Compatibility of "Single Coat" Tank Coatings with Retained Pre-construction Primer

NSRP Surface Preparation and Coatings Panel Project Report
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Executive Summary

A series of NSRP projects have led to Navy approval for retention of pre-construction primer in most tank and void applications during ship construction and maintenance. However, the risk posed by allowing pre-construction primer (PCP) retention under ultra-high solids, quick cure “single coat” system (MIL-PRF-23236 Type VII Class x/18) could not be addressed without additional data. Coating manufacturers have never tested the single coat products for use over retained PCP because Navy policy was to remove PCP prior to coating tanks. A series of three NSRP projects explored the performance of single coat systems over retained PCP in laboratory and simulation tests as well as shipboard demonstrations.

Single coat materials are more viscous and faster curing than legacy tank coatings. The key technical concern is that single coat materials may not adequately “wet” the PCP and therefore not have adequate adhesion to perform properly. Laboratory tests were performed on various single coat materials over alternative PCP’s with various secondary surface preparation methods. The systems were evaluated for coating adhesion, cathodic disbondment and performance in simulated seawater ballast exposure.

Initial laboratory testing showed that adhesion and cathodic disbondment tests were acceptable for single coat materials applied over retained pre-construction primer after brush blasting or pressure washing. However, within the bounds of acceptable performance, the data shows slightly lower adhesion and slightly more cathodic disbondment over retained pre-construction primer versus near white metal blasted surface. This suggests that there is some finite but acceptable performance risk associated with applying single coat products over retained pre-construction primer.

Based on the success of the laboratory and simulated ballast tank testing, HII-Ingalls Shipbuilding (Ingalls) requested (through the Navy-Industry working group) that Naval Sea Systems Command (NAVSEA) allow them to demonstrate the process on certain tanks and voids that present a low risk to the Navy. Ingalls identified a number of compartments on the LPD-17 class ships that were candidates for the proposed process. These compartments consist primarily of voids, fuel tanks, fuel oil tanks, and oily waste tanks. The objective of the test was to produce data showing the Ingalls process for applying MIL-PRF-23236, Type VII, Class 5/18 (single coat) coatings over retained PCP[1] does not appreciably degrade coating life as indicated by coating adhesion and other observations.

The project successfully demonstrated a process for retaining pre-construction primer on four prototype tanks during production of LPD-26. Ingalls production, Ingalls QA, SUPSHIPGC and coating manufacturer representatives agreed on a surface preparation production process and acceptance criteria. Excellent adhesion was demonstrated as measured by pull-off adhesion tests described in ASTM D4541, Method E, and X-cut tests described in ASTM D6677. The production procedure used for the prototype tanks has been successfully used on 48 additional tanks on LPD-26 comprising over 83,000 square feet of

[1] The “process” includes abrasive blasting steel plate and shapes to SSPC SP-10 (Near White Metal Blast) in the primer line, blasting welds/erection joints to SSPC SP-10 on the ways, brush blasting the retained PCP, and applying MIL-PRF-23236, Type VII, Class 5/18 coatings in accordance with Navy requirements.

coated surface. Current plans are to use this process on over 200 compartments comprising over 1 million square feet of coated surface on LPD-26

The Navy should monitor long-term coating performance as reflected in the Navy Corrosion Control Information Management System (CCIMS) to determine if the project goal is met (i.e., 80% of the tanks remain in CCIMS condition 1 or 2 after nominally 7-12 years of service). The Navy should also support additional demonstration projects as long as data continues to be favorable.

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Conclusions

1. The testing suggests that either brush blasting or pressure washing are suitable methods of secondary surface preparation. In the simulated ballast tank testing, the single coat products performed marginally better over pressure washed PCP while on the test panels the single coat products performed marginally better over SP-7, brush blasted surfaces.

2. The cathodic disbondment tests suggest that single coat products will perform acceptably over retained pre-construction primer that has received secondary surface preparation using either brush blasting or 2,800 psi pressure washing.

3. In both simulated ballast tank exposure and cathodic disbondment tests, performance was acceptable for single coat materials applied over retained pre-construction primer after brush blasting or pressure washing. However, within the bounds of acceptable performance, the data shows slightly lower adhesion and slightly more cathodic disbondment over retained pre-construction primer versus near white metal blasted surface. This suggests that there is some finite but acceptable performance risk associated with applying single coat products over retained pre-construction primer.

4. Blistering was observed on both control and single coat systems during the simulated ballast tank testing. The blisters did not appreciably change through the exposure test period. The blistering was similar for single coat over retained PCP with SP-7 "Brush Blast" or "Pressure Wash" preparation. Blistering was noticeably greater over retained PCP receiving solvent cleaning with spot power tool cleaning.

5. A successful process for retaining pre-construction primer was developed and demonstrated on 52 tanks (comprising over 83,000 square feet of coated surface) during production of the LPD-26 at HII-Ingalls Shipbuilding. The success is based on:

    a. The ability of Ingalls production, Ingalls QA, SUPSHIPGC and coating manufacturer representatives to agree on a surface preparation production process and acceptance criteria.
    b. Excellent adhesion as measured by pull-off adhesion tests described in ASTM D4541 and X-cut tests described in ASTM D6677.

Recommendations

1. Continue the LPD-26 demonstration of the process on over 200 compartments comprising over 1 million square feet of coated surface.

2. Continue to monitor the long-term coating performance as reflected in the Navy Corrosion Control Information Management System (CCIMS). The present project findings are based on adhesion data from production tanks and performance data from laboratory test panels and simulated ballast tanks. In-service experience will help build confidence in these results.

3. Adopt the secondary surface preparation requirement used during the demonstration on LPD-26 for other Navy ships. Monitor implementation to ensure that revised processes are sufficiently robust to work in different shipyards with various coating materials and on different ship classes.

4. Develop industry standards that will foster standard practices that in turn will improve performance and reduce costs for all stakeholders, including the Navy.

Introduction

A recently completed NSRP project has resulted in an approval to retain pre-construction primer during ship construction and maintenance for most Navy ship tank applications. However, the risk posed by allowing pre-construction primer (PCP) retention under ultra-high solids, quick cure “single coat” system (MIL-PRF-23236 Type VII Class x/18) could not be addressed without additional data. The key concern is that single coat products may not adequately “wet” the PCP and therefore not have adequate adhesion to perform properly. Given the high solids content and rapid cure time of the single coat products it is conceivable that they would not be able to effectively adhere to the relatively porous retained pre-construction primer.

If single coat systems could be applied over retained pre-construction primer, the Navy could recognize the benefits of two cost-saving coating processes – single coat systems and pre-construction primer retention. A series of three NSRP projects investigated the application of single coat systems over retained PCP. Table 1 presents a high-level schedule for the various project tasks. The first project conducted laboratory tests (cathodic disbondment and adhesion) on test panels prepared with forty-eight different combinations of single coat material, pre-construction primer, and secondary surface preparation. The first project also initiated seawater ballast exposure in simulated ballast tanks and test panels. Based on the success of the laboratory tests, a second project continued the seawater ballast test exposure and developed an approved plan for an extensive demonstration on over 200 tanks (and over 1 million square feet of coated surface) on LPD-26. The third project executed the demonstration on LPD-26 and extended the seawater ballast tank exposure. This report presents the combined results of all three projects.

Table 1 – Overall Schedule of Project Tasks

Project Task	**2011**	**2012**	**2013**	**2014**
Laboratory (Panel) Tests	XXXX			
Field Test in Simulated Ballast Tanks	XXXX	XXXX	XXXX	
LPD-26 Demonstration		XXX	XXXX	X
Finalize Technical Requirements			XX	X

Laboratory and Simulation Testing

Experimental Approach

The laboratory and simulation test phase of the project was focused on validating that adequate adhesion was achieved when single coat products are applied over retained pre-construction primer with various secondary surface preparation processes. The coating adhesion was evaluated in two tests – cathodic disbondment testing in accordance with the requirements in MIL-PRF-23236 and simulated seawater ballast tank exposure. The following three sections describe the procedures for preparation of the coated test surfaces, the experimental approach for the cathodic disbondment testing, and the simulated seawater ballast tank exposure.

Preparation of Coated Test Surfaces

The following discussion presents an overview of the pre-constriction primer application, weathering, secondary surface preparation,[2] and application of the primary coating to the test surfaces. A more detailed discussion of the test surface preparation is provided in the results and discussion section of this report.

Pre-construction Primer Application

Tanks. The tanks used for testing were originally fabricated in the late 1980’s for an NSRP project investigating the performance of ballast tank coatings over retained pre-construction primers. Subsequent to that test, they had been used for painter training. The tanks had an unknown epoxy coating but no significant corrosion. The tank surfaces were abrasive blasted to an SSPC SP-10 condition using recycled steel grit to a surface profile of 2-3 mils. In the tanks, the pre-construction primers were applied manually using spray equipment. Surface conductivity was determined in each compartment in general accordance with the requirements outlined in Navy Standard Item 009-32.

Before priming, small areas were masked by a transparent film used to obtain a representative sample of the applied PCP. The pre-construction primers was manually spray-applied to a target nominal DFT between 0.6 and 0.8 mils. Five tanks had a solvent base zinc silicate pre-construction primer while the sixth (S-1) had a zero VOC zinc silicate pre-construction primer. All surface preparation and primer application took place when the relative humidity was below 85% and the surface temperature was 5°F above the dew point. The first application of PCP resulted in significant areas with a thicker DFT than desired. It was difficult to maintain the thin target coating thickness in corners and other complex geometries with manual spray application. The first coat of PCP was removed by abrasive blasting and a

[2] Secondary surface preparation is defined as the collection of processes associated with cleaning, steel finishing/dressing treatments, and coating surface preparation that are performed on a structural assembly that has previously been subject to primary surface preparation, coated with PCP, and subsequently fabricated into larger vessel blocks/modules or the final product. It is performed prior to the application of the final specified primary coating system.

more consistent coat of PCP was applied. Thickness data for the tested PCP is presented later in this report.

Panels. The test panels were 6-inch by 9-inch flat panels cut from ¼-inch thick low alloy steel. PCP was applied to the steel test panels as outlined in Table 2.

Table 2 – Pre-Construction Primers Applied to Test Panels

Pre-Construction Primer	***Source/ Applicator***	***Panel Qty***	***Manufacturer Description***
Sigmaweld 199	BIW	20	Two-component moisture curing, low zinc (ethyl) silicate prefabrication primer with 25% solids by volume and 38% zinc in dried film by weight.
Carbozinc 8703	Carboline	20	Self-curing, inorganic, zinc silicate with 48% solids by weight and 85% zinc in dried film by weight.
Interplate 0	NASSCO (manual spray)	10	Water-based zinc silicate in a silica sol binder with 36% solids by volume
Interplate 997	NASSCO (plate line)	10	Zinc silicate pre-construction primer with 25% solids by volume
None (SSPC SP-10)	NASSCO	5	Not applicable

Weather and Contaminate Primed Surfaces

Tanks. The tanks were allowed to weather for a period of 60 days. The tanks were stored outdoors with all openings left open to allow ambient conditions to circulate through the tanks. A light potable water mist was applied to the interior surfaces of each tank once each week.

During the first month of exposure, eight flat steel strips were welded in the tank. No attempt was made to avoid damaging the primer during this process. The damaged primer was inspected approximately halfway through the 60-day exposure and determined to be weathering in a representative fashion compared to other weathered pre-construction primer at the NASSCO facility. Figure 1 shows representative pictures of the weathered tank surfaces.

Figure 1. Representative pictures of weathered pre-construction primer in the simulated ballast tanks.

Panels. The steel panels were stored outside at the NASSCO facility for approximately 60 days before coating application.

Secondary Surface Preparation

Tanks. Table 3 summarizes the four different secondary surface preparation procedures performed on different areas of each tank. The hatch received a pressure wash (also referred to as Low Pressure Water Clean or LPWC) with potable water at approximately 3,000 psi. The tank interior was divided in half vertically. The right half of the tank was subjected to spot solvent wipe (SSPC SP-1) of visible contaminants and power tool cleaning (between SSPC SP-3 and SSPC SP-11) of localized corrosion. The left half of the tank received a brush blast similar to that described in SSPC SP-7. The front half of the sidewall of the brush blasted side was prepared to an SSPC SP-10, near white metal blast. The drawing in Appendix A illustrates where the various surface preparations were performed. QA data for chloride concentration, surface profile and visual cleanliness were collected and are presented in the discussion section of this report.

Panels. Table 3 summarizes the four different secondary surface preparation procedures performed on test panels. Secondary surface preparation of the test panels involved either brush blasting or pressure washing. Test panels were also prepared to a near white metal blast to serve as controls for the cathodic disbondment tests.

Table 3 – Summary of Secondary Surface Preparation Methods Evaluated on Panels and Tanks

Surface Preparation	***Number of Panels***	***Tank Surfaces***
Power Tool clean[3] damaged areas Solvent Wipe	None	Right half of the tank
Brush Blast[4]	30 Total *(10 Sigmaweld 199, 10 Carbozinc 8703, 5 Interplate 0 and 5 Interplate 997)*	Left half of the tank except for the SP-10 portion
Low Pressure Water Clean (LPWC)	30 Total *(10 Sigmaweld 199, 10 Carbozinc 8703, 5 Interplate 0 and 5 Interplate 997)*	Hatch cover
SSPC SP-10	5 Total	2-foot by 4-foot section on the front of the left side of the tank

[3] Power tool cleaning was between an SP-3 and SP-11

[4] Brush blast approximated the requirements of SSPC SP-7 except that all corrosion was removed

Primary Coating Application

<u>Tanks and Panels</u>. Table 4 shows the tanks and panels that received the various primary coatings. The primary coating was applied in general accordance with the manufacturer's instructions. Coating manufacturer representatives were present during application of their system to the tanks and test panels at NASSCO. As indicated in Table 4, the Warren Environmental Safe-T Plus was applied by the manufacturer. Coating DFT was measured at multiple locations in each compartment (one gage reading on each side of each stiffener and one gage reading on each side, top and bottom). Selected QA data are provided in the results section of this report.

Table 4 – Primary Coatings Applied to Tanks and Panels

Primary Coating	***Applicator***	***Number of Panels***	***Tank Number***
Sherwin Williams Fast Clad	NASSCO	13	J-2
Sherwin Williams Fast Clad w/primer	NASSCO	13	J-1
Sherwin Williams SeaGuard 5000HS	NASSCO	13	J-3
International Interline 783	NASSCO	13	S-1 and S-2
International Intershield 300HS	NASSCO	None	S-3
Warren Environmental Safe-T Plus	Warren Environmental	13	None

Cathodic Disbondment Testing

Cathodic disbondment testing was performed on various combinations or pre-construction primer, secondary surface preparation and primary coating system to evaluate the adhesion of single coat materials to the various retained pre-construction primers. Table 5 shows the combinations that were evaluated.

