8-months Strength (psi) / Failure Mode **
SP-10	670 / IRC	1250 / IRC	640 / AD
Less than Light	1030 / IRC	1620 / IRC	1330 / AD
Light	1220 / IAC	1250 / IAC	1450 / ST
Medium	840 / IRC	1490 / IAC	1520 / ST
Heavy	910	1110	-

* AD – Adhesive, IRC – Intercoat, IAC – Intracoat, ST – Subtrate

** Each number is an average of 3 adhesion pulls based on ASTM D4541

Marine Atmospheric Exposure Testing

Panels from the freeboard and the non-skid systems were evaluated in natural marine atmospheric exposure. Panels were exposed for 15 months, with periodic interim evaluations. Samples remain exposed at this facility for future evaluation.

Freeboard System

During the periodic inspections of the freeboard samples exposed in Sea Isle City, NJ, none of the samples showed visible signs of blistering of the coating system or cutback from the intentional holidays. Minimal rusting was observed on these samples. The ASTM D610[17] ratings are shown in Table 5.

This table shows that the average rust ratings are similar for all initial surface conditions.

In addition to visual inspections, the freeboard samples were evaluated for coating adhesion to the substrate. Table 6 shows the adhesion strengths and failure locations for these samples.

Table 5: Freeboard System Average Rust Rating, Natural Marine Atmospheric Exposure Testing

Condition	Rust Rating (D610)	
	No Holidays	Holidays
SP-10	10.0	9.0
Less than Light	10.0	10.0
Light	10.0	10.0
Medium	9.5	10.0
Heavy	10.0	9.0

These adhesion test results show some variation over time. During this test, the location of failures of the coating system was varied, though none was at the substrate.

Non-Skid System

Non-skid test panels were visually evaluated periodically for signs of corrosion. Following 15 months of exposure testing, none of the samples showed any signs of rusting or blistering. Some discoloration of the topcoat (reddening) has been observed. This is likely a result of prolonged ultraviolet exposure; however, since no long-term color and/or gloss data has been taken, this cannot be confirmed.

Natural Seawater Immersion Testing

Panels from the tank and underwater hull coating systems underwent natural seawater immersion testing at Ocean City, NJ. Testing was performed for eight months, with interim evaluations of the samples.

Table 6: Freeboard System Adhesion Test Results, Natural Marine Atmospheric Exposure Testing*

Condition	11-months	15-months
	Strength (psi) / Failure Mode **	Strength (psi) / Failure Mode **
SP-10	920 / IAC	640 / AD
Less than Light	880 / IAC	1150 / IAC
Light	880 / IAC	750 / IRC
Medium	790 / IAC	750 / IRC
Heavy	N/A	800 / IAC

* AD - Adhesive, IRC - Intercoat, IAC - Intracoat

** Each number is an average of 3 adhesion pulls based on ASTM D4541

Tank System

Panels with and without intentional holidays were evaluated by immersion in natural seawater. Periodic evaluations of the condition of the panels (rusting, blistering, and cutback from the scribes) were conducted. During this test, no blistering of any samples was observed. There was no measurable cutback on the samples with holidays. However, varying degrees of rusting were observed on panels both with and without holidays. Figure 5 shows the final ASTM D610 rust rating of the tank system panels without holidays. The differences were not statistically significant. The difference from 8 to 10.5 was

