
Retention of Pre- Construction Primer

NSRP Surface Preparation and
Coatings Panel Project Report
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EXECUTIVE SUMMARY

Inorganic zinc pre-construction primers (PCPs) are a special class of inorganic zinc primers. PCPs are designed to withstand the welding processes and handling damages during the fabrication process of blocks or modules prior to their incorporation into the permanent finished structure. PCP selection is driven by welding as well as coating issues. The primer can have an effect on welding speeds and quality. The composition of the primer can have health and safety implications for the welding process.

Current US Navy practice requires removal of pre-construction primers on all critical-coated surfaces. NSRP has sponsored a number of studies over the past 30 years which have supported retaining pre-construction primers as a cost saving measure without any service life impact. Several foreign commercial shipyards have recently performed testing in support of retaining PCP within the scope of IMO PSPC regulations.

This report documents the procedures used to retain pre-construction primer during repair of USS VICKSBURG and during construction of the T-AKE class. In both cases the pre-construction primer is retained on steel in critical coated areas. Past studies and the present work conclusively demonstrate that pre-construction primer can be retained without impacting coating performance.

Based on the documented successful use of procedures to retain pre-construction primer, the project team developed suitable wording for insertion to Navy Standard Item 009-32 to allow pre-construction primer retention during Navy ship repair. It is estimated that allowing pre-construction primer retention can save the Navy in excess of \$7 million per year, the majority of which is associated with new construction. The change approved at the July, 2010 meeting of the NAVSEA Standard Specification for Ship Repair and Alteration Committee (SSRAC) will require brush blasting for secondary surface preparation of pre-construction primer except in fuel-related tanks. The approved change will not allow retention of pre-construction primer in potable water, reserve feedwater, and freshwater drain collecting tanks, nonskid applications (MIL-PRF-24667), and single coat applications (MIL-PRF-23236 Type VII Class 18/x). While these constraints limit the potential cost savings, they will help the Navy better quantify the risks and benefits of retaining pre-construction primer. More work in the issue of secondary surface preparation and compatibility of pre-construction primer with single coat materials is required to recognize the entire potential cost savings.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	3
TABLE OF CONTENTS.....	4
BACKGROUND	6
Inorganic Zinc Preconstruction Primers	6
Literature review.....	7
Global Pre-construction primer standards.....	9
Material Standards	9
Process Standards.....	10
KEY ISSUES FOR THE US NAVY.....	11
Primer Application Process (“Plate Line”).....	11
Secondary Surface Preparation Requirements	12
Solvent Cleaning.....	13
Power Tool Cleaning	13
Pressure Washing.....	13
Abrasive Blasting.....	13
Inspection and Acceptance of Prepared Surface.....	14
Visual Standards for Inspecting Secondary Surface Preparation.....	14
Water Break Test for Inspecting Secondary Surface Preparation.....	16
TECHNOLOGY DEMONSTRATION	17
USS Vicksburg (Repair, Low Pressure Water Cleaning)	17
T-AKE (New Construction, Sweep Blasting).....	20
Inspection of Contaminated PCP.....	21
Implementation	25
SI009-32 change	25
Potential Cost Savings	25
Cost Savings during Ship Repair	26
Cost Savings during New Build.....	27
Conclusions and Recommendations	29

BACKGROUND

Priming of carbon steel plates, beams, angle irons and other shapes prior to their fabrication into parts of industrial and marine structures has progressed from its earliest stages prior to module type fabrication to the current block stage or module process. The earliest practices involved using full thickness of both organic and inorganic primers intended to become the first coat in multi-coat systems. It was quickly recognized that these full coat primers impeded progress of welding and led to porosities in the welds that compromised the integrity of the entire coating system. Extensive damage during the fabrication process led to a need for quicker processes with less intercoat adhesion problems.

The coatings industry quickly met the need with more efficient inorganic zinc primers by adopting both thinner films and films with less zinc content as a means of meeting the production requirements of the fabricators; predominantly shipyards. While some organic pre-construction primers (mainly water-based inhibitive epoxy) have been used, they did not match either the production efficiencies or the protection of the carbon steel afforded by inorganic zinc pre-construction primers (PCP) during the fabrication process that often extends beyond a one year time frame. The major problems were extensive burn back from the weld area, fabrication damage and noxious fumes during welding and cutting processes.

Inorganic Zinc Preconstruction Primers

Inorganic zinc pre-construction primers (PCPs) are a special class of inorganic zinc primers. Whereas permanent inorganic zinc primers are formulated with zinc pigment content ranging from 45% to 92% depending on the manufacturer and the end-use requirement of 2-4 mil (50-100 μ m) dry film thickness (DFT), all IOZ PCPs have drastically reduced zinc pigment content with an end-use requirement of 0.6-0.8 mils (15-20 μ m) DFT. PCPs are designed to withstand the welding processes and handling damages during the fabrication process of blocks or modules prior to their incorporation into the permanent finished structure. Corrosion prevention is required, but only during the time frame from PCP application until the fabricated components are welded into modules that become joined into a completed structure. Application of the permanent protective coating system varies according to the shipyard's individual production process. It may involve application of the first coat of the permanent protective coating system just prior to reaching the module stage or it may involve 1st and 2nd coats being applied just prior to reaching the module stage. Rarely is the finish coat of the permanent protective coating system applied prior to the module stage.

Zinc content of PCPs are typically in the 28-48% range. Zinc content is chosen based on a tradeoff between welding issues (which favor lower zinc content) and corrosion protection during storage (which favors higher zinc content). Of course, other factors such as cost and usability will contribute to the final formulation. A common solution in the lower cost versions is to replace some of the zinc with inhibitors such as zinc phosphate. One of the first of the inorganic PCPs recommended for immersion service of more than 15 years without sweep blasting also has zinc oxide, vitreous silica, and kaolin in its formula.

PCP selection is driven by welding as well as coating issues. The primer can have an effect on welding speeds and quality. The composition of the primer can have health and safety implications for the welding process. A 1973 NSRP report discusses these issues.¹

Literature review

The debate over whether to retain pre-construction primers is not new. NSRP has sponsored a number of studies over the past 30 years which have been looking at the issue. Several foreign commercial shipyards have again performed testing in support of the IMO PSPC regulations. Following is a brief review of selected studies.