Table 5 – Matrix of Test Panels Prepared for Cathodic Disbondment Testing

Primary Coating	***Sigmaweld 199***		***Carbozinc 8703***		***Interplate 0***		***Interplate 997***		***SSPC SP-10 Near White Metal Blast***
	Brush Blast	***LPWC***	***Brush Blast***	***LPWC***	***Brush Blast***	***LPWC***	***Brush Blast***	***LPWC***	
Fast Clad	1	1	1	1	1	1	1	1	1
Fast Clad w/primer	1	1	1	1	1	1	1	1	1
SeaGuard 5000HS	1	1	1	1	1	1	1	1	1
Interline 783	1	1	1	1	1	1	1	1	1
WE Safe-T Plus	1	1	1	1	1	1	1	1	1

Cathodic disbondment testing was performed in accordance with the general provisions in MIL-PRF-23236D. The specification requires:

> 3.5 Cathodic protection (CP) compatibility (all types, all classes except 14, all grades). When tested as specified in accordance with 4.5.16, the coating system shall not peel, flake, blister, dissolve, or otherwise fail. Undercutting or peeling shall not exceed 4 percent of the area of the test panel and all undercutting and peeling shall be located within ½ inch of the holiday.
>
> 4.5.16 Cathodic protection (CP) compatibility. Two steel panels shall be prepared as specified in 4.5.2 and electrically connected to a commercial magnesium anode conforming to ASTM G8 and shall have a 0.25-inch (nominal) hole drilled through the coating to the metal at the center of the test panel. The electrical resistance between a point on the surface of the anode and the metal in the drilled hole of the test panel shall be less than 0.01 ohms, when checked with an ohm meter. Connecting points on the test panel shall be coated with an epoxy compound for insulation. The test panel shall be installed in a modified ASTM G8 test in such a manner as to separate the test panel from the magnesium anode by 2 feet (nominal) for a period of 3 months. At the completion of the 3-month test, inspect each test panel for peeling, flaking, blistering, dissolving, or other failure. Lifting, peeling or undercutting around the drilled hole shall be measured. Test results shall be in accordance with the requirements of 3.5.

Figure 2 shows the general arrangement of the testing. Testing was performed in tanks containing continuously refreshed natural seawater. Galvanic current and potential data as well as water chemistry was monitored throughout the test.

Figure 2. Cathodic disbondment test arrangement.

Simulated Seawater Ballast Tank Exposure

The testing utilized two test ballast tanks (each containing three compartments) which were fabricated as part of a previous NSRP project.

The test coatings were applied to six tank compartments and a series of test panels. Table 6 shows the treatment of each test ballast tank compartment. Appendix A contains a detailed drawing of a ballast tank compartment. Table 7 shows the matrix of test panels which were prepared for simulated seawater ballast exposure. Details on the various pre-construction primers, surface preparations, and primary coatings are provided elsewhere in the experimental approach.

Table 6 – Summary of Conditions in each Simulated Ballast Tank

Tank-Compartment	***PCP***	***Surface Preparation***	***Primary Coating***
J-1	Interplate 997	• Power Tool[5] to ensure a 1 mil profile/Solvent Wipe (½ tank) • Pressure Wash (hatch cover) • Brush Blast[6] (½ tank, less the SP-10 area) • SP-10 (2 ft by 4 ft of one tank side)	Sherwin Williams Fast Clad w/ primer
J-2	Interplate 997		Sherwin Williams Fast Clad
J-3	Interplate 997		Sherwin Williams SeaGuard 5000HS (Control)
S-1	Interplate 0		International Interline 783
S-2	Interplate 997		International Interline 783
S-3	Interplate 997	IAW IMO PSPC	International Intershield 300HS (Control)

Table 7 – Summary of Test Panels in Seawater Ballast Exposure

	Sigmaweld 199		***Carbozinc 8703***	
Primary Coating	***Brush Blast***	***Press Wash***	***Brush Blast***	***Press Wash***
Fast Clad	1	1	1	1
Fast Clad w/primer	1	1	0	1
SeaGuard 5000HS	1	1	1	1
Interline 783	1	1	0	1
Intershield 300HS	0	0	1	0
WE Safe-T Plus	1	1	1	1

Once cure to immersion time was reached for all coatings, the tanks were subjected to a ballast cycle wherein each tank is filled with seawater for 14 days. To avoid unnecessary disposal costs, the same water was cycled between the two tanks, thus one tank is dry while the other is wet. In addition to visual

[5] Power tool cleaning is expected to be better than SP-3, but not SP-11

[6] Brush blast will approximate the requirements of SSPC SP-7

observations, the pH and conductivity of the seawater were measured after each movement to ensure the seawater chemistry remained acceptable. At each inspection, the ballast water was disposed and the appropriate tanks filled with fresh seawater.

The coatings applied to the simulated ballast tanks were inspected after nominally 3, 6, 12, 17, and 33 months of exposure. During each inspection, the tank surfaces and test panels were inspected for rusting, blistering, and undercutting in accordance with ASTM procedures. At the 12-month and 33-month inspections, coating adhesion was also evaluated in accordance with ASTM D4541, method E.

Adhesion Testing

One of the primary motivating factors for this study was the concern that the single coat products may not adequately "wet" the PCP and therefore not have adequate adhesion to perform properly. In an attempt to evaluate the PCP/primary coating interface, pull off adhesion was measured in accordance with ASTM D4541, Method E. Briefly, the test involves adhering a test fixture to the coating and pulling it normal to the surface until failure. The failure load and location of failure (i.e., layer of coating or adhesive where the failure occurred) is noted. Note that the interface of interest for this testing is that between the PCP and the primary coating. If adhesion failures are observed at other interfaces, we can conclude that the interface of interest is not the weak point in the system and therefore not a concern.

Results and Discussion

The results of the project are presented in four sub-sections. First, the coating application and QA data are presented. Second, adhesion data on the applied coatings is presented. Third, the results of the cathodic disbondment testing are presented. Finally, the condition of the test tanks through 33 months of simulated seawater ballast exposure are presented.

Preparation of Coated Test Surfaces

Pre-construction Primer Application

Pre-construction primer was hand applied to the test tanks using conventional air equipment. The first application resulted in excessive PCP thickness. The PCP was removed by abrasive blasting to SP-10, near white metal blast with steel grit. The average surface profile for each tank (measured with replica tape) was between 2.75 and 3.5 mils. The PCP dry film thickness (DFT) was measured using two methods. Fifteen gage readings were taken in each compartment using a Type 2 electronic gage. The average PCP DFT in each compartment was between 1.02 and 1.24 mils. Because the target thickness is low compared to the surface profile, these readings are likely to be higher than the actual film build. In anticipation of this problem, the PCP DFT was also measured on a transparent film shim, which was placed in each of the tanks. These readings for each tank (made using a micrometer) indicated an average DFT between 0.24 and 0.5 mils. Figure 3 shows all of the PCP measurements in a cumulative probability format.

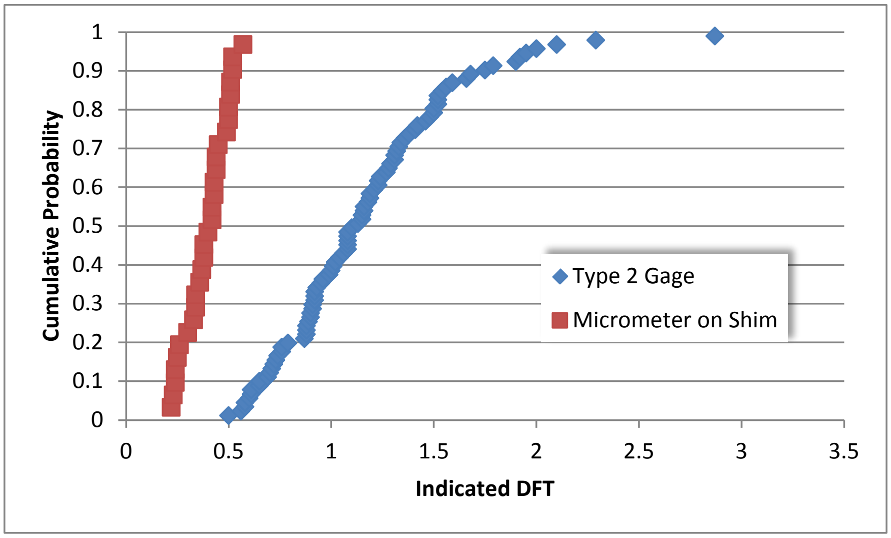

Figure 3. Cumulative probability representation of all PCP DFT measurements.

Secondary Surface Preparation and Primary Coating Application

The secondary surface preparation and primary coating application took place during the week of May 23, 2011. On Monday and Tuesday the International products were applied. On Wednesday and Thursday the Sherwin Williams products were applied. Final touch up was performed as required on Friday.

International Product Application (Compartments S1, S2 and S3)

After masking the right half of each compartment, sweep-blasting was performed on the left half of each compartment and the designated test panels. The abrasive blasting met SP-10 in the designated areas. After blasting, the protective sheeting was removed and power tool cleaning was performed on the right half of each compartment using needle guns, power wire brush and 3M abrasive disks. Power tool cleaning was limited to welds, exposed (rusted) metal, and damaged primer. The PCP surfaces that were cleaned with a power wire brush had a burnished appearance. Finally, the compartment openings were masked off with plastic and the compartment doors and designated test panels were pressure washed with ~2800 psi water. The tanks and panels were then moved to the paint bay. Figure 4 shows representative surfaces after secondary surface preparation.

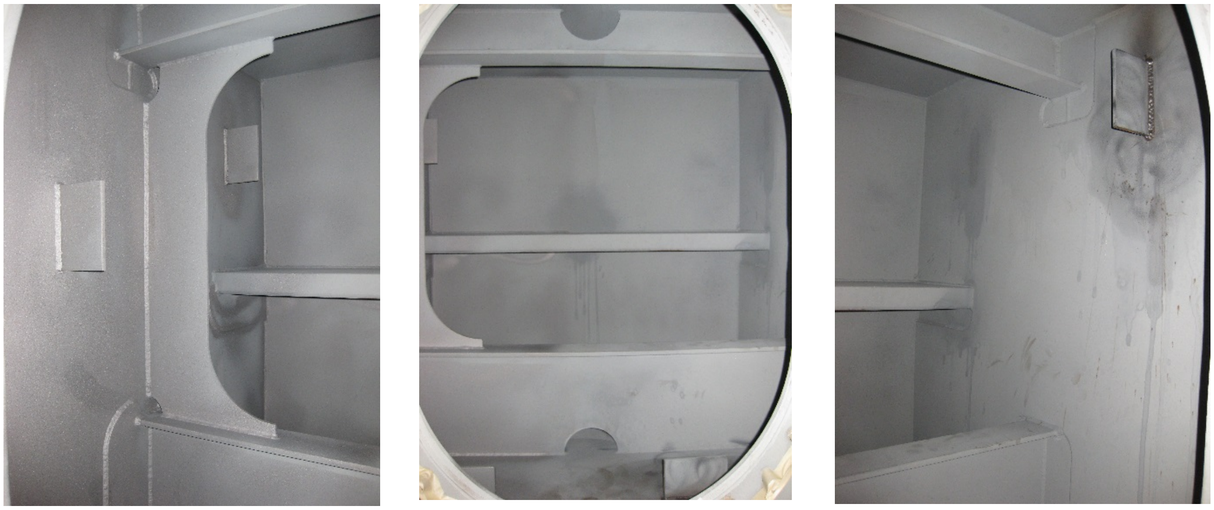

Figure 4. Representative secondary surface preparation. The left Photo shows SP-10 in the foreground and SP-7 toward the back. The middle figure shows SP-7 on the left and SP-1/power tool clean on the right. The right picture shows SP-1/power tool cleaned surface.

Before any coating application, surface preparation inspection was accomplished and the compartment interiors were solvent wiped. It was noted that the untouched PCP surfaces had somewhat high conductivity (47 and 49 uS), as compared to 30 µS for normal US Navy Standard tanks. The condition was intentionally not remedied as it was deemed representative of a “minimally prepared” surface. Interline 783 was applied to compartments S1 and S2 and twelve of the thirteen test panels. Next, Intershield 300HS (gray) was applied to compartment S3. After curing overnight, the second coat of Intershield 300 HS (gray) was applied to compartment S3.

Outgassing was noted on the test panels with pressure washed SigmaWeld 199 primer and Interline 783 topcoat. Further investigation suggested that the outgassing may be the result of the unusually high DFT of the primer (approximately 3 mils). On the third day, additional panels with SigmaWeld 199 were pressure washed and coated with a mist coat/full coat technique. Significant outgassing was observed after applying the mist coat of Interline 783 to the SigmaWeld 199/pressure wash panels. After about 15 minutes, the full coat of Interline 783 was applied and no outgassing was noted. Panel edges which were not completely coated were touched up with a roller.

<u>Sherwin Williams Product Application (Compartments J1, J2 and J3)</u>

After masking the right half of each compartment, abrasive blasting was performed on the left half of compartments J1, J2 and J3 and the designated test panels. The abrasive blasting met SP-10 in the designated areas, but the brush blasted (SP-7) condition on the “J” tanks appeared noticeably lighter than compartments S1, S2 and S3. The SP-7 prepared test panels were similar to those prepared for the International products. After blasting, the protective sheeting was removed and power tool cleaning was performed on the right half of each compartment using needle guns, power wire brush and 3M abrasive disks. Power tool cleaning was limited to welds, exposed (rusted) metal, and damaged primer.

The compartment openings were masked off with plastic and the compartment doors and designated test panels were pressure washed with 3000 psi water. The tanks and panels were then moved to the paint bay.

During the final inspection, an area of corrosion was noted below the tag on the top-rear of the left side of tank J3. This was supposed to be prepared to an SP-7. To keep the coating application on schedule, the area was noted and power tool cleaned. Also during final inspection, some of the power tool cleaned areas had a smooth feel and were re-worked with a needle gun.

After surface preparation, Sherwin Williams SeaGuard 5000 HS (red) was applied to tank J3 and the series of test panels. A mist coat/full coat technique was used on the SigmaWeld 199/pressure washed panels. Outgassing of the mist coat was observed but the full coat was successfully applied. During application, component B (catalyst) was not moving through the line readily and at one point the pump alarm went off. Subsequent to application, a small piece of plastic was found at the base of the pump which was likely restricting flow. On the morning of 28 May 2011, the coating could be scratched with a fingernail (using considerable effort) and left a light red mark on a solvent rag after 50 double rubs. It was felt that the cure may have been slightly impacted, but it did not warrant removal of the coating. The gray second coat of 5000HS was applied using airless equipment. The coating was applied to the test panels and tank J3 without incident.

Fast Clad primer with OAP technology was applied to tank J1 and a series of test panels without incident. A mist coat/full coat technique was used on the SigmaWeld 199/pressure washed panels, though no outgassing of the mist coat was observed. The primer appeared to cure properly overnight. A full coat of Fast Clad (gray) was applied to tanks J1 and J2 and test panels (both primed and un-primed). A stripe was brush applied to the tanks before spraying them. The initial attempt at striping was performed with product that was darker than the product that was used to mist coat the panels, indicating that too much component B was in the mix. The stripe was removed with a solvent rag and re-applied. For the Fast Clad application directly to the SigmaWeld 199/pressure washed panels, a mist coat/full coat technique was used. Outgassing of the mist coat was observed, but the final coating did not exhibit pinholes.

Final QA and Touch-up

Figure 2 shows representative surfaces of the simulated ballast tanks after the single coat system was applied. Table 8 shows the surface conductivity and profile for each tank after secondary surface preparation. Table 9 shows the average DFT readings after the primary coating was applied to each compartment. After final DFTs were performed, the inspector marked low areas for touch-up. Varying degrees of brush/roller touch was required in each of the tanks. Only two panels required touch-up (along bottom edge).

Figure 5. Representative surfaces of simulated ballast tanks with single coat tank coating.