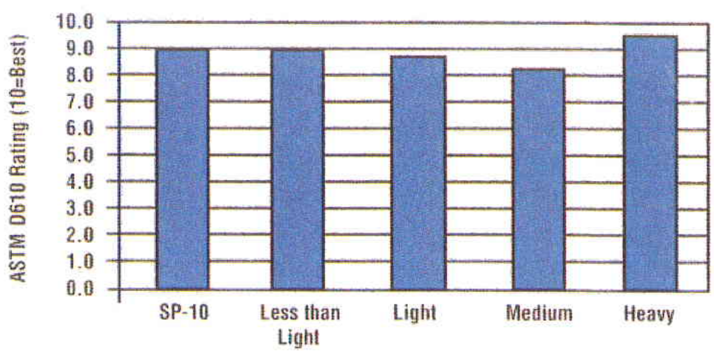

Fig. 5: Tank system without holidays, immersion test rust rating

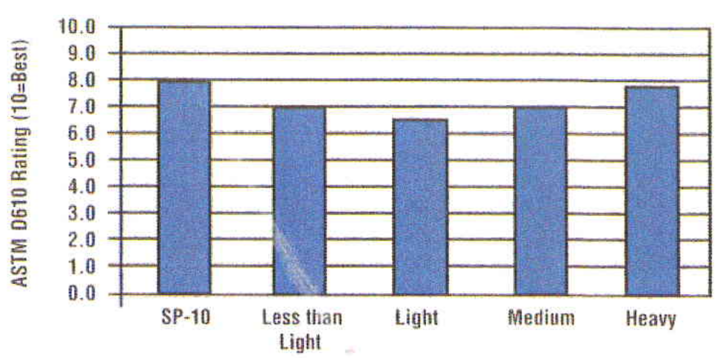

Fig. 6: Tank system with holidays, immersion test rust rating

Table 7: Tank System Adhesion Test Results, Natural Seawater Immersion Testing*

Condition	Pre-Test	4-months	8-months
	Strength (psi) / Failure Mode **	Strength (psi) / Failure Mode **	Strength (psi) / Failure Mode **
SP-10	1680 / AD	1680 / IAC	1130 / ST
Less than Light	1590 / AD	1590 / IAC	870 / AD
Light	2150 / IRC	2160 / IAC	1180 / AD
Medium	2180 / IRC	2170 / IAC	680 / AD
Heavy	1280 / ST	1280 / IRC	1210 / ST

* AD – Adhesive, IRC – Intercoat, IAC – Intracoat, ST – Subtrate
** Each number is an average of 3 adhesive pulls based on ASTM D4541.

only 0.1% to 0.01%. While this is an order of magnitude, on the whole scale, it is very small.

After eight months of exposure, the samples applied over SP 10, less than light and heavy flash rusting conditions, were the best performers (average ratings at 8 or above 9). Samples applied over a medium and light flash rusting were slightly worse with average ratings between 8 and 9. The overall range was approximately 0.1% to 0.01% rusting. Figure 6 shows the rust ratings for the tank system panels with holidays.

At the end of testing, the best performing samples were those applied over the heavy flash-rusted and SP 10 surfaces. The ratings of these panels were in the 7 to 8 range, which corresponds to 0.3 to 0.1% rusting. The worst performing samples were those applied over the light, medium, and less than light surfaces. The rating of these panels was 6 to 7, which corresponds to 1.0 to 0.3% rusting.

Adhesion testing of the seawater immersion panels was also performed at four-month intervals. Table 7 shows the results of this testing.