A 1985 NSRP report documents a visit to IHI International Inc. to assess if the “Japanese methodology” could provide adequate corrosion protection to their ships, given a 20 year life cycle of a ship.² A key consideration of this methodology was never removing the PCP to bare metal. The investigators also had the opportunity to visit 4 different ships, all at a different period in their life cycle. The ships were: a container ship at 1 year service life, a large tanker at 6 years into its life, a car carrier at 8 years service life, and a bulk cargo ship at the 14 year mark. At each inspection, assessments were made (whenever accessible) of coating condition on the freeboard, deck house, underwater hull, internal tanks, and engine room coatings. Finally, chief chemists of two large Japanese coating manufacturers, Nippon Paint Company, and Chogoku Marine were visited and interviewed. The general message from this report is that the Japanese coating systems are standard, simple, and designed for maintainability at predictable intervals, and designed with shipyard production in mind. As such, they are “good enough” to get a ship 20 years with “adequate” corrosion protection. Salient points of the report include:

- Assembly blocks are completely outfitted prior to attachment, therefore dust must be kept at a bare minimum. Hence, open blasting is virtually eliminated in Japanese construction – a heavy emphasis is placed on secondary surface preparation, typically disc sanding with 16 grit pads to produce a profile.
- The Japanese utilize standard coating systems (for very specific reasons), unlike in the US, where several coating types and of varying sophistication are employed. For example PCP’s consist of low film builds (typically 0.6 mils DFT) alkali silicate primers with zinc dust. This low DFT allows for fast cutting and weld-thru times. Higher build zinc-free PCP’s (1.5-2.0 mil DFT) can lead to slower cutting, slower welding, unacceptable fumes generated, and weld porosity. The standard ballast tank coating is coal tar epoxy. The standard exterior hull coating above the boot-top (freeboard) consists of chlorinated rubber, which is recoated very easily every 4 years. The standard underwater hull system is coal tar epoxy, followed by a vinyl tar tie coat to an ablative anti-fouling layer.

¹ *Improved Fabrication Primer for Protection of Steel*, National Shipbuilding Research Program Report # 0032, General Dynamics, February 1973.

² *A Survey of Japanese Shipyard Applied Marine Coating Performance*; John Peart (Avondale Shipyards) and Ben Fulz (Bechtel National, Inc.); MARAD/NSRP November 1985.

- The 4 ships that were visited all exhibited varying signs of coating breakdown and wear, based on the age and service area of the coating. The key concept was that the coatings selected, and the quick turn-around maintenance (never removing the PCP to bare metal) would provide “adequate” corrosion protection for the ship’s design life of 20 years.
- Other specific points are that the thin film PCP’s used above the waterline do not provide adequate corrosion protection from undercutting, as evidence after 1 year. There is a heavy dependence on secondary surface preparation, followed by touch up with organic zinc coatings. This practice precludes the use of sophisticated, more expensive coating systems with longer service life, as in the United States.

NSRP sponsored two laboratory test programs in the same timeframe as the aforementioned visit to the Japanese shipyard. One study involved topcoating a number of inorganic zinc primers with various epoxy topcoats (coal tar, MIL-P-23236, MIL-P-24441) and subjected to various immersion performance tests to see if delamination and blistering occurred.³ A second study performed four performance tests on six coating systems (coal tar epoxy, polyamide epoxy, inorganic zinc, chlorinated rubber, vinyl, and bleached tar) applied to retained and removed PCP.⁴ The tests included (a) 6 month 150F salt water immersion, (b) three 17 day cycles – 14 days of 80 psi immersion, 3 day atmospheric exposure, (c) 2 month alternating cycles of UV, heat, and immersion and (d) 2000 hour cyclic salt fog testing per ASTM B-117.

The laboratory testing did not lead to any conclusive position on the retention of PCP. Both studies contained interesting detailed observations on the effect of various topcoats and zinc loadings in the primer. The former study found that “...topcoats tend to blister when applied over inorganic zinc primers versus white-metal steel in underwater service.” However, “...the results suggest that topcoat blistering/disbondment is more probable on full-coat vs. preconstruction primers.” The later study concluded “Despite the reasons for differences in performance, the test program does not indicate that a significant increase in longevity will result by removing and replacing the zinc primer prior to application of the finish system.”

NSRP also sponsored two tests of PCP retention in simulated ballast tanks. A project completed in 1982 included retained PCP as part of a project looking at various coating systems with and without cathodic protection.⁵ After one year, no depletion of the inorganic zinc PCP was observed, along with minimal loss of Zinc anode – the author concluded that this system, based on the mock-up test, probably could last 20 years without replacement of the zinc anodes. The other systems had diminished performance with the soft coatings performing so poorly that they were removed from the testing phase a few months into the test due to complete coating breakdown and incompatibility with CP.

³ George Gehring, Jim Ellor (Ocean City Research Corporation), *Overcoating of Inorganic Zinc Primers for Underwater Service*, paper #25 presented at SNAME Ship Production Symposium, New Orleans, Aug. 1987.

⁴ KTA-Tator, Inc., *Adaption of Japanese Prefabrication Priming Procedure to US Shipbuilding Methodology*, paper #270 presented at SNAME Ship Production Symposium, New Orleans, Aug. 1987

⁵ *Cathodic Protection/Partial Coatings vs. Complete Coatings in Tanks*, NSRP project performed by Offshore Power Systems div. of Westinghouse and Avondale Shipyards, May 1982.

Another project involved a series of 4 simulated ballast tank assemblies were fabricated at NASSCO (San Diego, CA) in November 1998. Each tank was blasted and coated with various PCP's (a weldable control [Nippon Ceramo], a water-borne zinc PCP, and 2 solvent-borne PCP's). The tanks were fabricated and allowed to weather 60 days. Various topcoats were applied after secondary surface preparation (SP-1, SP-3 and SP-11 of welds). Two control tank compartments were included in the study – the control tanks had the original PCP blasted off to SP-10 and in one, the NAVSEA high solids (Sigmaguard system) was applied. The other control tank had MIL-P-24441 type IV applied.

Based on the overall performance of the coating systems tested throughout the 4 year cycle, the author concluded “The use of preconstruction primer in conjunction with standard tank lining systems did not degrade the overall performance of the lining system.”⁶

In 2005, Hyundai Industrial Research Institute reported on the performance of 2 mock-up blocks using Korean shipbuilding procedures.⁷ After fabrication a 1 month weathering period was observed. One mock-up was sweep blasted and the other was fully blasted. Both assemblies were coated with standard ballast tank epoxy topcoats. Tensile adhesion tests on both tanks met NORSOK requirements. This data along with Cathodic Disbondment testing per ASTM G8⁸ was used to conclude that retention of PCP is a viable option for process improvement and cost associated with shipbuilding and bridge building.

Global Pre-construction primer standards

Material Standards

A significant problem in the industry is that there is no standard for pre-construction primer material. A variety of coating materials have been marketed as PCPs. In the absence of a global standard, Classification societies such as ABS, DNV, Lloyds, etc. issue type approval certificates for PCPs. These certificates indicate that the materials meet the class society's requirements for PCPs. They do not establish a standard or meet a global standard. Competition among the Societies for dominance in a particular market creates the potential for less stringent standards.