Table 8 – Surface Preparation QA Data

		Tank S	Tank J
Average Conductivity, uS/cm	***SP-10***	15	26
	SP-1/SP-3	48	22
	LPWC	8	29
Surface Profile, mils	***SP-10***	3.1	3.8
	SP-1/SP-3	3	3.4
	LPWC	2	3.15

Table 9 – Average Thickness of Primary Coating Systems

Coating Thickness, mils	***Tank S***			***Tank J***		
	S1	***S2***	***S3***	***J1***	***J2***	***J3***
Primer (Ty 2 Gage)	1.02	1.15	1.24	1.3	1.1	1.2
Primer (Shim)	0.42	3.9	0.5	0.24	0.46	0.34
First Coat			5.92	8.43		4.63
Final Thickness	20.37	20.12	10.38	26.12	23.52	13.3

Coating Adhesion

Adhesion tests were performed on unexposed coated test panels after a minimum of 14 days cure. Figure 6 is a cumulative probability plot of the data. Cumulative probability plots express the likelihood in which an observation will be less than or equal to a given value. As an example, the right-most SP-10 data point would conclude that there is approximately an 89% likelihood that the next data point collected will be less than approximately 3400 psi.

The graph shows the distribution of adhesion failure loads for various populations as indicated in the legend. Each shape represents the data set indicated in the legend while the color indicated the plane of failure. For these tests the "interface of interest" is one which involved the pre-construction primer (e.g., substrate-PCP, within the PCP or PCP-primary coating system). Within each population, the red data points predominately failed at this interface of interest (i.e., more than 50% of the failed surface area). The yellow data points had some indication of failure at the interface of interest and the green data points had no failure at the interface of interest. Data sets which result in a line toward the lower right of the graph are indicative of "better" adhesion. Adhesion above 1000 psi is generally considered good for these types of coatings. The data suggest that all of the coatings have good adhesion but there is slightly better adhesion for (1) control coatings over retained PCP (PCP/UHS) and (2) for coatings over a near-white metal blasted surface. For single coat products over retained PCP, brush blasting results in better adhesion than pressure washing.

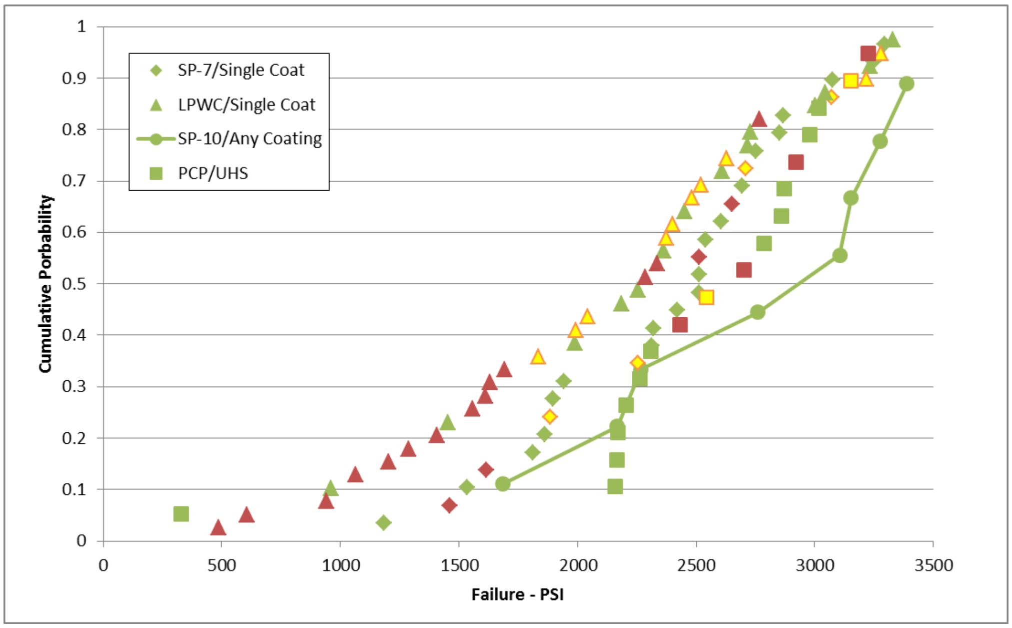

Figure 6. Cumulative probability of as applied pull-off adhesion.

Note: within each population of similarly shaped data points, the red data points predominately failed at the PCP-primary coating interface. The yellow data points had some indication of failure at the PCP-primary coating interface and the green data points had no failure at the PCP-primary coating interface.

Cathodic Disbondment Testing

After testing, the disbonded coating was removed with a dull putty knife to determine the extent of undercutting. Based on the specification requirement, "undercutting or peeling shall not exceed 4 percent of the area of the test panel and all undercutting and peeling shall be located within ½ inch of the holiday." Since 4 percent of the panel area (2.16 square inches) is greater than the surface area within ½ inch of the holiday (1.18 square inches) the latter requirement is the driving requirement. This essentially means that undercutting should extend less than ½-inch (12.6 mm) from the holiday. None of the panels tested with retained PCP met this cathodic disbondment requirement. Interestingly, one of the panels prepared with an SP-10, white metal blasted surface did *not* meet the requirement.

Figure 7 presents the cathodic disbondment test results grouped by primary coating system. The data do not suggest any significant difference in performance between the control systems and those with single coat. Figure 8 presents the cathodic disbondment data test results grouped by surface preparation. As mentioned above, it is interesting that the only system to not meet the specification requirement had an SP-10, near white metal blast preparation. However, the remaining systems over an SP-10 surface had minimal undercutting. The system which failed was applied by the coating manufacturer several weeks after the initial surface preparation and it is not known if surface cleanliness was maintained before the coating application.

It is worth noting that minor blistering was observed on the face of 5 out of 49 panels. Consistent with observations in the simulated ballast tanks, the majority of the blistering was observed on the brush blasted panels. Four out of 20 (20%) of the brush blasted panels exhibited minor blistering while none of the pressure washed panels exhibited blistering. One of the five SP-10 panels exhibited minor blistering.

Pull off adhesion measurements were made on the test panels after cathodic disbondment testing. Figure 9 shows the resulting data. Within each population, the red data points predominately failed at the interface of interest. The yellow data points had some indication of failure at the interface of interest and the green data points had no failure at the interface of interest. Data sets which are toward the lower right of the graph are indicative of “better” adhesion. Adhesion above 1000 psi is generally considered good for these types of coatings. The data suggest that all of the coatings have good adhesion but there is slightly better adhesion for coatings over a near-white metal blasted surface. These does not appear to be any significant difference among the various levels of secondary surface preparation or between the single coat and control systems applied over retained PCP.

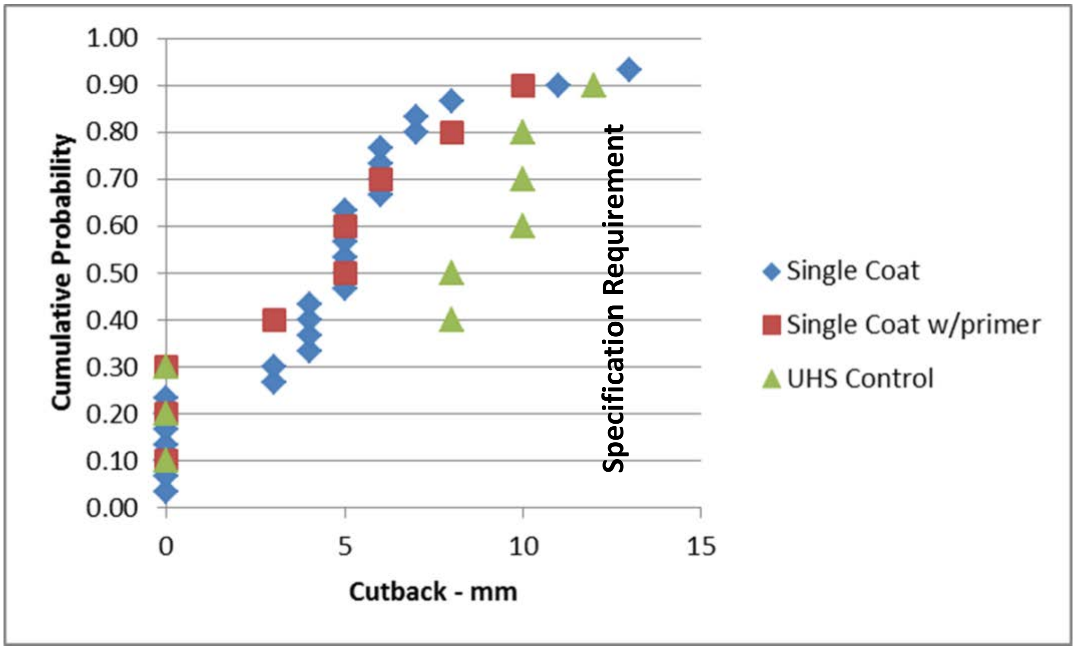

Figure 7. Cumulative probability of cathodic disbondment test results grouped by primary coating system.

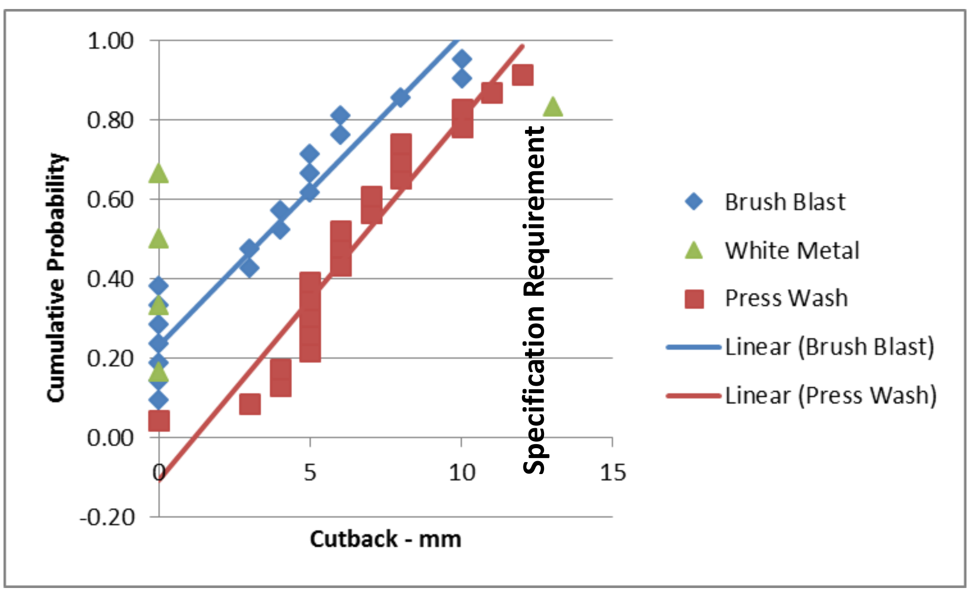

Figure 8. Cumulative probability of cathodic disbondment test results grouped by surface preparation.

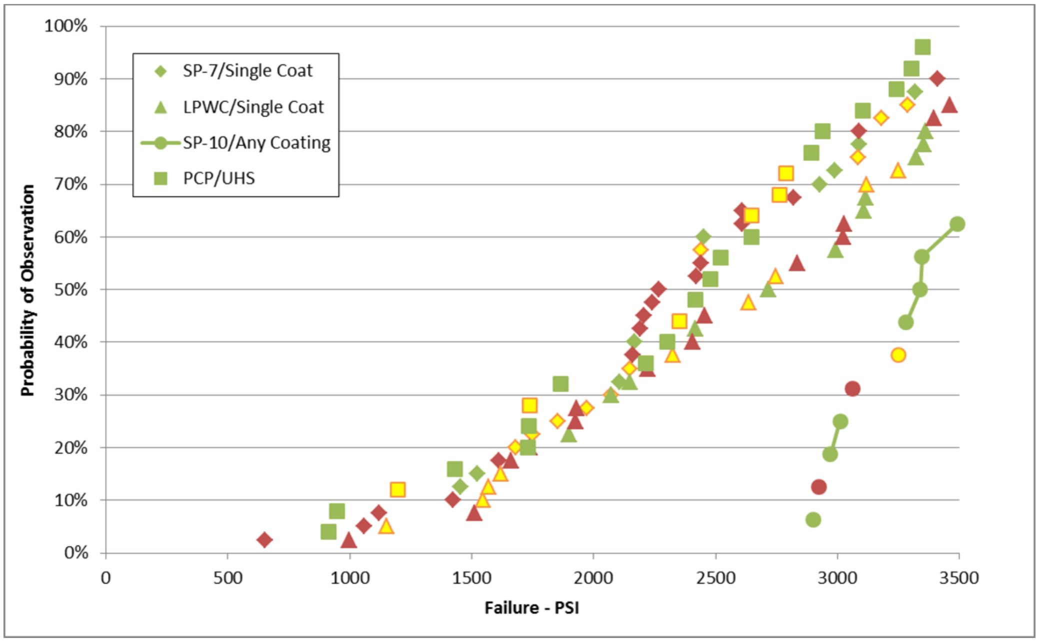

Figure 9. Cumulative probability of pull-off adhesion measured after cathodic disbondment testing.

Note: within each population of similarly shaped data points, the red data points predominately failed at the PCP-primary coating interface. The yellow data points had some indication of failure at the PCP-primary coating interface and the green data points had no failure at the PCP-primary coating interface.

Simulated Seawater Ballast Tank Exposure

On June 21, 2011 the testing began by filling compartments J1, J2 and J3 with seawater from San Diego Bay adjacent to the NASSCO facility. On July 6, 2011 the water was transferred to compartments S1, S2 and S3. The test tanks were subjected to a cycle of nominally two weeks filled with seawater and two weeks empty. When initially filled, the tank was full to within a few inches of the top of the tank. Over time, the fill level dropped a few inches before the seawater was refreshed. With the exception of inspection periods, the cycle was continued throughout the test period. At each inspection,[7] both tanks were emptied, cleaned and inspected. New seawater was introduced into the appropriate tank in accordance with the original schedule.

Figure 10 shows the measured ballast water pH and conductivity throughout the testing. The data was taken after each exchange. Seawater pH was predominately between 6.5 and 7.5. Conductivity was predominately between 20 and 40 mS/cm.

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[7] Inspections were performed after nominally 3, 6, 17, and 33 months of exposure.

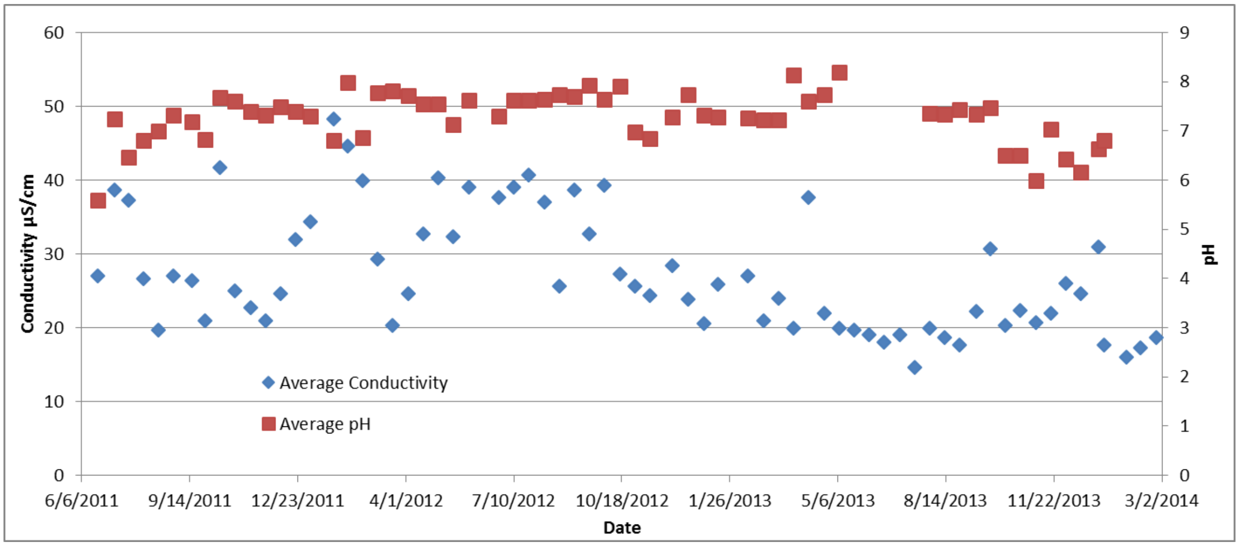


Figure 10. Measured ballast water pH and conductivity

Simulated Ballast Tank Inspections

The coatings applied to the simulated ballast tanks were inspected after nominally 3, 6, 12, 17, and 33 months of exposure. The majority of the inspection were visual inspections for coating deterioration. At the 12-month and 33-month inspections, coating adhesion was also evaluated. A brief discussion of each inspection is presented below.