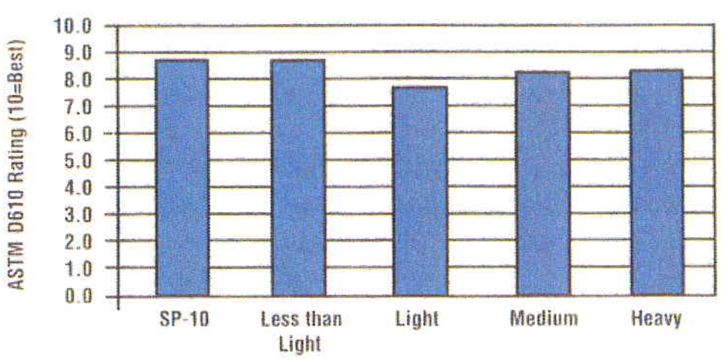

Fig. 7: Underwater hull system without holidays immersion test rust ratings

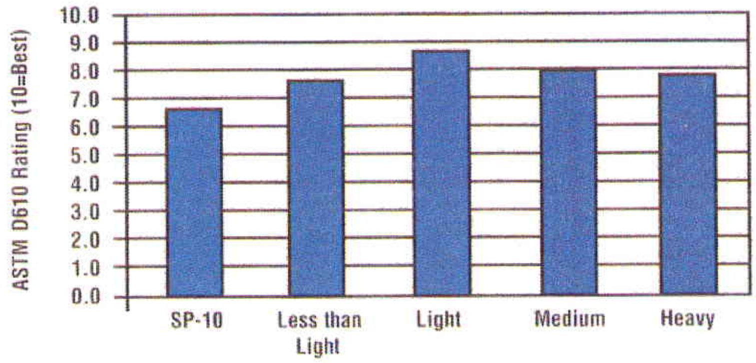

Fig. 8: Underwater hull with holidays, immersion test rust ratings

The average adhesion strength of these panels decreases over time, although most were intra- or intercoat failures. At the completion of testing, only two substrate conditions had failures at the substrate. These were the SP 10 and heavy flash-rusted samples. All other samples had failures of the adhesive used to attach the adhesion test dollies.

Table 8: Underwater Hull System Adhesion Test Results, Natural Seawater Immersion Testing*

Condition	Pre-Test	4-months	8-months
	Strength (psi) / Failure Mode **	Strength (psi) / Failure Mode **	Strength (psi) / Failure Mode **
SP-10	1750 / AD	1750 / IAC	910 / AD
Less than light	2070 / AD	2060/ AD	1060 / AD
Light	2150 / IRC	2150 / IAC	660 / AD
Medium	1830 / AD	1830 / IAC	1040 / AD
Heavy	1440 / AD	1440 / IRC	540 / AD

** AD – Adhesive, IRC – Intercoat, IAC – Intracoat*
*** Each number is an average of 3 adhesion pulls based on ASTM D4541.*

Underwater Hull System

Panels with and without intentional holidays were evaluated by immersion in natural seawater. Periodic evaluations of the condition of the panels (rusting, blistering, and cutback from the scribes) were conducted during this test. No blistering of any samples was observed. There was no measurable cutback on the samples with holidays; however, varying degrees of rusting were observed on panels both with and without holidays. Figure 7 shows the final rust rating of the underwater hull system panels without holidays.

The immersion test results for this coating system without intentional holidays are similar to the rust results for the tank coating system. During this test, all conditions except light flash rusting were in the 8 to 9 range (0.1 to 0.03 % rusting), with less than light flash rusting and SP 10 conditions having marginally higher ratings than the medium and heavy flash conditions. The light flash rusting condition panels were in the 7 to 8 range (0.3 to 0.1% rusting). Figure 8 shows the rust ratings of the underwater hull system with intentional holidays.

In general, the final ratings of these samples were worse than the same system without holidays. The best performing samples were those applied over light and medium flash rusting conditions, which were between 8 and 9 (0.1 to 0.03 % rusting). The samples applied over less than light and heavy flash rusting were the next best performers with ratings between 7 and 8 (0.3 to 0.1% rusting). The SP 10 control samples were the worst performers having an average rating of 6.5 (0.1 to 0.03 % rusting).

Adhesion testing of the natural seawater immersion panels was also performed at four-month intervals. Table 8 shows the results of this testing.

Table 9: Accelerated Corrosion Test Results

Initial Condition	As Coated		With Holidays	
	D610	D714	D610	D714
SP-10	10.0	10.0	6.0	10.0
Less than Light	9.7	10.0	8.0	10.0
Light	9.3	10.0	7.5	10.0
Medium	9.0	10.0	7.5	10.0
Heavy	8.9	10.0	7.0	10.0

Table 10: Adhesion during Accelerated Corrosion Testing*

Condition	Pre-Test	3-months
	Strength (psi) / Failure Mode**	Strength (psi) / Failure Mode**
SP-10	850 / IAC	1000 / IAC/IRC
Less than Light	900 / IAC	910 / IAC/IRC
Light	900 / IAC	900 / IAC/IRC
Medium	920 / IAC	980 / IAC
Heavy	640 / IAC	880 / IAC

* IRC – Intercoat, IAC – Intracoat

** Each number is an average of 3 adhesion pulls based on ASTM D4541

Table 11: Cathodic Disbondment Test Results

Initial Condition	Average Cutback (mm)	Average D714
SP-10	17.0	4F
Less than light	11.8	10
Light	5.7	10
Medium	2.1	10
Heavy	46.6	2M

The failure locations of all measurements were at the adhesive used to attach the test dollies to the coated surface or within the coating system itself, but not at the substrate. The general decrease in strength suggests that some degradation of the coating material may have occurred during testing. Furthermore, this suggests that the adhesion measured is an evaluation of the coating system performance rather than the effect of flash rusting on the system.