The nearest thing to a standard is the International Maritime Organization (IMO) Resolution (MSC215(82)) PERFORMANCE STANDARD FOR PROTECTIVE COATINGS FOR DEDICATED SEAWATER BALLAS TANKS IN ALL TYPES OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS (PSPC). This resolution became mandatory through amendment of the SOLAS convention and applies to ships contracted on or after July 1, 2008. It specifies inhibitor free zinc silicate

⁶ Ben Fultz (Associated Coatings, Inc.), *Retention of Preconstruction Primer in Tank Coating Systems – Final Report* MARAD/NSRP (NSRP Paper #3-96-3), November 2002.

⁷ Baek, Chung, Lee, Lee, Shin (Hyundai Industrial Research institute, HHI Co. Ltd), *Effect of retaining Preconstruction Primer (PCP) on the Quality of High Performance Protective Coatings Systems*; NACE Corrosion 2005 Paper 05003.

⁸ Baek, Chung, Lee, Lee, Shin (Hyundai Industrial Research institute, HHI Co. Ltd), Report to IMO Sub-Committee on Ship Design and Equipment DE 49/6/19, *Effect of retaining Preconstruction Primer (PCP) on the Quality of High Performance Protective Coatings Systems*, December 2005.

shop primer or equivalent. Equivalence is not defined; therefore the determination of equivalence is often determined by the manufacturer of the PCP and/or the classification society doing survey work in the shipyard. This Resolution is based on specifications and requirements which intend to provide a target useful coating life of 15 years for the entire coating system, which is considered to be the time period, from initial application, over which the coating system is intended to remain in “GOOD” condition. The actual useful life will vary, depending on numerous variables including actual conditions encountered in service.

The specific requirements of the IMO PSPC Resolution relating to PCPs include:

- Shop-primer is defined as the prefabrication primer coating applied to steel plates, often in automatic plants (and before the first coat of a coating system).
- The shop primer shall be zinc containing, inhibitor free zinc silicate based or equivalent.
- Shop primer compatibility with main coating system shall be confirmed by the coating manufacturer.
- The complete coating system comprising epoxy based main coating and shop primer shall have passed a pre-qualification certified by test procedures in [annex 1].⁹
- The retained shop primer shall be cleaned by sweep blasting, high pressure water washing or equivalent method.

Process Standards

The Japan Ship Technology Research Association (JSTRA) published their Standard for the Preparation of Steel Substrates for PSPC-2008. (SPSS for PSPC) This photographic collection of surface preparation examples are intended as a reference when implementing the PSPC. These photographs may also serve as a reference when applying the Performance Standard to void spaces as well as cargo oil tanks developed or to be developed by the IMO.

ISO 8501-1:1998/Suppl:1994 provides photographic examples of grades Sa21/2 or St3 surface preparation, but only for rusted flat steel surfaces without a shop primer. Therefore, it does not provide photographic examples of typical areas after block assembly as well as at the erection stage.

Several coatings manufacturers have their own process standards for preparing aged pre-construction primer prior to applying a coating. The JSTRA standard and two coating manufacturer standards are discussed later in this report.

⁹ The annex describes a 180-day test of panels installed in a simulated ballast tank with wave movement.

KEY ISSUES FOR THE US NAVY

As far back as the 1960's many shipyards routinely applied pre-construction primer to stock plates and shapes. The technique was a cost-effective way to protect the steel during fabrication. Ideally, the primer could be retained as part of the final coating system, but it was removed to facilitate proper welding or when the primer was deemed incompatible with the final coating system. Applying Navy specified coating systems has historically required complete removal of the pre-construction primer. However, as a result of advances in primer and epoxy coatings, it has become common to retain PCPs during commercial shipbuilding. Following is a discussion of three issues which the Navy must resolve to adopt this technology – primer application, secondary surface preparation and inspection of the PCP surface before coating application. In July 2010 the deliverable of this project was a SSRAC proposal to add the retention of PCP in the NSI 009-32. The proposal was accepted “as modified” and is currently in the approval phase of the SSRAC process. Details of the proposal can be found later in this report.

Primer Application Process (“Plate Line”)

Pre-construction primers are typically applied in a shop process sometimes referred to in the industry as a “plate line.” The primer application may be a continuous or a batch process. In either case, the surface preparation and coating application are performed on steel in a controlled, sequential process which is automated to varying degrees. The quality of the coating process is improved as a result of automating the abrasive blasting and primer application. Minimizing the time between surface preparation and painting has the added benefit of reducing the risk of surface contamination which may interfere with coating performance.

If the Navy were to allow pre-construction primer to remain on the surface, it is logical to require the primer application process to meet the requirements of NAVSEA Standard Item 009-32. The pertinent elements of the Standard Item are those relating to surface preparation. The requirements of SI 009-32 and those typical for pre-construction primer manufacturers are shown in Table 1. The manufacturer's recommendations are consistent with the SI 009-32 requirements.

Table 1 - Surface Preparation Requirements

Parameter	NAVSEA SI 009-32	Typical Primer Manufacturer Requirement
Cleanliness	SSPC SP-10/NACE No. 5	Sa 2 ½ or SP-10
Surface Profile	2-4 mils	Angular profile of 1-3 mils
Non-visible contaminants	Chloride measurements below 3µg/cm ² or conductivity below 30µS/cm	Low salt levels
Visible contaminants	ISO 8502-3, Rating 2, Class 2	Low dust levels
	Free of contaminants IAW SSPC SP-1	

Another issue which must be considered is the inspection requirements contained within SI 009-32. The inspection frequency and degree of oversight contained in SI009-32 has been developed from the perspective of a space being painted on a ship. Inspection frequency is based on the surface area of the item being painted. Checkpoints exist where the shipyard and/or government representative inspects the quality of the work on the item.

A plate line is typically processing steel which may be designated for use in multiple work items. In fact, one steel plate might be cut such that it enters multiple work items (e.g., multiple tanks). Thus, it is logistically difficult to apply the inspection frequency on the basis of work item surface area.

A plate line is also a controlled process which runs more or less continuously through the day. The process involves application of the same products using the same surface preparation to relatively simple shapes. Significant cost savings are recognized because of the uninterrupted, consistent process. The efficiencies would be reduced or eliminated is the process needed to stop for a “hold point.” Because the process is continuous, shipyard or government inspectors should be able to observe and inspect the work at any time the plate line is operating. This type of inspection is consistent with an “I-Point” (verification and documentation by an individual other than the person who has accomplished the work) rather than a “G-point” (requiring government notification) as defined in NAVSEA Standard Item 009-04.