The first inspection was performed on 19 Sep 2011. After 3-months of exposure, there was no rusting or coating delamination observed in any of the tank compartments. Varying degrees of blistering were observed in most of the tanks. Compartments J-1 (single coat with primer) and S-3 (control system) were in the best condition, with no blistering noted on any of the surfaces. Compartments J-2, S-1, and S-2 (all single coat systems) had some blistering on the SP-7 and SP-1 surfaces but had no blistering on the pressure washed and SP-10 surfaces. Compartment J-3 (control system) was in the worst condition with blistering on all of the surfaces. The condition of J-3 is likely due to the suspected off-ratio primer application.

The second inspection was performed on 16 Jan 2012. After 6 months of exposure, there was no rusting or coating delamination observed in any of the tank compartments. All tank compartments exhibited blistering similar to that observed in each compartment in the 3-month inspection. The surface area which was blistered was mapped so that the blistered surface area could be calculated for each surface preparation and coating system. Figure 11 shows some of the observed blistering.

Figure 12 graphically shows the square footage of blistering observed by surface preparation and primary coating system. The data show that most of the blistering was observed on the SP-1/power tool cleaned surfaces. The brush blasted surfaces had the next highest level of blistering. Negligible blistering was observed on the pressure washed or near white metal blasted surfaces. The single coat systems had similar or slightly more blistering than the properly applied control coating (the other control system was suspected to have an off-ratio primer). The single coat system with primer had negligible blistering.

Figure 11. Examples of blistering observed in the single coat (left) and control (right) systems after 3 months of seawater ballast exposure.

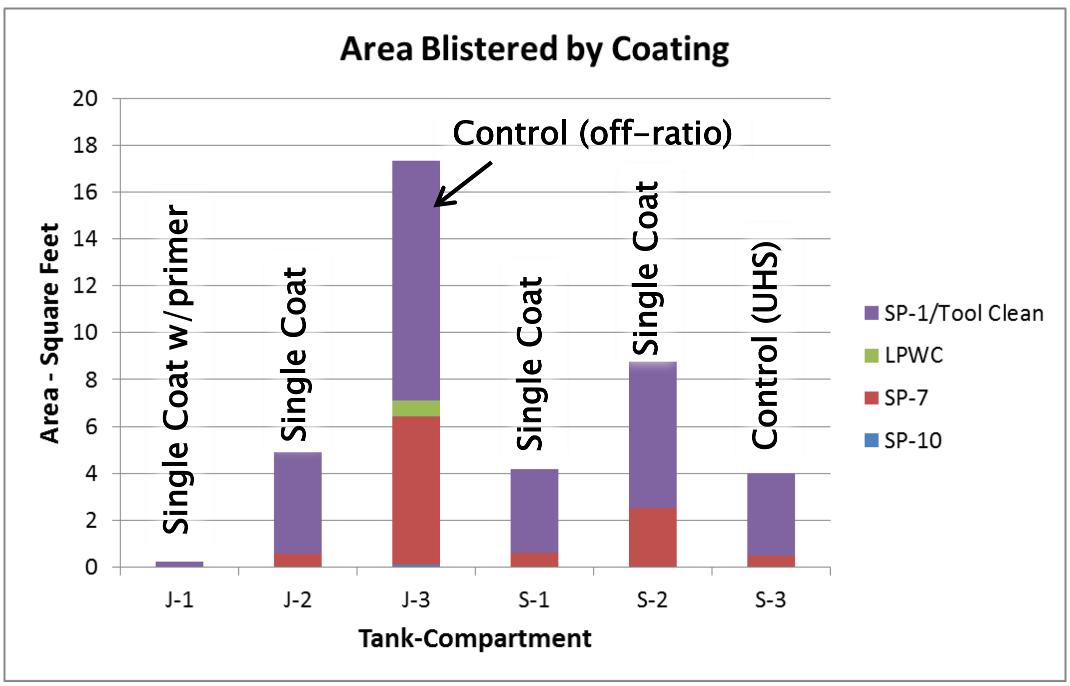


Figure 12. Square footage of blistering observed in simulated ballast tanks after 6 months

The third inspection was performed on 11 Jun 2012. After 11 months of exposure, there was no rusting or coating delamination observed in any of the tank compartments. All tank compartments exhibited blistering similar to what was observed in each compartment in the prior inspections. The surface area which was blistered was mapped out so that the blistered surface area could be calculated for each surface preparation and coating system. In conjunction with this inspection, selected areas of coating were repaired by power tool cleaning and application of a compatible repair coating. Table 10 shows the total surface area repaired in each compartment.

Table 10 – Surface Area of Coating Repairs

	Total Repaired Area
Compartment J-1	2.17 square feet
Compartment J-2	3.59 square feet
Compartment J-3	4.39 square feet
Compartment S-1	1.41 square feet
Compartment S-2	2.99 square feet
Compartment S-3	1.98 square feet

Prior to performing the coating repairs, blistered areas were destructively inspected. The coating was easily removed with a knife in the blistered areas, corresponding to an ASTM D6677 rating of "0."[8] None of the blisters were filled with fluid, though some surface wetness was observed. A surface pH of 9 to 10 was measured using indicator paper. Coating samples were provided to the respective coating manufacturers for laboratory analysis. Sherwin Williams concluded that their single coat materials were properly catalyzed and the surface profile was suitable (2-3 mils). They detected water soluble salts on their coating samples, suggesting osmotic blistering. No response was received from International Paint.

Coating adhesion was also determined in accordance with ASTM D6677 on SP-10 and LPWC surface preparation sections where blistering was not observed. The coating was tightly adhered to these surfaces and would be rated a "10" in accordance with ASTM D6677.

[8] ASTM D6677 involves using a knife to make an X-cut in the coating and then attempting to pry the coating from the substrate. The difficulty with which the coating is removed is rated in accordance with the following table. Coating removed during the cutting process in neglected in the rating.

Rating	**Description**
10	Coating is extremely difficult to remove; fragments no larger than approximately 0.8 by 0.8 mm (1⁄32 in. by 1⁄32 in.) removed with great difficulty.
8	Coating is difficult to remove; chips ranging from approximately 1.6 by 1.6 mm (1⁄16 by 1⁄16 in.) to 3.2 by 3.2 mm (1⁄8 by 1⁄8 in.) can be removed with difficulty.
6	Coating is somewhat difficult to remove; chips ranging from approximately 3.2 by 3.2 mm (1⁄8 by 1⁄8 in.) to 6.3 by 6.3 mm (1⁄4 by 1⁄4 in.) can be removed with slight difficulty.
4	Coating is somewhat difficult to remove; chips in excess of 6.3 by 6.3 mm (1⁄4 by 1⁄4 in.) can be removed by exerting light pressure with the knife blade.
2	Coating is easily removed; once started with the knife blade, the coating can be grasped with ones fingers and easily peeled to a length of at least 6.3 mm (1⁄4 in.).
0	Coating can be easily peeled from the substrate to a length greater than 6.3 mm (1⁄4 in.).

The fourth inspection was performed on 29 Nov 2012. After 17 months of exposure, there was no rusting or coating delamination observed in any of the tank compartments. All tank compartments exhibited blistering similar to that observed during prior inspections. The surface area which was blistered was mapped out so that the blistered surface area could be calculated for each surface preparation and coating system.

The fifth and final inspection was performed on 5 Mar 2014. After 33 months of exposure, there was no rusting or coating delamination observed in any of the tank compartments. All tank compartments exhibited blistering similar to that observed in prior inspections. The surface area which was blistered was mapped out so that the blistered surface area could be calculated for each surface preparation and coating system. Coating adhesion was determined in accordance with Method E of ASTM D4541[9] and ASTM D6677.[10]

Figure 13 shows the trend of blistered area in each tank over the test period. Note that the drop in blistered area between 12 and 17 months is primarily the result of the repairs that were performed. Also note that it was difficult to accurately measure the area blistered in tank S-3 until the final inspection when the panel rack was removed. The data suggest a comparable extent of blistering for the single coat products and the non-MILSPEC control. The control coating which was inadvertently applied off-ratio had slightly more blistering than the other coatings.

Figure 14 shows the trends in blistering as a function of surface preparation. The low-pressure water cleaned surfaces and SP-10 surfaces had negligible blistering. Note that these surface preparation methods were used on smaller areas and did not include horizontal surfaces. The SP-7 surfaces had more blistering and the SP-1/power tool cleaned surfaces had the most extensive blistered area. The changes in blistered area are suspected to simply reflect variation in surface area estimates, though it was noted that some of the repaired area did begin to exhibit blisters. As noted above, no cracked blisters were observed at any of the inspections.

The blistering observations are consistent with osmotic blistering due to surface contamination. The blistering tended to be on front portion of the tank floor (where contamination is more likely during coating application). Blistering was also more common on surfaces where residual contamination would be less likely to be removed (brush blasting and SP-1/power tool clean). Blistering was worst on the SP-1/power tool cleaned surfaces which would be most likely to have non-visible salts remaining the surface.

Figure 15 shows the cumulative probability distribution of adhesion test results as a function of surface preparation for all tanks after 33 months of simulated seawater ballast exposure. The data show that all secondary surface preparation techniques result in adhesion values similar to or better than the SP-10 surface preparation. The low pressure water cleaned surface has a slightly higher pull adhesion value, consistent with results on the test panels.

[9] ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

[10] ASTM D6677, Standard Test Method for Evaluating Adhesion by Knife

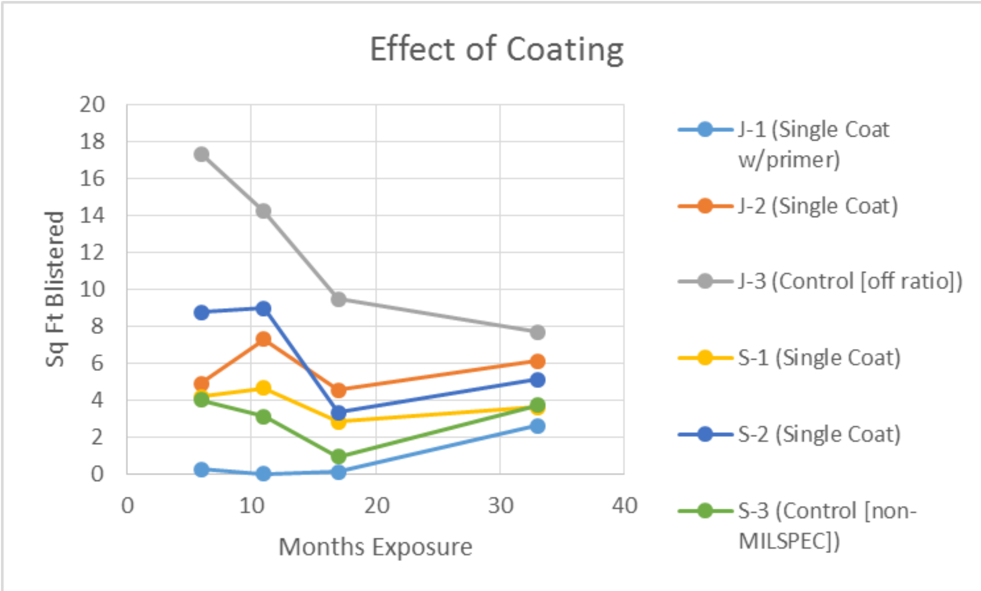


Figure 13. Estimated blistered surface area in each simulated ballast tank over time.

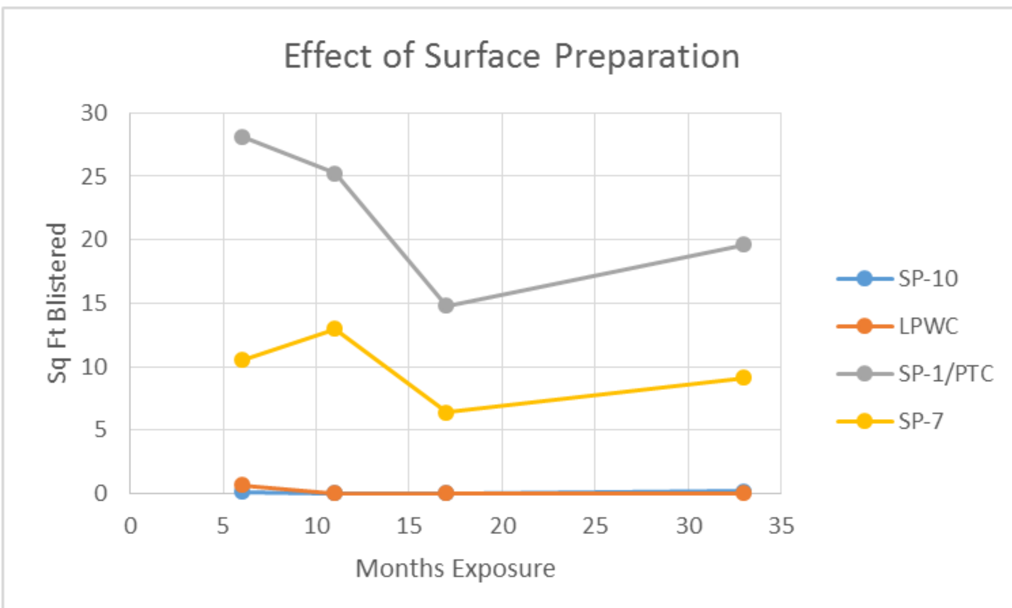


Figure 14. Estimated blistered surface area as a function of secondary surface preparation over time.

Figure 16 shows the results of ASTM D6677 X-Cut adhesion for the single coat systems applied to the simulated ballast tanks after 33 months exposure. Footnote 8 provides a description of the ratings. The data show performance over retained pre-construction primer is better than over SP-10, near white metal blasted surface and low-pressure water cleaned surface.