Accelerated Corrosion Testing

Panels from the freeboard system underwent accelerated corrosion testing. During this test, panels were subjected to a cyclic salt fog/dry-off exposure for three months. Following this exposure, panels were inspected for visible signs of corrosion.

Table 9 shows that following three months of exposure, none of the samples exhibited any blistering of the intact coating systems. Varying degrees of through-film rusting were observed on the test panels. On the as-coated samples, the rusting increased with increasing levels of flash rusting; however, the rating difference between these samples is minimal, with the worst performing system having a final rating of 8.9 (slightly above 0.03% surface rusting). Overall, the condition of these panels was similar, regardless of initial surface condition.

Table 10 shows adhesion measurements taken before testing and after three months. Coating adhesion measurements were taken, although no substrate failure was observed either before testing or after three months. Therefore, no inferences can be made concerning the effect of flash rust level on coating system adhesion.

An additional set of test panels was evaluated in this test. These panels were prepared with intentional holidays through the coating system. These samples also showed no blistering, but they did have lower ASTM D610 rust ratings. Most of the panels had average ratings in the 7.0 to 8.0 range, which is equivalent to 0.3 to 0.1% rusting. These panels also exhibited lower ratings as flash rusting increased, with the exception of the SP 10 panels, which had an average rating of 6.0 (1.0% rusting).

Cathodic Disbondment Testing

Panels from the underwater hull system were evaluated using cathodic disbondment testing. During this test, panels were immersed in natural seawater and coupled to a magnesium anode to provide cathodic protection. Following 90 days of exposure, samples were removed and evaluated for blistering and destructive cutback from the intentional scribe. Table 11 shows the results of this testing.

Table 11 shows that the worst performing systems were the heavily flash-rusted and SP 10 control samples. These samples had the highest destructive cutback and exhibited blistering of the intact coating system. The best performing systems were those applied over the medium and light flash-rusted surfaces; no blisters were observed. These results suggest that some flash rusting on the surface may promote adhesion on steel surfaces under cathodic protection. However, the presence of heavy flash rusting does appear to significantly affect adhesion, as evidenced by the significant cutback.

Conclusions

In most instances, pull-off adhesion measurements did not fail at the substrate. The failure modes in these cases varied between intracoat and intercoat, thus indicating the cohesive coating strength and not the effect of flash rust on the coating to substrate adhesion. Where failure was observed at the substrate, the pull-off adhesion measured over 1,000 psi (67 bar) in all cases, indicating that flash rust does not significantly affect pull-off adhesion.

Cathodic disbondment testing gives an indication of coating adhesion to the substrate and coating performance when used in conjunction with cathodic protection. The scribe cutback results showed that coating systems applied over light and medium levels of flash rusting had good adhesion compared to the SP 10 control panels, whereas coatings applied over heavy flash rusting had poor adhesion. This suggests that heavy flash rusting may compromise coating adhesion.

On panels with intentional holidays, the light and medium flash rusting surface conditions exhibited the least amount of surface rusting, whereas the SP 10 surface condition was observed to have the highest surface rusting, followed by heavy flash rusting.

Based on poor adhesion in cathodic disbondment testing and low rust rating on panels with damaged coatings, this testing leads to a general conclusion that heavy flash-rusted surfaces are not acceptable for paint application. This conclusion, however, is based on the limited coating systems tested and may not be applicable to other systems.

These results seem to indicate that flash rusting has very little effect on coating performance based on the tests conducted for these coatings under the conditions in the tests.

Editor's Note: For another approach to understanding flash rusting after waterjetting and its effect on coating performance, see the two-part French study published in JPCL, *"Quantification of the Products of Corrosion after UHP Waterjetting" (November 2002), pp. 74-91, and "Evaluation of Behavior of Reference Paint Systems after UHP Waterjetting," (January 2003), pp. 48-54, by Philippe Le Calve, Philippe Meunier, and Jean Marc Lacam.*

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