Secondary Surface Preparation Requirements

Between priming and fabricating steel the pre-construction primer is likely to be contaminated or damaged as a result of handling, outdoor storage and/or welding. While the preconstruction primer does not have to be removed, a surface preparation step must be accomplished before applying the final coating system to the pre-construction primed steel. This step, commonly referred to as “secondary surface preparation” may consist of solvent cleaning, power tool cleaning, pressure washing, abrasive blasting or a combination of these methods. Each method is discussed below.

Solvent Cleaning

SSPC SP 1 - Solvent Cleaning describes a method for removal of oil, grease, dirt, soil, salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion, or steam. This procedure is commonly performed on a spot or as-needed basis though it can be applied to an entire surface regardless of initial condition. While it can be used as a stand-alone cleaning method, solvent cleaning is also recommended *before* performing any of the following surface preparation techniques.

Power Tool Cleaning

Welds and damaged primer should be mechanically cleaned to remove surface oxides and restore a profile before applying the main coating system. In many cases, power tool cleaning is the most cost-effective way to prepare these sections. There are a number of existing specifications for power tool cleaning including:

SSPC SP 3 - Power Tool Cleaning covers removal of loose rust, loose mill scale, and loose paint to degree specified, by power tool chipping, descaling, sanding, wire brushing, and grinding.

SSPC SP 11 - Power Tool Cleaning to Bare Metal covers complete removal of all rust, scale, and paint by power tools, with resultant surface profile.

SSPC SP 15 - Industrial Grade Power Tool Cleaning is a specification between SP 3 and SP 11. Removes all rust and paint but allows for staining; requires a minimum 1 mil (25 µm) profile.

Pressure Washing

Pressure washing of a surface with pre-construction primer is an economical way to address the entire surface. By pressure washing the entire surface, non-visible contaminants should be removed. *SSPC SP 12/NACE No. 5 - Surface Preparation and Cleaning of Metals by Waterjetting Prior to Coating* defines four degrees of cleaning for visible contaminants (similar to SP 5, 6, 7, and 10) and three levels of flash rust and describes three levels of non-visible surface cleanliness for non-visible soluble salt contamination. For preparation of surfaces with pre-construction primer, Low Pressure Water Cleaning should be used to achieve a WJ-4 condition (Light Cleaning). This involves using water at pressures less than 34 MPa (5,000 psig) to create a surface finish which, when viewed without magnification, is free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose coating. In conjunction with pressure washing, welds and damaged primer will require power tool cleaning or abrasive blasting. The mechanical surface preparation would remove any rusting (or flash rusting) which may occur. A level of acceptable soluble salt contamination should be specified.

Abrasive Blasting

Abrasive blasting may be used to sweep blast in-tact primer as well as prepare welds and damaged areas. Sweep blasting is performed in accordance with *SSPC SP 7/NACE No. 4 - Brush-Off Blast Cleaning*. The standard requires blast cleaning of all except tightly adhering residues of mill scale, rust, and coatings, while uniformly roughening the surface. All pre-construction primed surfaces may be sweep blasted. Sweep blasting of preconstruction primers can be challenging because the primer color matches that of abrasive blasted steel. It can be difficult for blasters who are used to near white metal blast to adjust to

the lesser level of surface preparation. However, once trained sweep blasting can roughly double the production rate and reduce the amount of abrasive consumed versus a near white metal blast.

Welds and damaged areas require a higher degree of surface preparation to remove any oxides and create a surface profile. These areas should be prepared to one of the following specifications:

SSPC SP 6/NACE No. 3 - Commercial Blast Cleaning which describes blast cleaning until at least two-thirds of the surface is free of all visible residues with only staining permitted on the remainder.

SSPC SP 10/NACE No. 2 - Near-White Blast Cleaning which described blast cleaning nearly to White Metal cleanliness, until at least 95% of the surface is free of all visible residues with only staining permitted on the remainder.

Inspection and Acceptance of Prepared Surface

Once the secondary surface preparation is complete, the prepared surface should be inspected prior to applying the final coating system. Because the prepared surface will contain in-tact primer the measurement of surface profile is only appropriate on areas that have been cleaned to bare metal (such as welds). Key considerations are visual cleanliness and non-visible salt contamination. This section discusses inspection and acceptance criteria for prepared pre-construction primer.

Visual Standards for Inspecting Secondary Surface Preparation

There are several visual standards for prepared pre-construction primer. In this section we will discuss the visual standards published by two coating manufacturers and The Japan Ship Technology Research Association (JSTRA). These visual standards include photographs and descriptions for comparing the prepared surfaces but they do not contain physical test procedures. Most manufacturers refer to washing and blowing down in addition to mechanical methods for preparing PCP. However, the visual standards predominately address the extent and condition of in-tact paint remaining after mechanical surface preparation techniques. The inspection standards describe levels of surface preparation but do not provide guidance on acceptance criteria prior to overcoating (i.e., what level of cleanliness is required). Such guidance is commonly contained in the product data sheet for the main coating system.

Abrasive Sweep Standards for Shop Primed Steel Surfaces – Published by International Paint

International Paint has published a visual standard which provides nine photographs representing three levels of surface preparation for three different shop primers. The shop primers are differentiated by color - Red Oxide, Green and Gray. For each of the shop primers, three levels of preparation illustrated:

- AS.1 – Light abrasive sweeping
- AS.2 – Medium abrasive sweeping
- AS.3 – Heavy abrasive sweeping

Standards for the Preparation of Steel Substrates for PSPC – Published by Japan Ship Technology Research Association in 2008

JSTRA has published a visual standard which contains 84 reference photographs which represent a variety of conditions prior to surface treatment and after various surface treatments. The surface

preparation levels include those that would comply with PSPC requirement of Sa 2½ or St 3 as well as a higher grade than PSPC requirement (designated Sa 2½+ or St 3+ in the standard).

For damaged areas, the standards provide representative surfaces cleaned using abrasive blasting (Sa 2½) or power tools (St 3). For each of the following damage conditions, a reference condition and preparation to Sa 2½, St 3, Sa 2½+ or St 3+ is shown: spot rust, light pitting, burned, manual weld, semi-automatic CO₂ fillet weld, semi-automatic CO₂ butt weld, automatic butt weld, collar plate weld, and corner weld.

For undamaged shop primer with surface contamination, the visual standards show cleaning to recommended conditions using abrasive blasting (Sa 2½ or Sa 2½+). The following conditions are represented: light fume by steel cutting, heavy fume by steel cutting, zinc salt, slightly heated, and fume by welding.

For undamaged shop primer with surface contamination, the visual standards show cleaning to recommended conditions using power tools (St 3, St 3+). The following conditions are represented: zinc salt, fume by welding, surface overdue for overcoating. For oil contamination, a photograph of “Other cleaning” to recommended condition is shown. The other cleaning appears to be some sort of solvent wipe.