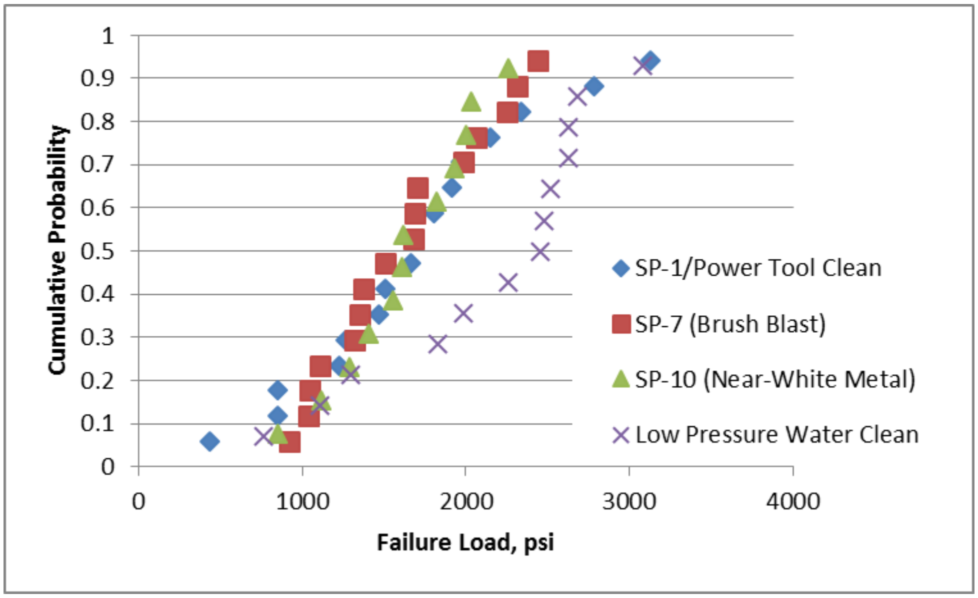


Figure 15. Cumulative probability distribution of pull-off adhesion values for each secondary surface preparation technique.

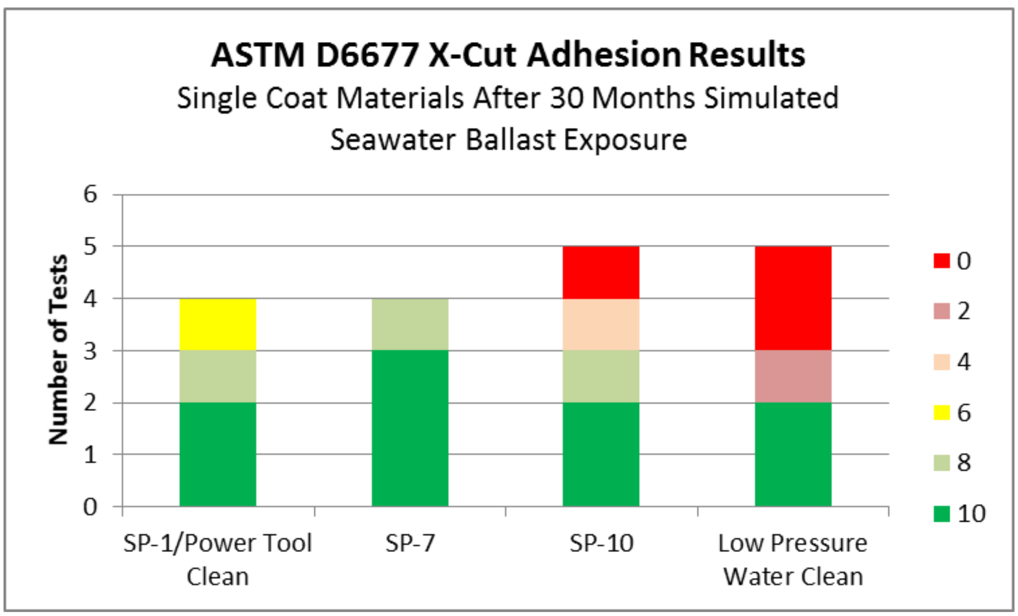


Figure 16. X-Cut adhesion test results for single coat systems as a function of secondary surface preparation. See footnote 8 for rating scheme.

Coating Adhesion on Test Panels Exposed to Seawater Ballast Cycle

Selected test panels were installed in a specially designed rack in compartment S-3. Table 11 shows the coating systems that were applied to the test panels and their install date. Figure 17 shows the rack and some of the installed test panels.

Table 11 - Test Panels Installed in Simulated Ballast Compartment S-3

Test Panels started June 21, 2011	
• Carbozinc 8703/Brush Blast/FastClad • Carbozinc 8703/Brush Blast/ SeaGuard 5000HS • Carbozinc 8703/Brush Blast/Intershield 300HS • SigmaWeld 199/Brush Blast/FastClad with Primer • SigmaWeld 199/Brush Blast/FastClad • SigmaWeld 199/Brush Blast/SeaGuard 5000HS • SigmaWeld 199/Brush Blast/Interline 783	• Carbozinc 8703/LPWC/FastClad with Primer • Carbozinc 8703/LPWC/FastClad • Carbozinc 8703/LPWC/ SeaGuard 5000HS • SigmaWeld 199/LPWC/FastClad with Primer • SigmaWeld 199/LPWC/FastClad • SigmaWeld 199/ LPWC / SeaGuard 5000HS • SigmaWeld 199/LPWC/ Interline 783
Test Panels Installed September 19, 2011	
• Carbozinc 8703/Brush Blast/ Warren Environmental Safe-T Plus • SigmaWeld 199/Brush Blast/Warren Environmental Safe-T Plus	• Carbozinc 8703/LPWC/ Interline 783 • Carbozinc 8703/LPWC/ Warren Environmental Safe-T Plus • SigmaWeld 199/LPWC/ Warren Environmental Safe-T Plus

Figure 17. Left half of test panel rack installed in Compartment S-3.

After 6 and 33 months of simulated ballast tank exposure, adhesion was measured on the test panels. Figure 18 shows the pull-off adhesion data after 33 months of exposure grouped by primary coating type. The data suggest that even after 33 months of seawater ballast exposure, all of the coatings continue to have good adhesion. Figure 18 suggests that there is not any significant difference in post-exposure adhesion among the different coating types when applied over retained pre-construction primer. Figure 19 illustrates similar adhesion was observed for brush blasted and pressure washed surfaces after 33 months of seawater ballast exposure.

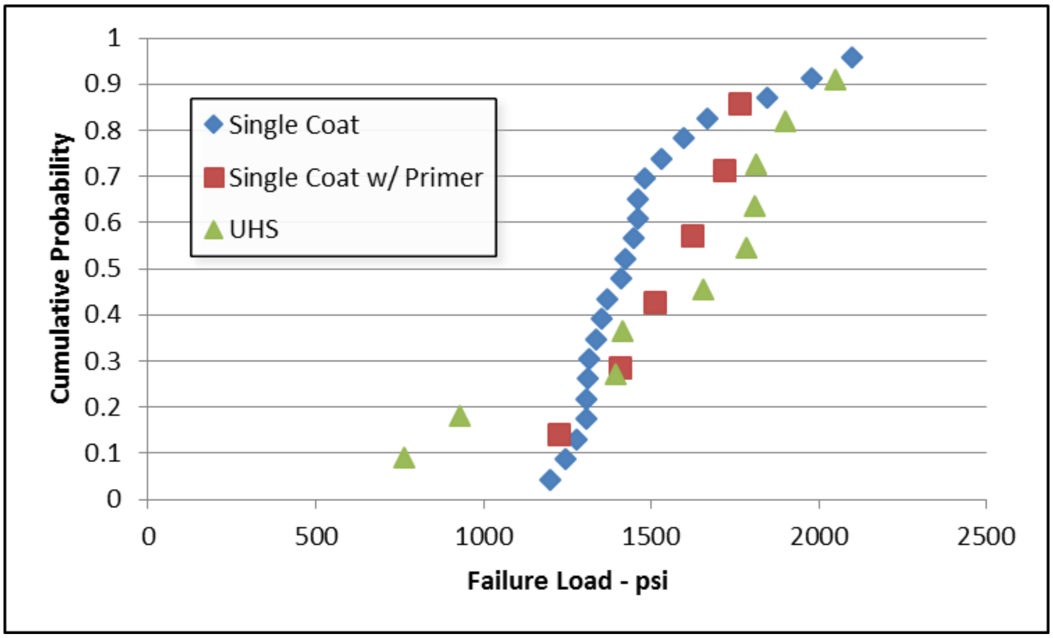


Figure 18. Cumulative probability of pull-off adhesion data after 33 months of seawater ballast exposure as a function of primary coating type.

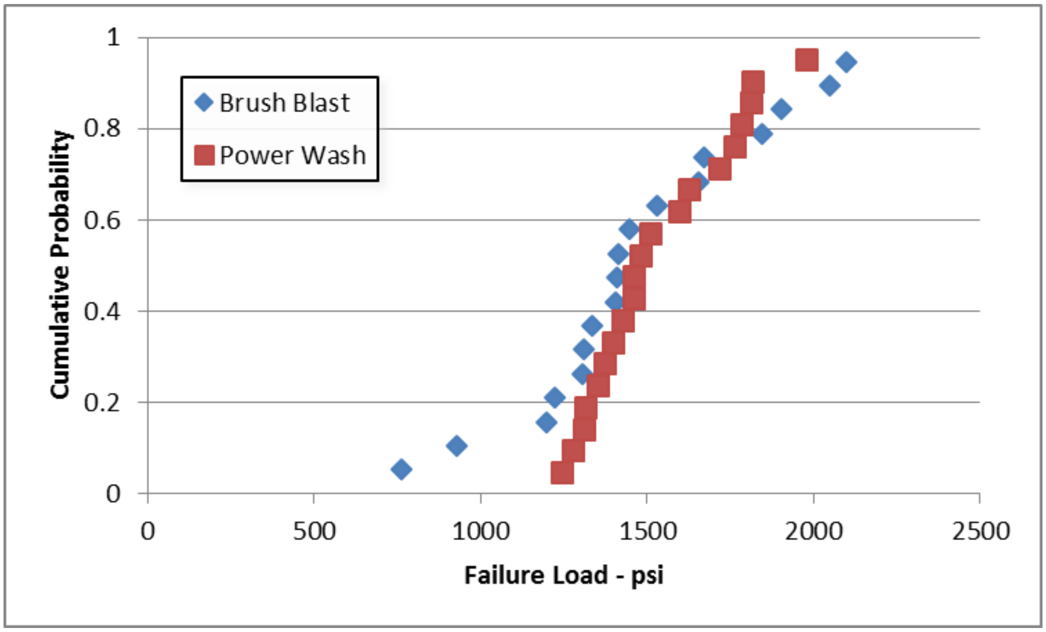


Figure 19. Cumulative Probability of pull-off adhesion data as a function of surface preparation.

Demonstration Testing

In an effort to reduce the cost of Navy shipbuilding, Naval Sea Systems Command (NAVSEA) formed four Navy-Industry working groups to consider topics in each of four areas of expertise.[11] Based on the success of the laboratory and simulated ballast tank testing of MIL-PRF-23236, Type VII, Class 5/18 ("single coat") coatings over retained pre-construction primer, HII-Ingalls Shipbuilding (Ingalls) requested that Naval Sea Systems Command (NAVSEA) allow them to demonstrate the process on certain tanks and voids which present a low risk to the Navy. In response to this request, NAVSEA 05P2 developed an Approved Alternate Technical Requirement titled "Allow Retention of Preconstruction Primer (PCP) in Fuel Oil Storage, Fuel Oil Service, Compensated Fuel and Diesel Tanks and on Underwater Hull."

The NAVSEA Chief Engineer (CHENG) transmitted this approved alternate technical requirement to Ingalls in April 2012.[12] In this letter, it was requested that Ingalls identify applicable portions of existing NAVSEA contracts and ship specifications that would need to be modified to implement the change. Ingalls identified a number of compartments on the LPD-17 class ships that are candidates for the proposed process. These compartments consist primarily of voids, fuel tanks, fuel oil tanks and oily waste tanks. Aviation fuel (JP-5) and potable water tanks were not be considered candidates for the proposed process. Ballast tanks were added once sufficient data was available from the low-risk areas for the Technical Warrant Holder to approve the process in these higher risk areas.

A test procedure was developed by the NSRP project team with input from the LPD program office, SUPSHIP Gulf Coast (SUPSHIPGC), and NAVSEA 05P2. The objective of the test was to produce data showing the Ingalls process for blasting to SSPC SP-10 in the plate line, blasting welds/erection joints to SSPC SP-10[13] on the ways, brush blasting the retained PCP, and applying MIL-PRF-23236, Type VII, Class 5/18 coatings does not appreciably degrade coating life as indicated by coating adhesion and other observations.

The goal of this demonstration is to collect data that will give some assurance that the tanks and voids do not show significant coating failure at the first docking. NAVSEA 05P2 and the NSRP project team agreed that a reasonable expected performance metric is for 80% of the tanks to remain in Corrosion Control Information Management System (CCIMS) Condition 1 or 2 after nominally 7-12 years of service.

Approach

In lieu of the current technical requirements, Ingalls preserved four Test Compartments in general accordance with NAVSEA Approved Alternate Technical Requirement titled "Allow Retention of

[11] NAVSEA 5000 Ser. 05D/607 of 9 December 2011

[12] NAVSEA ltr 5000 Ser. 05D/145 of 2 April 2012 from RADM Eccles to HHI-Ingalls (Mr. Edenzon)

[13] SSPC-SP 10/NACE No. 2, Near-White Blast Cleaning (2007)

Preconstruction Primer (PCP) in Fuel Oil Storage, Fuel Oil Service, Compensated Fuel and Diesel Tanks and on Underwater Hull" except that MIL-PRF-23236, Type VII, Class 5/18 was allowed as a primary coating system. The general approach was to prepare prototype tanks beginning with the proposed procedure and modifying the procedure as necessary on subsequent prototype tanks.

Ingalls identified four tanks that are deemed suitable as "prototypes" to be coated with the proposed process prior to full production work. The tanks are identified as "Jacket Water Holding Tanks" (8-68-1-W and 8-85-2-W) and Oily Waste Drain Collection Tanks (8-118-1-W and 8-128-2-W). The process resulted in two pairs of prototype tanks – the first two tanks (8-68-1-W and 8-85-2-W) were coated with Ingalls's "standard" brush blasting approach for moderately critical areas. Their standard procedure references SSPC SP-7[14] and is described as follows:

> *For moderately critical areas, surface preparation in the unit blast stage shall include abrasive blasting of all welds and rusted surfaces to SSPC-SP-10, near white metal. All loose primer and surface contaminants shall be removed by sweep blasting with SSPC-SP-7 as the minimum level of acceptance, except that no rust or mill scale shall be allowed. Sound pre-construction primer shall be clean and intact. All surfaces shall be free of grease and oil. Beyond the unit blast stage, rust and loose primer shall be removed by power tool cleaning to SSPC-SP-11 open abrasive blasting or with portable vacuum blast equipment.*

During the prototype tank preparation, the project team recognized that the level of surface preparation was more extensive than SSPC SP-7 requires. Specifically, a significant portion of the pre-construction primer is removed. Project participants and industry standards suggest that more extensive removal of pre-construction primer should increase the probability of success for this system.[15] Prior to preparing the second set of tanks, an internal production process was developed which invoked a slightly stricter standard specification, SSPC SP-14[16] which described the extent and degree of cleanliness which was

---

[14]SP 7/NACE No. 4, Brush-Off Blast Cleaning (2007) states "A brush-off blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose coating. Tightly adherent mill scale, rust, and coating may remain on the surface. Mill scale, rust, and coating are considered tightly adherent if they cannot be removed by lifting with a dull putty knife after abrasive blast cleaning has been performed.

The entire surface shall be subjected to the abrasive blast. The remaining mill scale, rust, or coating shall be tight. Flecks of the underlying steel need not be exposed whenever the original substrate consists of intact coating."