The visual standard also contains a section on the repair of “Main Coating.” The Main Coating is the material which is applied over the retained PCP. This section contains photographs of various types of damage before and after cleaning using power tools to St 3 or St 3+. The following types of damage are represented: Burned, Fillet Weld, Mechanical spot damage.

Sigmaweld Secondary Surface Preparation Visual Standards – Sigma Coatings

Sigma Coatings produced a visual standard prior to being acquired by PPG Protective & Marine Coatings. The standard contains thirty photographs representing five levels of surface preparation for each of six surface types. Table 2 lists the surface types and levels of surface preparation which are represented by the standard.

Table 2 - Sigmaweld Visual Standard Conditions

Type of Surface	Level of Surface Preparation
<ul style="list-style-type: none"> • Weld seams, manually welded • Weld seams, automatic welded • Burned through areas • Corrosion, pin point • Corrosion, localized • Zinc salts (white rust) 	<ul style="list-style-type: none"> • Original condition • Power tool cleaned to remove zinc salts and loose foreign matter • Power tool cleaned to remove almost all corrosion product and foreign matter • Abrasive sweep blast • Abrasive blast to Sa 2½

Water Break Test for Inspecting Secondary Surface Preparation

Contaminants which may interfere with the wetting of the main coating (and subsequent adhesion) may not be visible to the naked eye. A water break inspection can be used to detect hydrophobic contaminants which may interfere with coating adhesion.

Water break refers to the appearance of a discontinuous film of water on a surface which signifies non-uniform wetting and is usually associated with a surface contamination. ASTM F22 - 02(2007) *Standard Test Method for Hydrophobic Surface Films by the Water-Break Test* describes a test method for control and evaluation of processes for the removal of hydrophobic (non-wetting) contaminants. When properly conducted, the test will enable detection of molecular layers of hydrophobic organic contaminants. On very rough or porous surfaces, the sensitivity of the test is decreased.

The test can be performed by simply observing the process water used for water washing PCP during secondary surface preparation. If the surface is inadequately cleaned, the spherical form of the drop is largely retained, and the surface must be cleaned once more. If the water runs on the treated surface, then wetting has been satisfactory and the part is suitable for coating. If the surface is being inspected after the process water has dried, simply spray the surface two to three times from at least 6" away with a spray bottle containing distilled water. Apply the above criteria to determine if the surface is suitable for painting.

TECHNOLOGY DEMONSTRATION

The process for retaining pre-construction primer was demonstrated on actual ships during ship repair (USS VICKSBURG) and new construction (T-AKE class). In addition, test panels were prepared to demonstrate the effectiveness of the water break test for identifying hydrophobic contaminants which may interfere with coating adhesion.

USS Vicksburg (Repair, Low Pressure Water Cleaning)

In May, 2008 the US Navy authorized a deviation from specification (DFS) to retain pre-construction primer (PCP) as part of the coating system that was installed on T-beams installed as part of a ShipAlt. The ShipAlt included installation of approximately 5,000 lineal feet of T-beams in the aft bank of fifteen fuel and JP-5 tanks. The test installation was carried out with the following process:

1. The plate shop produced a profile of > 2 mils and the profile was measured before PCP application on at least one stiffener going into each tank.
2. Environmental requirements of NAVSEA SI 009-32 were maintained from surface preparation through the application and cure of the PCP. Environmental reporting requirements were suspended after the coating cured and re-established prior to starting any secondary surface preparation on the stiffeners after they were installed in the tanks.
3. PCP DFT readings were measured and recorded on at least one stiffener going into each tank. Stiffeners were moved to the fabrication shop where they were worked before being transported to the ship for installation.
4. The installed stiffeners were cleaned using SSPC SP-1. The SP-1 process used water to remove chlorides from hand prints associated with the install.
5. The install welds were blasted to SSPC SP-10.
6. After cleaning and surface preparation, the stiffeners were inspected using a spray bottle and distilled water for a water-break. Three areas on one stiffener going into each tank (each area being a minimum of 1.5-inch in diameter) were sprayed with distilled water and examined for evidence of water beading or breaking on the surface. If the water beaded or broke, the entire stiffener was to be re-cleaned starting with the SSPC SP-1 process. However, on all beams the water uniformly wetted the surface. Excess water was wiped off the surface and the PCP surface was allowed to dry. This step was considered to be equivalent to the checkpoint for validating surface profile (i.e., a G point) in a standard abrasive-blasting-based coating evolution.
7. Interline 624, an ultra high solids epoxy meeting MIL-PRF-23236, Type VII was applied over the PCP as well as weld areas.

Figure 1 shows the primed shapes before they are cut for installation. Figure 2 shows the primed stiffeners cut to fit the specified areas of the ship. Figure 3 shows the stiffeners installed on the ship, ready for painting.



Figure 1. Shapes after being primed with 0.7 mils of PCP.



Figure 2. Stiffeners cut to fit from the primed shapes.



Figure 3. Installed stiffener with PCP surface and welds prepared for painting.

The project recognized a cost and schedule savings by not having to remove the PCP and install the UHS primer on the shapes prior to shipboard installation. However, meeting the requirements of 009-32 in the plate line significantly increased the cost of surface preparation and priming. This cost was largely driven by the need to have a formal checkpoint on one stiffener for each tank on the ship. A greater cost savings could be realized if the plate line process could be qualified and subjected to random surveillance. Part of the qualification process may include recording the data required by 009-32 at least once during each shift.

On February 12, 2010 two of the Vicksburg tanks were opened and inspected. After approximately 20 months in service, there was no visual evidence of delamination or other coating failure. Figure 4 shows the coating after 20 months of service.



Figure 4. Stiffeners with retained PCP after 20 months in service.

T-AKE (New Construction, Sweep Blasting)

The T-AKE is a dry cargo/ammunition ship designed to operate independently for extended periods at sea while providing underway replenishment services. The T-AKE will replace the aging T-AE ammunition ships and T-AFS combat stores ships that are nearing the end of their service lives. The ships are built in San Diego by General Dynamics National Steel and Shipbuilding Company. The lead ship, USNS Lewis and Clark was delivered to MSC June 20, 2006. The T-AKE program is expected to total 14 ships, with a total contract value of about \$5.2 billion. In February 2010, NASSCO received an \$825 million contract that provides full funding for T-AKE 13 and 14.

Pre-construction primer is retained in most areas of the T-AKE class ships, including all tanks except potable water and fuel. As part of this project, blasting and painting of modules for the T-AKE 10 was observed as well as the plate line operation.