[15] International Maritime Organization (IMO) standards require "Sa 2 removing at least 70% of intact shop primer, which has not passed a pre-qualification certified by test procedures in 1.3." (Sa 2, "Thorough Blast Cleaning" is equivalent to SSPC SP-6/NACE No. 3, "Commercial Blast Cleaning")

[16] SP 14/NACE No. 8, Industrial Blast Cleaning (2007) states "An industrial blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, and dirt. Traces of tightly adherent mill scale, rust, and coating residues are permitted to remain on 10 percent of each unit area of the surface (approximately 5,800 mm2 [9.0 in.2]) (i.e., a square 76 mm x 76 mm [3.0 in. x 3.0 in.]) if they are evenly distributed. The traces of mill scale, rust, and coating are considered to be tightly adherent if they cannot be lifted with a dull putty knife.

actually accomplished during the secondary surface preparation. A second set of tanks (8-118-1-W and 8-128-2-W) were prepared and coated without additional engineering oversight to ensure the normal production and Quality Assurance (QA) personnel were comfortable with the process. The revised secondary surface preparation procedure was described as follows:

> *All visible grease and oil shall be removed by solvent cleaning (SSPC-SP-1) prior to abrasive blasting or mechanical cleaning. Abrasive blast all welds and rusted surfaces to SSPC-SP-10, near white metal. All loose primer and surface contaminants shall be removed by sweep blasting the entire area in accordance with SSPC-SP-14 except that all rust, surface contaminants, staining, chalk marks, loosely adherent pre-construction primer and all coating other than pre-construction primer shall be removed. Sound pre-construction may be retained on up to 10% of the surface area as defined in SSPC SP-14. Sound pre-construction primer shall be clean and intact. All surfaces shall be free of grease and oil.*

Once the revised procedure was validated in production, HII was authorized to begin installation of single coat over retained pre-construction primer on LPD-26 tanks as a demonstration. As of this report date, the most significant issue which arose during the production process was the definition of the unit area which is considered when establishing whether the secondary surface preparation criteria are met. The secondary surface preparation procedure was revised as follows:

> *All visible grease and oil shall be removed by solvent cleaning (SSPC-SP-1) prior to abrasive blasting or mechanical cleaning. Abrasive blast all welds and rusted surfaces to SSPC-SP-10, near white metal. All loose primer and surface contaminants shall be removed by sweep blasting the entire area in accordance with SSPC-SP-14 except that all rust, surface contaminants, staining, chalk marks, loosely adherent pre-construction primer and all coating other than pre-construction primer shall be removed. Sound pre-construction may be retained on up to 10% of the surface area ~~as defined in SSPC SP-14~~ in a 12"x12" Square. Sound pre-construction primer shall be clean and intact. All surfaces shall be free of grease and oil.*

The remainder of this section describes in some detail the prototype tanks and the status of the demonstration project at the time of this report.

Prototype Tank Set 1 – Jacket Water Holding Tanks 8-68-1-W and 8-85-2-W

The first two prototype tanks were coated September 19-21, 2012. The following summarizes the key events of the first prototype demonstration

Prior to the demonstration, both tanks were inspected to determine their initial condition. Interzinc 75V was applied to the weld areas to stop rust.[17] The tops of the tank had some spots of rust where

Shadows, streaks, and discolorations caused by stains of rust, stains of mill scale, and stains of previously applied coating may be present on the remainder of the surface."

[17] Note that for the purposes of the NAVSEA proposed Alternate Technical Requirement, pre-construction primers are defined as silicate-zinc "weld through" primers that are applied in an automated process line in accordance with

condensation occurred. Tank 8-68-1-W also had some corrosion on the floor near the ladder. The steel for these tanks was initially primed with Interplate 997 approximately 18 months prior to this coating application. Figure 20 shows representative tank surfaces prior to blasting.

Figure 20. Representative surfaces of 8-85-2-W prior to surface preparation.

A group of project participants observed several sample sweep blasted areas and test plates outside of the tank. Sweep blasting to the original Ingalls process description was achieved using a medium garnet abrasive[18] at a nozzle pressure of 105 psi. The surface achieved was by all accounts similar to what is achieved in the blast house; hence the production crews should be familiar with the extent of sweep blasting required. It is worth noting that garnet was used on these tanks (and all shipboard blasting) whereas a shot/grit blend is used in the blast house. After the degree of cleanliness was agreed upon, 8-85-2-W was sweep blasted.

After sweep blasting, Tank 8-85-2-W was inspected for metal cleanliness and profile. Dark spots on the welds around of the top of the tank were identified as requiring additional blasting and were repaired. The remaining surfaces were well cleaned – most areas had less than 10% PCP remaining and it was rarely concentrated in any significant area (no greater than a few square inches). Figure 21 shows representative surfaces after secondary surface preparation by sweep blasting. The dark spots along the welds seemed to be staining (black/brown) coming from under or through the profile that could not be removed with solvent cleaning (there was some consensus that it was weld flux residue from within the welds). Since the welds were to remain uncoated until tightness testing was completed, the welds were masked rather than re-worked at this time.

specific criteria and approved by final coating system vendor for compatibility with Navy coating systems. Interzinc 75V would not meet this definition and therefore must be removed.

[18] Barton 30X60 PLUS™ (Barton Mines Co. L.L.C., Lake George, NY).

Figure 21. Representative surfaces of 8-85-2-W after secondary surface preparation (note black spots along the welds in the right picture).

For future adhesion testing, four areas were identified where PCP seemed to be remaining in higher concentration:

> Approximately 6 inches below an angle stiffener in the space containing the ladder, toward the aft end of the bulkhead to the starboard side.
>
> On Frame 85 (forward bulkhead of the tank, in the space not containing the ladder) 19 inches from the starboard bulkhead and 27 inches from the top of the tank.
>
> On the starboard bulkhead of the tank (in the space not containing the ladder), about 4 to 5 inches from the forward bulkhead (FR 85) between 21 and 36 inches from the top of the tank.
>
> On Frame 87.5 (aft bulkhead of the tank, in the space not containing the ladder) 16 inches from the center stiffener and 27 inches from the top of the tank.

Ingalls QA made profile and conductivity measurements at various locations in the tank (complete data is presented later in this section). At 0930, SUPSHIPGC accepted the surface preparation under the condition that the welds were taped off and the floor was solvent wiped. Sometime after 1300, approval was given to apply the MIL-PRF-23236, Type VII, Class 5/18 product (Interline 783) in tank 8-85-2-W.

Tank 8-68-1-W was briefly inspected before they began to remove spent media. There were several weld areas which did not meet SP-10 and some locations where writing residue was still visible. These “pick-up” items were identified to be re-blasted before the tank was presented for inspection. After blasting pick-up areas, the tanks were cleaned and presented for inspection. On September 21, 2012 the surface preparation was approved and the primary tank coating applied.

Table 12 summarizes the QA data from the secondary surface preparation and coating application.

Table 12 – Summary of QA data from Prototype Tank Set 1

	Requirements	**8-85-2-W**	**8-68-1-W**
Date Coated	N/A	20SEP2012	21SEP2012
Surface Profile, Mils*	2.0 - 4.0 mils	3.0 - 3.5 mils	3.0 - 4.0 mils
Surface Conductivity, µS/cm	Less than 30 µS/cm	0.05 - 0.07 µS/cm	0.06 - 1.0 µS/cm
Relative Humidity, %	Less than 50%	42.1% - 53.0%	42.2% - 49.6%
Surface Temp. Depression, °F	Less than 5°F	9.1°F – 18.1°F	11.5°F – 18.9°F
Dry Film Thickness, mils	20 – 50 mils	21.97 – 30.70 mils	29.70 – 31.53 mils
Average DFT, mils	20 – 30 mils	27.81 mils	30.27 mils

** Surface profile was measured after secondary surface preparation in areas where retained pre-construction primer did not impact the measurement.*

Adhesion tests were performed on 5-6 November 2012, approximately 6 weeks after the coating was applied. At twelve locations in each tank, DFT's were recorded, an X-Cut test was performed in accordance with ASTM D6677[19] and pull-off adhesion was determined in accordance with ASTM D4541, Method E.[20] The coating was lightly sanded with 120 grit aluminum oxide paper and wiped with a clean solvent soaked rag prior to attaching the pull-off adhesion test fixture.

The adhesion testing in 8-85-2-W was completed at approximately 0900. Environmental data in the tank during this time was 82.7% relative humidity, 66.0°F air temperature, 59.6°F surface temperature, 61.8°F dewpoint and -2.2°F temperature depression.

Tank 8-68-1-W had standing water in the two port spaces and condensation on the top and upper portions of the exterior bulkheads. The tank openings had been covered but rainwater still found its way into the tank. At twelve locations, coating dry film thicknesses (DFT's) were recorded, an X-Cut test was performed in accordance with ASTM D6677, and the surface was prepared for an adhesion test fixture to perform ASTM D4541 testing. (The coating was lightly sanded with 120 grit aluminum oxide paper but the fixture was not attached at this time due to high humidity and wetness. When required, a rag was used to dry the surface before sanding.). After removal of all standing water and approximately three hours of waiting the tank's environmental conditions improved, but the humidity was still high and condensation was present at the top of the tank. Compressed air and rags were used to dry the surfaces near wet test areas. The coating was lightly re-sanded with 120 grit aluminum oxide paper and wiped with a clean solvent soaked rag prior to attaching the test fixture. This work was completed at 1400. Environmental data in the tank at ~1330 was 58.9% relative humidity, 77.1°F air temperature, 71.7°F surface

[19] ASTM D6677 - 07(2012) Standard Test Method for Evaluating Adhesion by Knife, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA

[20] ASTM D4541 – 09(2009) Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA

temperature, 61.5°F dewpoint and -10.2°F temperature depression. Plastic was used to cover the tank and a dehumidified air duct was connected to the tank for the evening in anticipation of evening showers.

At 1300 on 6 November, the adhesion tests were performed in the two tanks. Table 13 and Table 14 summarize adhesion test data from the two tanks. The results demonstrate good adhesion of the coating. All but one of the X-cut adhesion tests were "10" (the highest possible rating). Only one pull-off adhesion test showed any failure at the interface of concern (i.e., the PCP/topcoat interface), and that was at 2499 psi (location 85-1). The remaining pull tests predominately failed at the glue interface, indicating that the adhesion of the primary coating to the retained pre-construction primer is higher than the measured value. Glue failures as high as 3015 psi were recorded.

In 8-68-1-W, a few additional test fixtures were installed due to concerns with tank wetness. The lower failure loads in this tank versus 8-85-2-W are likely the result of the high humidity in the tank. However, there are a sufficient number of high readings that, in combination with the X-cut results are indicative of good adhesion.

Table 13 – Adhesion Test Data from Tank 8-85-2-W

ID	Cell	Wall	Location	DFT	D6677	D4541		Notes
85-1	Port	Center	6" below angle at stern	22.4	8	2499 psi	33% PCP-single coat, 67% glue	
85-2	Port	Stbd	18" down, 24" from aft	21.5	10	1858 psi	100% glue	
85-3	Port	Floor	Aft-Port corner	28.3	10	1920 psi	100% glue	SP-10 location
85-4	Stbd	Fwd (Fr 85)	27" down, 19" from Stbd	19.3	10	2823 psi	100% glue	
85-5	Stbd	Fwd (Fr 85)	27" down, 27" from Stbd	20.2	10	2937 psi	100% glue	
85-6	Stbd	Stbd	36" down, 4" from Fr 85	20.2	10	1758 psi	100% glue	
85-7	Stbd	Fwd (Fr 85)	36" down, 4" from Stbd	25.9	8	1872 psi	100% glue	SP-10 location
85-8	Stbd	Aft (Fr 87.5)	27" down, 27" from center	21.0	10	3015 psi	100% glue	
85-9	Stbd	Aft (Fr 87.5)	26" down, near center wall	23.3	10	2717 psi	100% glue	SP-10 location
85-10	Port	Top	13" aft, near center wall	23.6	10	2237 psi	100% glue	SP-10 location
85-11	Port	Stiffener	Fwd side, 10" from top	25.5	10	2692 psi	20% I-783 cohesive, 80% glue	
85-12	Port	Aft (Fr 87.5)	20" down, 24" from center	20.5	10	1796 psi	100% glue	

Table 14 – Adhesion Test Data from Tank 8-68-1-W

ID	Cell	Wall	Location	DFT	D6677	D4541		Notes
68-1	Aft-Stbd	Stbd	40" down, 24" from Stbd	31.6	10	2028 psi	100% glue	
68-2	Aft-Stbd	Port	6" down, 27" from fwd	23.7	10	1713 psi	100% glue	
68-3	Aft-Stbd	Floor	4" from fwd, 12" from Stbd	29.4	10	2444 psi	100% glue	
68-4A	Fwd-Stbd	Roof	8" from fwd, 24" from Stbd	24.2	10	1218 psi	100% glue	
68-4B						1455 psi	100% glue	
68-5	Fwd-Stbd	Stbd	3" down, 9" from fwd	26.9	10	1812 psi	100% glue	
68-6	Fwd-Stbd	Aft	3" down, 40" from Stbd	25.6	10	962 psi	100% glue	
68-7	Fwd-Port	Aft	31" down, 54" from stbd	22.9	10	1420 psi	100% glue	near port wall (SP-10 area)
68-8	Fwd-Port	Stbd	4" down, 44" from fwd	29.7	10	1627 psi	100% glue	
68-9	Fwd-Port	Aft	11" down, 28" from stbd	30.5	10	1990 psi	100% glue	
68-10	Aft-Port	Aft	17" down, 44" from stbd, 12" from port	23.2	10	2077 psi	100% glue	
68-10X						1996 psi	100% glue	
68-11	Aft-Port	Port	center of forward facing stiffener	28.3	10	1317 psi	100% glue	
68-11X						1905 psi	100% glue	
68-12	Aft-Port	Floor	Top of stiffener on floor aft of ladder	42.8	10	865 psi	100% glue	
68-top	Aft-Port	Top	Aft-Port corner	N/M	N/M	1748 psi	100% glue	DFT and D6677 not measured

Prototype Tank Set 2 – Oily Wastewater Drain Collection Tanks 8-118-1-W and 8-128-2-W

After the successful adhesion test results from the first two prototype test tanks, an internal production procedure was prepared using the ASTM F941[21] format. The most significant technical component of the procedure is the secondary surface preparation requirement:

> *Pre-construction primer shall receive a secondary surface preparation in the blast and paint stage prior to top coating in any stage of construction. Secondary surface preparation of surfaces primed with pre-construction primer shall be as follows:*
>
> *All visible grease and oil shall be removed by solvent cleaning (SSPC SP-1) prior to abrasive blasting or mechanical cleaning. Abrasive blast all welds and rusted surfaces to SSPC SP-10, near white metal. All loose primer and surface contaminants shall be removed by sweep blasting the entire surface in accordance with SSPC SP-14 except that all rust, surface contaminants, staining, chalk marks, loosely adherent pre-construction primer and all coatings other than pre-construction primer shall be removed. Sound pre-construction primer may be retained on up to 10% of the surface area as defined in SSPC SP-14. Sound pre-construction primer shall be clean and intact. All surfaces shall be free of grease and oil.*

The draft procedure was the basis for the second two prototype tanks. Initially, two Jacket Water Holding Tanks (8-116-2-W and 8-133-2-W) were abrasive blasted and coated using the prototype process on 26-

[21] ASTM F941 - 99(2009) Standard Practice for Inspection of Marine Surface Preparation and Coating Application, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA

28 November 2012. The intent was to have the prototype tanks prepared and coated with minimal outside influence. Secondary surface preparation began on the morning of 26 November 2012 and a surface preparation checkpoint was scheduled for 27 November 2012 at 0800. Due to weather, the checkpoint inspection was delayed until the next day. The tanks were dehumidified and environmental conditions monitored during this time.

On 28 November 2012 SUPSHIPGC representative approved the surface preparation checkpoint. The coating was applied later that morning. Unfortunately, the coating was not properly mixed during application and therefore had to be removed from the tank. On 29 November 2012, two alternative prototype tanks were selected and prepared (Oily Wastewater Drain Collection Tanks 8-118-1-W and 8-128-2-W). They were blasted in the morning. The surface preparation was accepted at 1330. SUPSHIPGC, Ingalls QA and coating vendor representatives were present at the checkpoint. The coating was applied in the afternoon without incident. International Interline 783 was also used as the coating in these two tanks.

Table 15 summarizes the QA data from the secondary surface preparation and coating application.

Table 15 – Summary of QA data from Prototype Tank Set 2

	Requirements	**8-128-2-W**	**8-118-1-W**
Date Coated	N/A	30NOV2012	30NOV2012
Surface Profile, Mils*	2.0 - 4.0 mils	3.0 - 4.0 mils	3.3 - 3.9 mils
Surface Conductivity, µS/cm	Less than 30 µS/cm	0.4 - 0.5 µS/cm	0.4 – 0.6 µS/cm
Relative Humidity, %	Less than 50%	42.4% - 47.3%	41.8% - 47.2%
Surface Temp. Depression, °F	Less than 5°F	16.1°F - 22.7°F	17.0°F - 21.1°F
Dry Film Thickness, mils	20 – 50 mils	22.6 – 31.2 mils	26.8 – 29.6 mils
Average DFT, mils	20 – 30 mils	26.85 mils	28.01 mils

** Surface profile was measured after secondary surface preparation in areas where retained pre-construction primer did not impact the measurement.*

Adhesion tests were performed on 17-18 December, approximately 19 days after the coating application. At twelve locations in each tank, DFT's were recorded, an X-Cut test was performed in accordance with ASTM D6677 and pull-off adhesion was determined in accordance with ASTM D4541, Method E. The coating was lightly sanded with 120 grit aluminum oxide paper and wiped with a clean solvent soaked rag prior to attaching the pull-off adhesion test fixture.

On the day the adhesion test fixtures were applied, it was raining with air temperatures around 60°F, however dehumidified air was provided to the tanks.[22] Both tanks remained dry while the test fixtures were attached. Test fixtures were attached in 8-128-2-W by 0830 and in 8-118-1-W around 1000. Adhesion tests were performed the next morning at 0900 in tank 8-128-2-W and around 1100 in tank 8-

[22] Dehumidification was also provided for a few days prior to the adhesion testing, however there was an interruption during a weekend power outage.

118-1-W. Representatives from SUPSHIPGC, Ingalls and the coating vendor witnessed all adhesion tests.

Table 16 and Table 17 summarize adhesion test data from the two tanks. The results demonstrate good coating adhesion. All but four of the X-cut adhesion tests were "10" (the highest possible rating). The remaining four tests were an acceptable "8." The pull tests predominately failed at the glue interface, indicating that the adhesion of the primary coating to the retained pre-construction primer is in excess of the measured value. None of the pull-off adhesion tests showed any failure at the interface of concern (i.e., the PCP/topcoat interface). Pull tests as high as 2880 psi indicate that the adhesion of the primary coating to the retained pre-construction primer exceeds this value.

Table 16 – Adhesion Test Data from Tank 8-128-2-W

			Location, Distance in inches from					D4541		
ID	Cell	Wall	Top	Fore	Port	DFT	D6677	psi	Location	Notes
128-1	--	Stbd	12	40	46	32.3	10	2482	10% cohesive, 90% glue	
128-2	--	Top	0	24	24	19.7	8	2648	100% glue	Near weld
128-3	--	Floor	44	12	40	23.7	10	2880	99% glue, small chip cohesive	
128-4	--	Floor	44	12	12	29.0	10	2298	100% glue	
128-5	--	Port	24	22	0	26.0	10	2688	99% glue, small chip cohesive	Btwn Stiffener
128-6	--	Port	12	56	0	33.5	10	1938	100% glue	
128-7	--	Roof	0	54	2	19.6	10	2392	100% glue	Near weld
128-8	--	Stbd	2	77	47	23.0	10	1711	100% glue	
128-9	--	Stbd	41	67	47	21.4	10	2266	100% glue	
128-10	--	Aft	36	99	20	21.4	10	2740	15% cohesive, 85% glue	
128-11	--	Top	0	94	23	45.6	10	2627	20% cohesive, 80% glue	
128-12	--	Port	29	93	0	20.8	10	2263	100% glue	

Table 17 – Adhesion Test Data from Tank 8-118-1-W

			Location, Distance in inches from					D4541		
ID	Cell	Wall	Top	Fore	Port	DFT	D6677	psi	Location	Notes
128-1	Port	Floor	47	4	4	22.3	10	2375	100% Glue	
128-2	Port	Floor	47	11	42	29.2	10	2024	100% Glue	
128-3	Port	Stbd	44	44	46	26.5	10	1870	100% Glue	
128-4	Port	Top	0	22	4	32.3	10	2548	100% Glue	
128-5	Port	Stbd	24	93	46	23.5	10	1764	100% Glue	
128-6	Port	Aft	16	99	6	24.5	10	2182	100% Glue	
128-7	Port	Floor	47	72	2	26.3	8	2495	100% Glue	
128-8	Port	Center	14	54	0	26.4	10	1798	100% Glue	
128-9	Stbd	Top	0	51	19	21.8	10	1195	100% Glue	
128-10	Stbd	Center	12	51	46	24.3	10	1653	100% Glue	
128-11	Stbd	Floor	47	18	24	24.7	8	2204	100% Glue	
128-12	Stbd	Port	19	48	0	22.5	8-10	2208	100% Glue	

LPD-26 Production Tanks

On 19-20 March 2014, a review of the production process was performed. The review included interviews of personnel in the production, QA and engineering departments, a review of QC records, a review of the primer line procedures and adhesion testing on two production tanks.

At the time of the review, 41 tanks (approximately 42,000 sq ft) were completed by HII production using the new process. Four tanks (approximately 48,000 sq ft) were in the coating process. HII subcontracted 104 tanks (approximately 821,000 sq ft). The subcontractor began work in mid-January, 2014 and had 24 tanks in process (~160,000 sq ft), 11 of which appear to have been accepted by HII QA department.

The coatings office has written records from each tank coated by HII production. Records from five tanks (8-88-3-W, 7-135-2-G, 5-68-1-F, 6-93-2-F, and 7-31-0-W) were reviewed and found to be in order. Of note all of the tanks had RH above 50% but below 85%. The coatings office does not have any records for the tanks coated by the subcontractor. The HII QA department maintains records for both HII and subcontractor coated tanks. These records were not reviewed.

The quality system for the pre-construction primer line has been improved since the beginning of the project. Most of the steel for LPD-26 was primed prior to these changes, so the improvements will predominately impact LPD-27 and future ships. As before, DFT and coating thickness are checked at the beginning of each shift. Surface profile is checked at 4-6 locations on the first sheet or set of shapes using Testex tape. Profile measurements around 3 mils were observed on the sheets which were available. The coating thickness measurement process has been changed. Rather than using electronic gages on the blasted steel, they insert three steel shims (approx. 2.5” by 3”) at 6-inch intervals in the direction of part feed, downstream of the blasting chamber. The 6-inch intervals were selected to represent variation in the 18-inch spray pattern of the spray guns. The coating thickness on the shims is measured using an electronic gage. Environmental data is recorded three times per shift. All of the QA data are entered into a computer system for easy retrieval. A separate system can figure out from a drawing what batch a particular sheet of steel came from, track that to the day it was primed and then from that date, obtain the QA data for the prime line. This established a degree of traceability for LPD-27 that was not possible for LPD-26. For the LPD-26, the policy was to retain PCP QA data for 6 months.

Adhesion tests were performed on two auxiliary fuel service tanks (6-142-1F and 6-141-1-F) that had been coated approximately 2 weeks prior. Each tank had approximately 850 square feet of coated surface. At nine locations in each tank, DFT’s were recorded, an X-Cut test was performed in accordance with ASTM D6677 and pull-off adhesion was determined in accordance with ASTM D4541, Method E. The coating was lightly sanded with 120 grit aluminum oxide paper and wiped with a clean rag prior to attaching the pull-off adhesion test fixture. The test fixtures were pulled about 24 hours after being installed. Table 18 presents the adhesion test data. The results demonstrate good coating adhesion. All but three of the X-cut adhesion tests were “10” (the highest possible rating). The remaining three tests were an acceptable “8.” None of the pull-off adhesion tests showed any failure at the interface of concern (i.e., the PCP/topcoat interface). The pull tests predominately failed at the glue interface, indicating that the adhesion of the primary coating to the retained pre-construction primer is in excess of the measured value. The adhesive did not appear to have fully cured under the fixtures in tank 6-142-1-F (it could be indented with a fingernail); resulting in adhesion values less than 1000psi. The adhesion results in 6-141-

1-F were higher; results between 1384 psi and 1782 were recorded for complete glue failure. Two lower results were recorded where the failure included adhesion between the touch up (t/u) and primary coating.

Tank	Location	Avg DFT	PSI	Interface	D6677
6-142-1-F	A	26.5	776	100% Glue	8
6-142-1-F	B	33.5	680	100% Glue	10
6-142-1-F	C	44.9	544	100% Glue	10
6-142-1-F	D	40.6	632	100% Glue	10
6-142-1-F	E	43.8	766	100% Glue	8
6-142-1-F	F	29.2	924	100% Glue	10
6-142-1-F	G	24.9	894	100% Glue	10
6-142-1-F	H	45.4	797	100% Glue	10
6-142-1-F	I	31.3	694	100% Glue	8
6-141-1-F	A	16.1	1028	btwn t/u and primary	--
6-141-1-F	B	>60	1537	100% Glue	10
6-141-1-F	C	31.7	1511	100% Glue	--
6-141-1-F	D	20.3	1608	100% Glue	10
6-141-1-F	E	>60	1212	Glue & t/u	10
6-141-1-F	F	34.6	1649	100% Glue	10
6-141-1-F	G	31.3	1782	100% Glue	10
6-141-1-F	H	48.4	1510	100% Glue	10
6-141-1-F	I	15.7	1384	100% Glue	10

Discussion

The prototype and demonstration tanks have demonstrated that MIL-PRF-23236, Type VII, Class 5/18 coatings may be applied over retained pre-construction primer with a reasonable expectation of successful performance. This is based on (1) the ability to acceptably complete secondary surface preparation on several hundred square feet of tank surface in a production environment and (2) acceptable adhesion of the MIL-PRF-23236, Type VII, Class 5/18 coating over retained pre-construction primer prepared in accordance with the Ingalls process. Tank coating condition as documented in the Navy CCIMS should be monitored to confirm coating performance over long-term service.

Secondary Surface Preparation

In all, 56 spaces with a combined surface area of over 83,000 square feet had been prepared to the specification at the time of this report without any significant problems. It is reasonable to expect that secondary surface preparation can be accomplished to the described SP-14 requirement in a production environment.

The prototype tanks included four small spaces totaling over 1100 square feet of surface area with secondary surface preparation completed by a combination of two slightly different degrees of sweep blasting and welds blasted to SP-10 (near-white metal). While minor rework was required on some of the tanks, none of the surface preparation checkpoints resulted in any disputed conditions. Multiple representatives from Ingalls production, Ingalls QA, SUPSHIPGC and the coating manufacturer observed the secondary surface preparation production process and acceptance criteria.

During the initial phases of production, HII personnel prepared 41 tanks consisting of over 47,000 square feet of steel in accordance with the requirement. The only significant issue that came up was that SP-14 only allows 10% coating in each 9 square inch area. The nature of sweep blasting results in streaks of in-tact coating which are not well suited to that small of an evaluation area. The QA and production personnel revised the wording to allow 10% of pre-construction primer to remain in any 12-inch by 12-inch area.

In January, 2014 a subcontractor began production. At the time of the project team's last review, the subcontractor had prepared 11 tanks consisting of over 35,000 square feet of steel in accordance with the requirement. While no issues were reported, interviews with project personnel indicated that the subcontractor is achieving close to an SP-10 surface. The subcontractor has chosen not to re-train blasting personnel to the lesser degree of surface preparation. They reportedly realize a cost savings from reduced re-work resulting from the less stringent surface preparation requirement.

Primary Coating System Adhesion

Adhesion was measured at multiple locations in each of four prototype tanks and two production tanks. Each adhesion test location included a X-cut test in accordance with ASTM D6677 and a pull-off adhesion test in accordance with ASTM D4541 Method E using a Type V Self-Aligning Adhesion Tester.

One objective of the prototype demonstration was to develop a surface preparation procedure that does not result in the failure of the coating system at the substrate-primary coating interface below 1,750 psi when tested in accordance with ASTM D4541. Only one of seventy tests (1.4%) showed any indication of failure at the retained pre-construction primer and topcoat interface. On that particular test, the failure load was 2499 psi, in excess of the objective value.

The detailed pull-off adhesion results have been presented earlier in this report. Figure 22 presents all of the pull-off adhesion values in a cumulative probability graph. Each shape represents the data from a different tank. The lone red diamond is the test that included 33% of the failure surface at the pre-construction primer interface. The remaining tests predominately failed between the adhesive and MIL-PRF-23236, Type VII, Class 5/18 coating (i.e., "glue failures") at loads between 544 psi and 3015 psi. The average failure load was 1817 psi and the median was 1812 psi. Forty-one of the data points failed in excess of 1750 psi, indicating that the pre-construction primer interface is definitely stronger than the target value at these locations. At the twenty-nine locations where the adhesive failed at less than 1750 psi, we only know with certainty that the pre-construction primer interface is stronger than the measured value. However, the low adhesion values are consistent with a coating product that meets the desired objective of 1750 psi. The majority of the low load failures are in tanks 8-68-1-W and 6-142-1-F where the adhesive on the test fixture did not appear to cure properly for differing reasons.

Figure 23 contains all of the adhesion data from Figure 22 combined as single population (the square data points). The data is compared to data from laboratory test panels prepared to SSPC SP-7 and SSPC SP-10 presented earlier in this report. For each data set, tests where there was no failure at the interface of interest (i.e., retained PCP-primary coating interface) are green, tests where failure at the interface of interest was a secondary mode are yellow and data where the primary mode of failure was at the interface of interest are red.

The shift of the LPD-26 data set to the left is indicative of the adhesive (glue) performance. The lack of failure at the interface of interest for nearly all of the tests supports satisfactory adhesion of the single coat coating to the retained pre-construction primer. The lab test panels prepared to SP-7 included seven failures between the retained PCP and primary coating system at loads less than 1750 psi. The fact that such failures were not observed in the prototype tanks suggests that they have better adhesion than the laboratory test panels. On the laboratory test panels with SP-10 (near white metal blast) the lowest adhesive failure at the interface of interest was 2922 psi.

ASTM D6677 data are presented earlier in this report. A test result of "8" was agreed to be considered acceptable for a newly applied coating. None of the tests were rated less than "8." Figure 24 shows the number of tests that were rated an "8" and "10" in each tank. Over 85% of the tests had a rating of "10" while the remaining 9 of 64 tests had a rating of "8."