Figure 5 shows a sheet of primed steel exiting a plate line. The plate line can handle steel plate in sizes up to 52 feet by 10 feet by 2 inches thick. The sheets are fed into an automated wheel blaster which

prepared the surface to a near-white metal with an angular 2-3 mil profile. After blasting, dust and abrasive is removed from the plate in a three-step process. First, a blade scrapes the majority of the shot from the plate. Then, roller brushes remove remaining shot and finally, an air knife removes dust and remaining particles. Following blasting, the primer is sprayed onto the sheet using a robotic sprayer such that the resulting DFT is approximately 0.5 mils. Once primed the steel is taken by conveyor to a cutting machine or storage area. Quality assurance is performed at the end of each shift by measuring the surface profile and primer thickness. Surface profile is measured using replica tape. Coating thickness is measured on a removable clear strip of plastic that is attached to the plate prior to entering the paint booth.



Figure 5. Primed steel exiting a plate line.

Once fabricated, secondary surface preparation include spot degreasing, brush blasting all surfaces to an SSPC SP-7 and abrasive blasting welds and damaged paint to an SSPC SP-10, Near White Metal condition. Inspection of the secondary surface preparation is visual. The surfaces are inspected by a representative of the ship owner, coating manufacturer and NASSCO. Once the secondary surface preparation is complete, a high solids epoxy coating system is applied to all surfaces.

According to NASSCO, for the first 9 ships of the class they did not have to perform warranty repairs on any surfaces where preconstruction primer was retained.

Inspection of Contaminated PCP

Most inspection criteria for PCP after secondary surface preparation are based on a visual inspection. A key condition is to have a surface free from visible greases and oils. Such materials might interfere with adhesion of the main coating system. NAVSEA has suggested enhancing the visual inspection with a water break test to be performed as required on suspect areas. A series of test panels was developed to

demonstrate the ability of various inspection techniques to detect the contaminants and the ability of simple cleaning techniques to remove them.

Twenty (20) 4-inch by 6-inch panels with pre-construction primer were provided by NASSCO for testing. The panels were cut from steel which had been primed on their plate line. The steel had an unknown yet brief exposure period in the NASSCO yard. Once the test panels were received, half of them were exposed at a marine exposure location with seawater spray applied to the panels each working day from a sprayer. The remaining half of the panels were stored inside during the same period. After approximately 2 months exposure, the weathered and unweathered panels were contaminated with each of the following four contaminants: marine grease, hydraulic fluid, motor oil, and synthetic motor oil. Figure 6 shows the test panels after contamination.

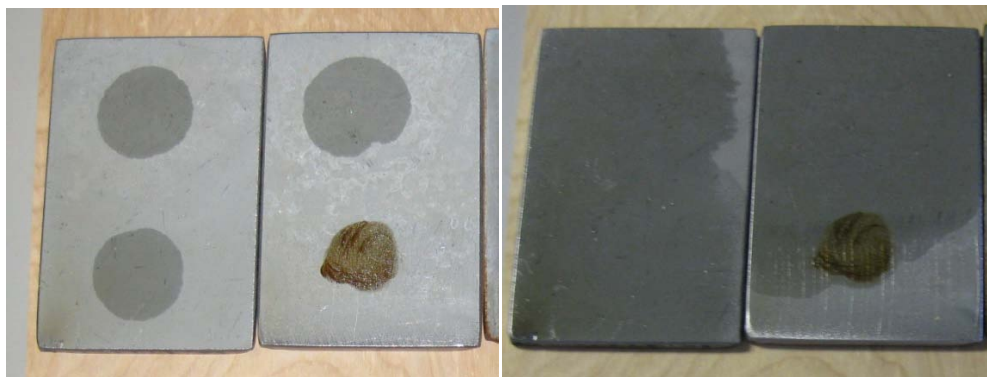


Figure 6. Representative test panels immediately after contamination (left) and one day later (right). Contaminants, clockwise from upper left: oil, hydraulic fluid, grease and synthetic motor oil.

Each of the contaminated panels was inspected using the following methods: blacklight, water break as described earlier and visual inspection by the naked eye in ambient light. After this inspection, panels were cleaned using one of the following four methods: abrasive blast, pressure wash, hose wash and solvent wipe. The panels were then cleaned with one of the following methods: Solvent Wipe with MEK, pressure wash at 2500 psi and brush blast using 16-40 grit black beauty. After cleaning the panels were again be inspected as above.

Figure 7 shows the panels after solvent cleaning. Note that the panels pass the water break test (left picture) but that some grease is perceptible under the black light. Figure 8 shows the panels after ~2500 psi pressure washing. Note that all of the areas except the grease passes the water break and black light inspection. Figure 9 shows a similar set of test panels after the hose wash. While only the grease is evident under black light, the water break shows evidence of the grease and both oils.

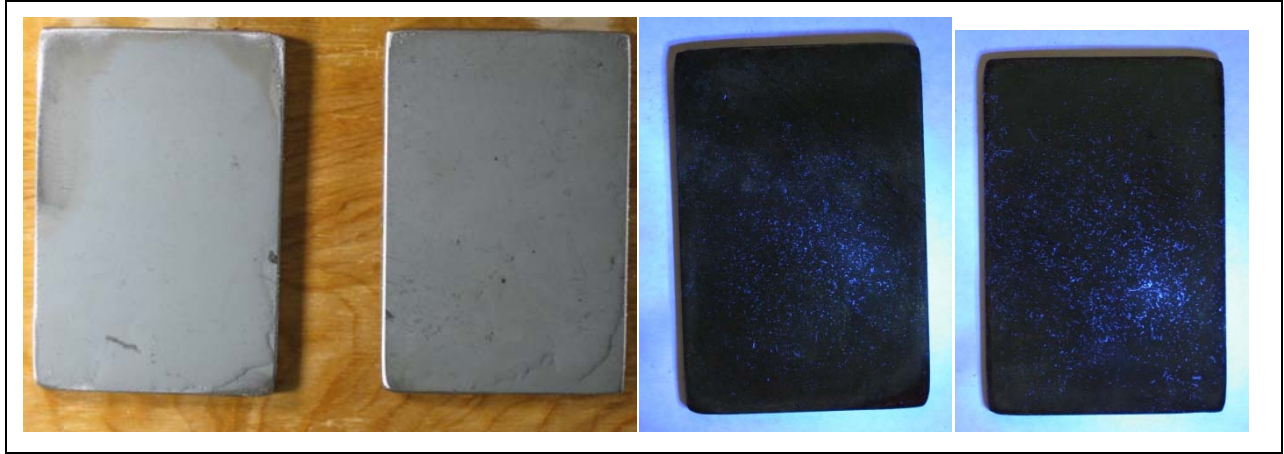


Figure 7. Representative Test Panels after Solvent Cleaning.



Figure 8. Representative Test Panels after 2500 psi pressure wash.



Figure 9. Representative Test panels after Hose Washing.

After the cleaning was complete, one coat of Sherwin Williams NovaPlate UHS was applied to the test panels using a roller. After curing, the pull-off adhesion of the coating was measured in general

accordance with ASTM D 4541. Figure 10 shows the test results. The adhesion data are consistent with the observations from the water break test in the previous figures. Note that the surfaces prepared with the hose wash all had low adhesion except for the hydraulic fluid which easily passed the water break test.

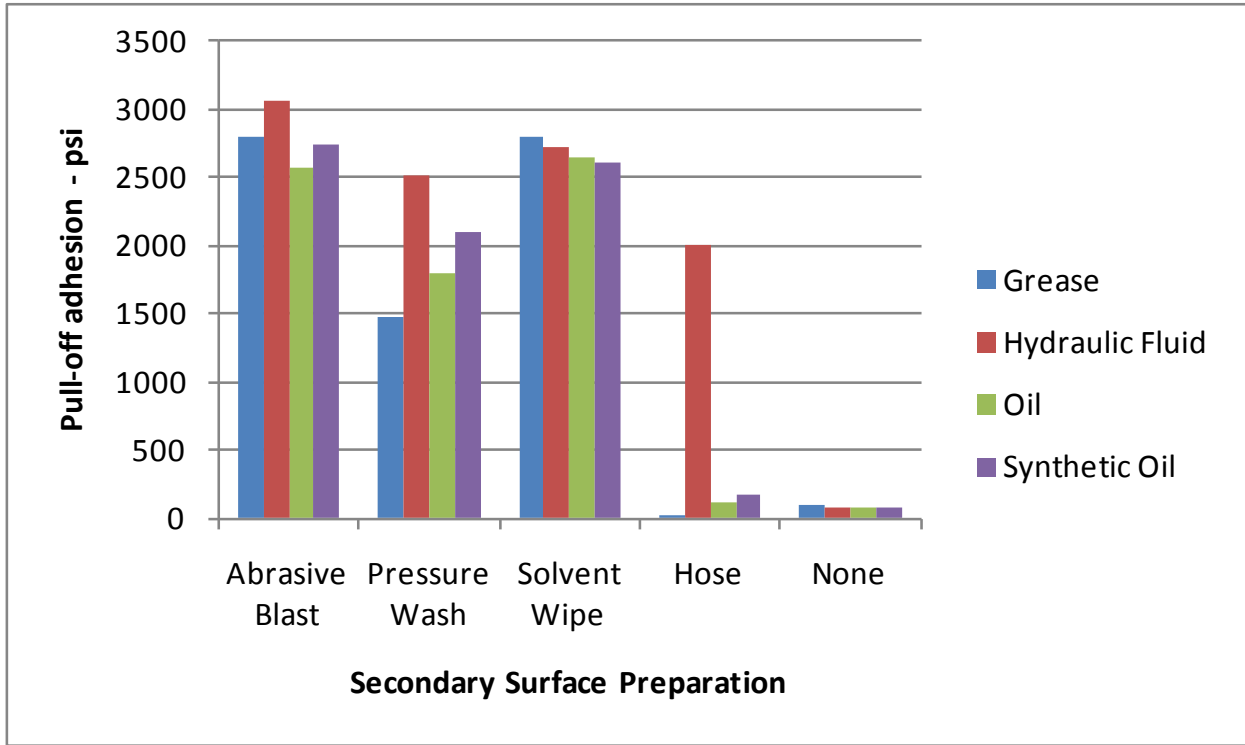


Figure 10. Average pull-off adhesion.

Implementation

SI009-32 change

As a direct result of this project, the Navy Standard Item 009-32 was changed to allow retention of PCP. This change was approved at the July, 2010 meeting of the NAVSEA Standard Specification for Ship Repair and Alteration Committee (SSRAC). This change will officially be effective in the FY2012 version of the standard. However, it may be used on individual projects before the effective date of the standard item if agreed to by the shipyard and Navy. Following are the changed paragraphs based on the meeting and subsequent revisions by the NAVSEA Technical Warrant Holder.

3.1.5 For surface ships, pre-construction primer may be retained and overcoated with applicable coating systems specified in Tables One through 5, with the exception of potable water, reserve feedwater, and freshwater drain collecting tanks, nonskid applications (MIL-PRF-24667), and single coat applications (MIL-PRF-23236 Type VII Class 18/x), if the pre-construction primer application process meets the following:

3.1.5.1 The pre-construction primer shall be a zinc silicate material. Compatibility with the coating systems specified in Tables One through 5 shall be confirmed by the coating manufacturer.

(I) "PROCESS INSPECTION" (See 4.4)

3.1.5.2 The pre-construction primer shall be applied in a process which is certified to ISO 9001, SSPC-QP 1, or SSPC-QP 3. The process shall be verified to meet the technical requirements of 3.10.2, 3.10.6/3.11.3, and 3.10.7 a minimum of once per shift.

3.1.5.3 The relative humidity requirement of 3.10.2 shall be 85 percent.

3.1.5.4 The secondary surface preparation, once the steel is installed shipboard, shall be accomplished as follows: Brush-off blast the surface to SSPC-SP 7 to remove contaminants and loose paint. For fuel-related tanks a thorough pressure wash of the area with fresh water at 3,000 to 5,000 PSI may be substituted for the brush-off blast to SSPC-SP 7. Upon completion, the surface shall meet the requirements of SSPC-SP 1 of 2.5. A visual water break test (ASTM F-22) on the surface may be used to validate SSPC-SP 1

Note that a brush off blast is required for all applications other than fuel-related tanks. Also note that pre-construction primer cannot be retained in single coat applications (MIL-PRF-23236 Type VII Class 18/x). There was reluctance by the coating manufacturers and the Navy to allow pressure washing as the secondary surface preparation until compatibility has been demonstrated, especially with the recently approved Ultra high solids, quick cure coatings.

Potential Cost Savings

The following analysis is one approach to determining what savings may result by allowing pre-construction primer to be retained on certain surfaces of ships where it must currently be removed. The analysis considers ship repair separately from new build. The analysis suggests a potential cost savings to the US Navy in excess of \$7 million per year. While this is believed to be a reasonable order of

magnitude estimate, it is important to recognize certain assumptions which are most critical to the analysis. Specifically, the quantity of steel replaced in Navy ships and the projected ship build rate could impact this analysis.