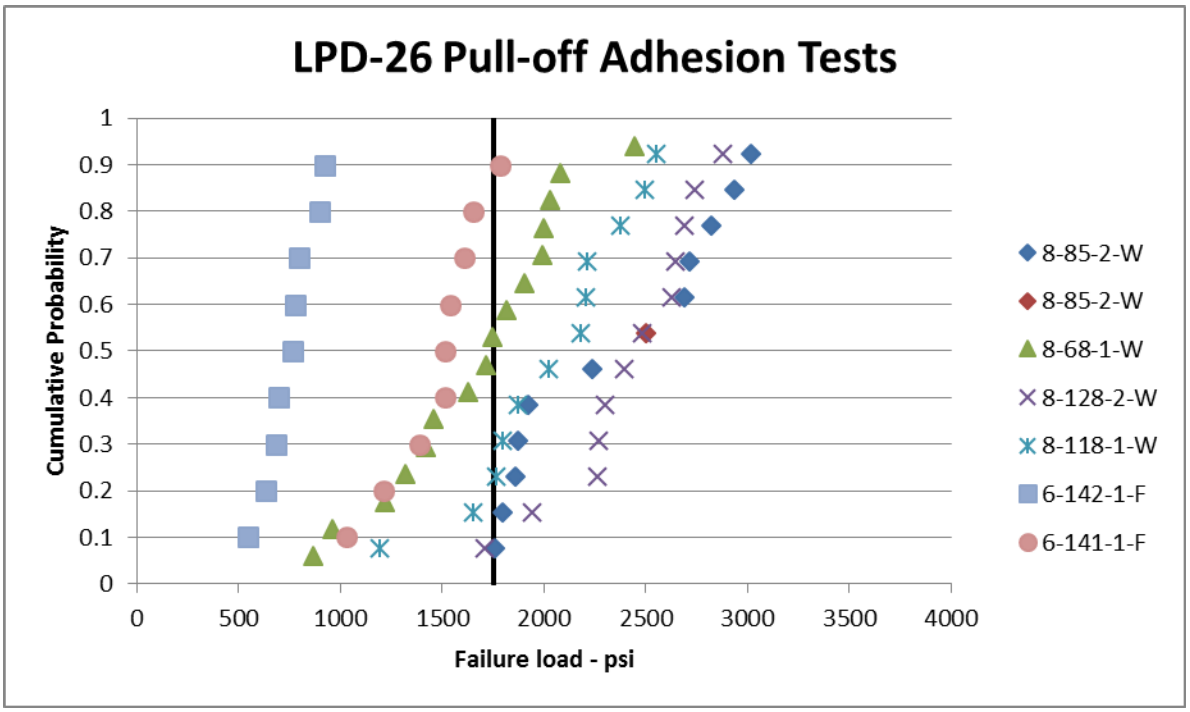


Figure 22. Cumulative probability plot of LPD-26 adhesion test results.

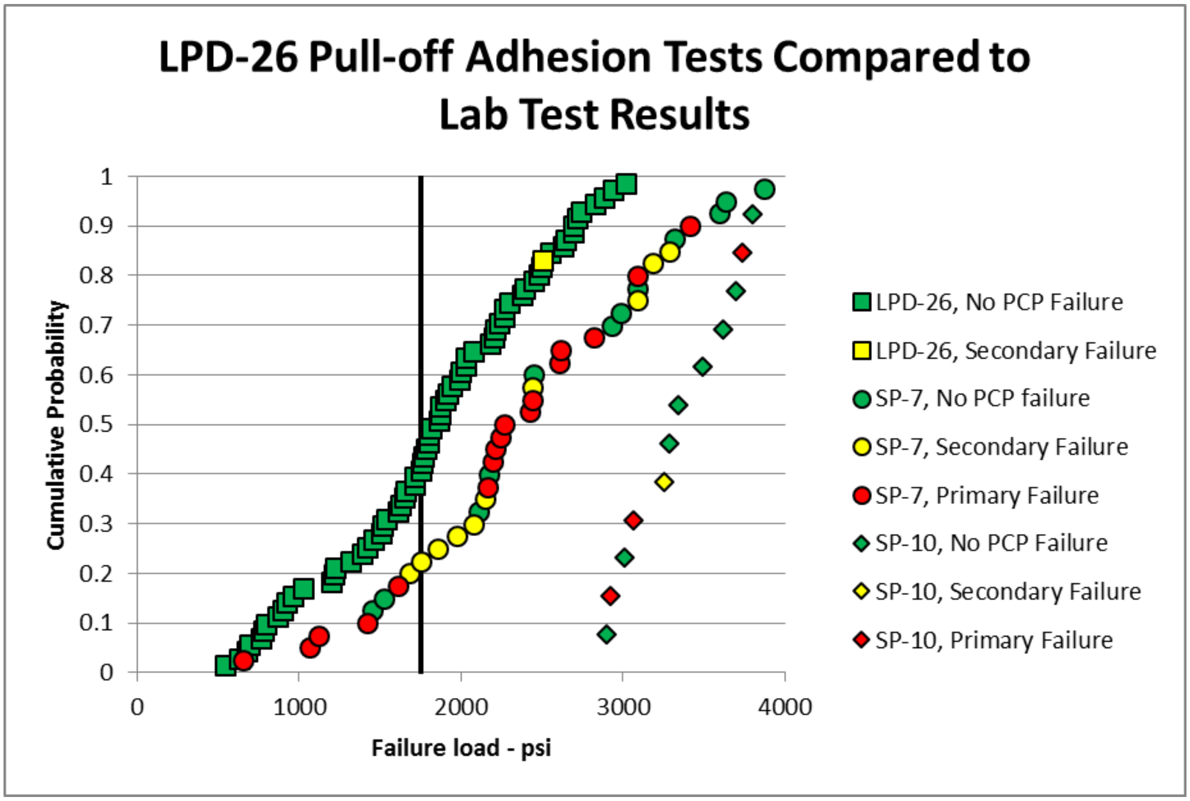


Figure 23. Comparison of LPD-26 adhesion data with laboratory test data.

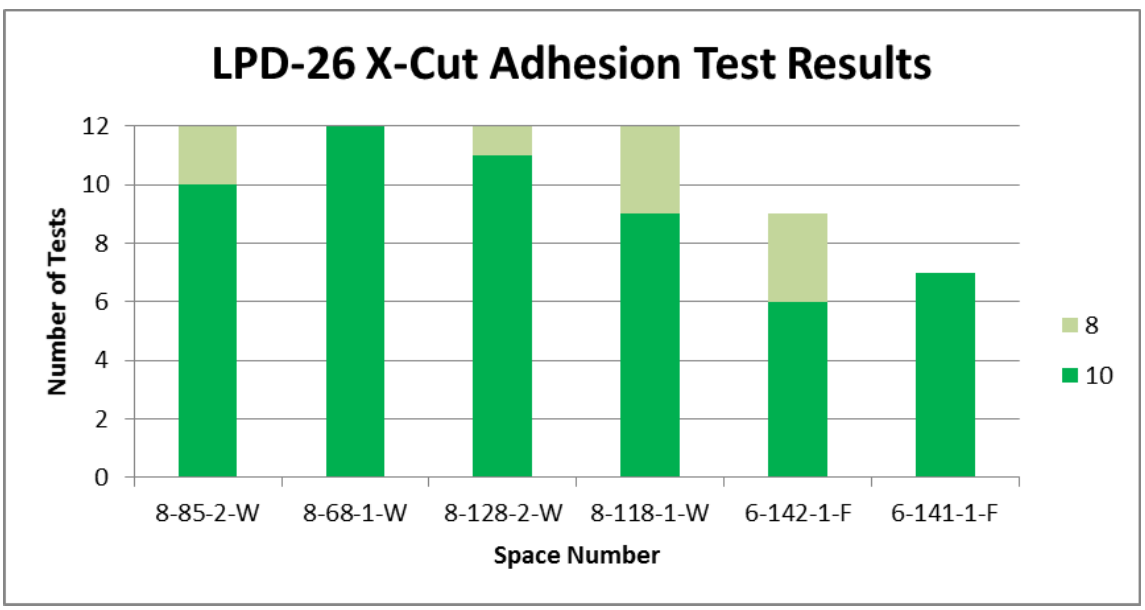


Figure 24. Summary of ASTM D6677 test results.

Implementation

Industry Standard

One of the challenges associated with retaining pre-construction primer is the lack of industry guidance that addresses the various technical challenges. The majority of the guidance that exists is either fragmented or specific to a coating manufacturer's product line. As part of this project, an SSPC working group was formed to develop a guide document with the following preliminary scope:

> *This guide document provides the specifier and user with information regarding the use of pre-construction primers (PCP) on structural steel in shipbuilding. It provides background on the reasons to use and retain PCPs, the types of PCPs and their application and inspection, and the secondary surface preparation processes that are used when PCPs are retained in the final, compatible primary coating system.*

The working group includes representatives from Newport News Shipbuilding, Bath Iron Works, HII-Ingalls Shipbuilding, Bechtel Engineering, US Army Corps of Engineers, Sherwin Williams, International Paint, Blastech Mobile LLC, Elzly Technology and others. At the time of this report, an initial working draft was developed. The working draft covered the following topics: pre-construction primer materials, material properties, selection of a compatible primary coating system, application of pre-construction primers, when to retain pre-construction primers, and secondary surface preparation.

Consideration by Other Navy Programs

This project has demonstrated a process for applying single coat tank coatings over retained pre-construction primer for the LPD-17 program. To-date it has been successful on the LPD-26 and has been approved for the LPD-27. There is no technical reason why the process could not be used for other ships built by HII-Ingalls (DDG and LHA).

Weld-through pre-construction primers have not historically been used by the CVN program though there has been a renewed interest in their use. The ability to retain pre-construction primers in voids and certain tanks could result in a savings to the program.

Weld-through pre-construction primers have historically been used by Fincantieri/Marinette Marine (MMC) during shipbuilding. On the LCS, MMC retains preconstruction primers in accordance with NAVSEA guidelines on all spaces except potable water tanks, water mist tanks and lube oil tanks. For various reasons, MMC has not yet adopted single coat (MIL-PRF-23236 Type VII Class x/18) coatings. This project addressed one of the issues associated with switching coating systems – the need to remove pre-construction primers before applying the single coat material.

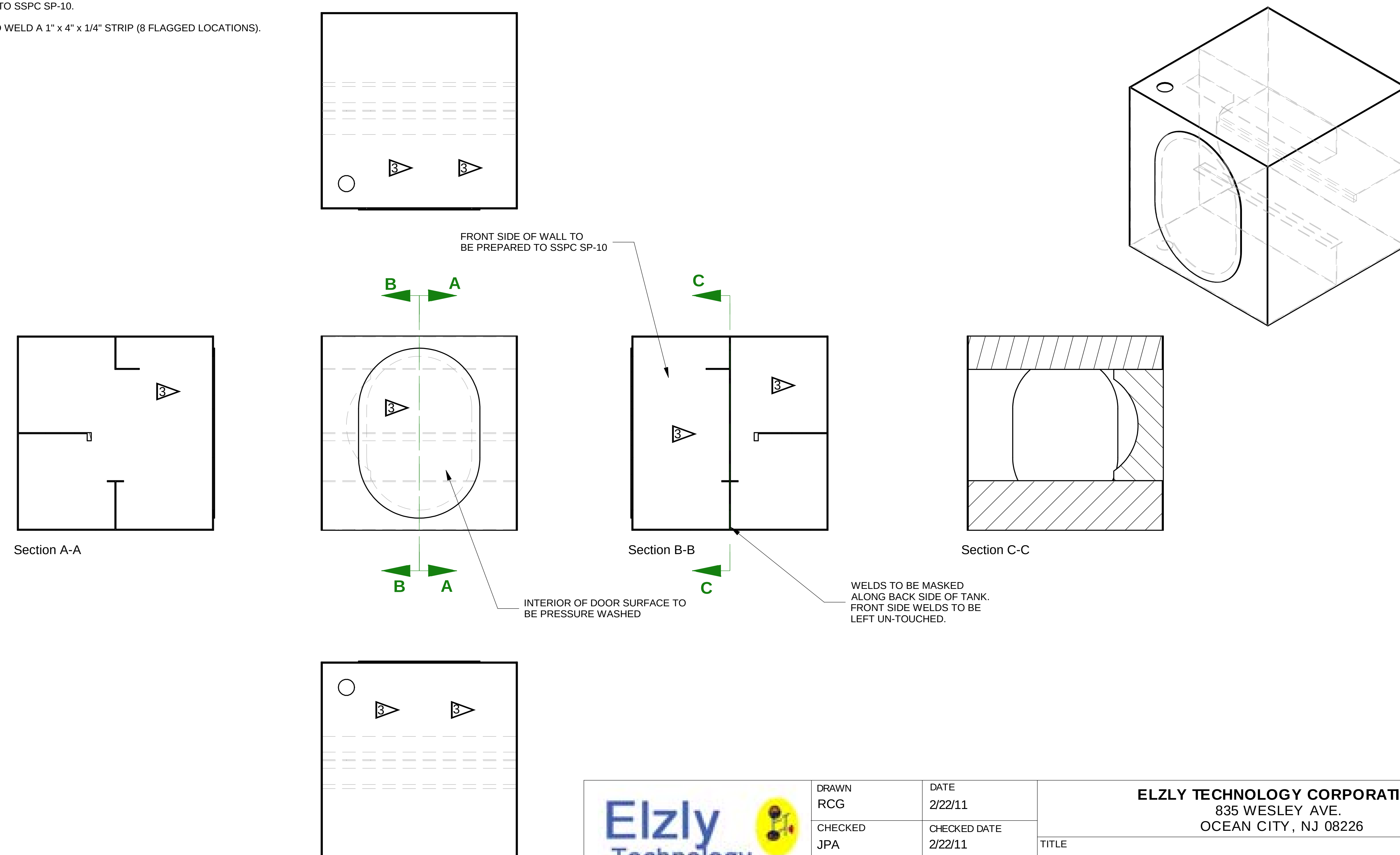
Weld-through pre-construction primers have historically been used by the DDG51 program though there has been a requirement to remove them from critical coated areas including all tanks and voids. The ability to retain pre-construction primers in critical coated areas could result in a savings. The DDG program is currently transitioning to single coat (MIL-PRF-23236 Type VII Class x/18) coatings; the results of this project will be relevant to that effort.

Appendix A – Simulated Ballast Tank Test Compartment

NOTES:

1. SECTION A-A TO BE SPOT SOLVENT WIPED AND POWER TOOL CLEANED.
2. SECTION B-B TO BE BRUSH BLASTED WITH THE EXCEPTION OF THE WALL CALLED OUT TO BE PREPARED TO SSPC SP-10.
3. TYPICAL LOCATIONS TO WELD A 1" x 4" x 1/4" STRIP (8 FLAGGED LOCATIONS).

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
A	TANK PAINT PROCEDURE	2/22/11	JPA



Elzly Technology Corporation

DRAWN	DATE
RCG	2/22/11
CHECKED	CHECKED DATE
JPA	2/22/11

UNLESS OTHERWISE SPECIFIED

ALL DIMENSIONS ARE APPROXIMATE

ELZLY TECHNOLOGY CORPORATION
835 WESLEY AVE.
OCEAN CITY, NJ 08226

TITLE

TYPICAL TANK COMPARTMENT

SIZE	FSCM NO.	DWG NO.	REV
B			A

SCALE	MATERIAL	SHEET
1:28		1 OF 1