Cost Savings during Ship Repair

To arrive at a cost savings for repair performed on US Navy ships, two calculations were performed. First, the potential savings was approached from a process perspective. For this analysis we'll make the following assumptions:

- 120,000 square feet of primed steel is installed in Navy ships each year
- Half of the steel is brush blasted which is twice as productive as a near white metal blast
- Half of the steel is water washed which is eight times as productive as near white metal blast
- The base cost of near white metal blast surface preparation is \$5.00 per square foot
- Steel is installed in 24 “batches” averaging 5,000 square feet; each of which requires 168 QA hours for the primer, 125 of which could be eliminated.

Table 3 shows the calculations from these assumptions. The total estimated savings slightly over \$500,000.

Table 3 - PCP Savings during Ship Repair

Item	Assumption	Annual Savings
Plate line QA savings		
QA hours	3,000	
QA rate	\$ 50.00	\$ 150,000
Brush Blast savings		
Normal SP-10 productivity (SF/hr)	100	
Brush Blast productivity (SF/hr)	200	
Total SF processed per year	60,000	
Unit Cost per square foot to SP-10	\$ 5.00	\$ 150,000
Water rinse savings		
Normal SP-10 productivity (SF/hr)	100	
Water wash productivity (SF/hr)	800	
Total SF processed per year	60,000	
Unit Cost per square foot to SP-10	\$ 5.00	\$ 262,500
Total Savings		\$ 562,500

Commercial benchmarks were consulted to validate the assumed square footage of steel requiring replacement. According to ABS, on oil tankers they replace (max) 1.7% of the total steel in the 3rd or 4th special survey (special survey 3 is performed between ship age 10-15 years, special survey 4 is performed at ship age greater than 15 years). On a VLCC, the estimate is closer to 1% of the total weight. Thus, ABS data suggests that sometime after 10 years of life 1% to 1.7% of the steel is replaced. For this analysis, assume that 280 ships each with 1 million square feet of painted steel are in the Navy fleet. If

1% of that surface required repainting every 15 years, then 0.067% of the surface would be painted each year on average. At a savings of \$5.00 per square foot, this equates to just under \$1 million per year. Table 4 summarizes the calculations.

Table 4 - Estimated Cost Savings during Repair

Number of applicable Navy ships & submarines	280
Average painted square feet per ship	1,000,000
1% of the painted surface area is replaced every 15 years (square feet)	2,800,000
Average surface area of steel replacement per year (square feet)	186,667
Average savings per square foot by allowing PCP retention during repair	\$5.00
Annual savings potential	\$ 933,333

The two analyses suggest a potential annual savings between \$500,000 and \$1,000,000 per year for Navy ship repair. Obviously a key contributor to the estimate is the assumed quantity of steel repair which would be affected by the change. Refining this number is beyond the scope of this project, but it is believed to be a reasonable first estimate.

Cost Savings during New Build

The overall cost savings associated with retaining Pre-construction primer must consider new build projects as well as repair. Table 5 shows one assessment of the potential savings. The savings come from (1) reduced QA effort as a result of the plate line process and (2) reduction in the cost of secondary surface preparation. For this calculation, we assumed that 650,000 square feet of steel on a new build would have otherwise had pre-construction primer removed. It is assumed that QA on the plate line will be reduced by 4,000 hours. It is also assumed that the secondary surface preparation is \$0.75 per square foot less expensive than a near white metal blast. As the table shows, the overall cost savings is slightly under \$700,00 per ship. At the presently projected build rate of 10 ships per year,¹⁰ the total savings to the Navy could exceed \$6 million per year.

¹⁰ Congressional Research Service report 7-5700, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*.

Table 5 - Potential Cost Savings for New Build

Plate line QA savings		
QA hours (~ 6 hrs per 1,000 sq ft)	4,000	
QA hourly rate	\$ 50.00	\$ 200,000
Secondary surface prep savings		
Square feet of PCP retained	650,000	
Savings per SF (brush blast vs SP-10)	\$ 0.75	\$ 487,500
Total Savings per ship		\$ 687,500

It is important to recognize that the above projected savings are from a baseline that would include the practice of priming steel before fabrication and performing a near white metal blast before installing the new coating system. This baseline is not appropriate for all ship surfaces; current practice allows the pre-construction primer to be retained on certain non-critical surfaces such as interior spaces. Hence the assumed surface area would be only those portions of the ship where the primer would otherwise have to be removed.

As a point of comparison, one author presented a cost analysis which suggests an average savings of approximately \$2.00 per square foot.¹¹ This is approximately twice the unit cost that is presented in the above analysis. In addition to the cost savings, there author identifies schedule and logistical impacts shown in the following table. The duration of surface preparation may be cut in half and the abrasive consumption (plus associated logistics of moving the material) can be substantially reduced.

Item	PCP Removal	PCP Retention
Schedule (10 Abrasive Blasters)	8 weeks	4 weeks
Man-hours	3000	1725
Compressed Air Requirement	3500 CFM	3500CFM
Number of Crane Lifts	84	49
Tons of Abrasive	3375	1940

¹¹ Benjamin S. Fultz, Preconstruction Priming: A Cost-Effective Solution to Painting Ship Ballast Tanks, Journal of Ship Production, Volume 20, Number 2, May 2004 , pp. 122-129(8); Society of Naval Architects and Marine Engineers (SNAME).

Conclusions and Recommendations

1. Past studies and the present work conclusively demonstrate that pre-construction primer can be retained without impacting coating performance.
2. Suitable wording has been developed for insertion to Navy Standard Item 009-32 to allow pre-construction primer retention during Navy ship repair. The Navy should attempt to validate the cost savings resulting from the change.
3. Concern remains regarding the performance of single coat rapid cure coatings applied over pre-construction primer. These materials are relatively new and were developed specifically for the Navy which, heretofore did not allow pre-construction primer retention. As a result, no test data exists on single coat rapid cure coatings over pre-construction primer. Since they are becoming the standard tank coating for the Navy, requiring pre-construction primer removal under single coat rapid cure coatings will impact the cost savings recognized. The performance of single coat rapid cure coatings applied over pre-construction primer should be evaluated.
4. There has been some concern that pressure washing may be inadequate secondary surface preparation for the high solids coatings described in MIL-PRF-23236, Type VII. Requiring brush blasting for all Type VII coatings (i.e., without some further distinction as defined by the coating application tables of 009-32) precludes some of the potential cost savings. The USS VICKSBURG T &E work completed and inspected showed acceptable performance of at least one MIL-PRF-23236, Type VII (International Paint Interline 624 Ultra High Solids coating over a pressure washed surface. Additionally the paint manufacturers regularly approve the application of many of their commercially available coatings that meet the MIL-PRF-23236 requirements to be applied over the pressure washed surface.
5. Language similar to that developed for Navy Standard Item 009-32 should be incorporated into NSTM Chapter 631, the ABS Guide for Building and Classing Naval Vessels (aka "Naval Vessel Rules" [NVR]) and other documents which may impact Navy shipbuilding.