A Study on Retaining Preconstruction Primers Under Standard Lining Systems for Ship Tanks

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Europe leads the world in the development of new, high-performance, immersion-grade marine coating systems. Asia and the Pacific Basin are believed to be more advanced in process and equipment development but not as advanced in new coatings development. Process and equipment improvements can reduce worker hours, whereas high-performance coating systems can increase initial costs but provide good long-range performance.

In the USA, development of new, high-performance marine coating systems has been stalled. With most newbuilds being Navy ships, which require the use of military specification coating systems, there has been little commercial incentive to develop new coatings technology, especially for ballast tanks. However, the U.S. Navy is now investigating and qualifying European coating systems for ballast tanks.

One aspect of European marine coatings work being carefully studied in the USA is the practice of retaining the preconstruction primer (PCP) on ballast tanks, fuel oil tanks, and other immersion areas as the permanent primer.

The economic benefit of this practice is that new construction money need not be spent to remove the PCP—typically used as a temporary coating to protect steel from corrosion during weld-
ing, storage, and fabrication—before application of a high-performance coating system.

A research project sponsored by MARITECH/ASE, formerly the National Shipbuilding Research Program (NSRP), Panel SP-3, Surface Preparation and Coatings, is currently studying this issue.

As part of the project, which began in late 1997, a survey was conducted of PCP practices in Europe based on input from coating manufacturers, shipyards, and a research institute. Product testing of various PCP and topcoat combinations began in December 1998. It is expected to last five years.

While retaining the PCP on ship newbuilds is common in Europe, the background information and the results of this study should still be of interest on both sides of the Atlantic.

This article presents an overview of information from the initial investigation for the research project, including the history of PCPs (primarily from the American perspective), European PCP selection criteria, process controls for dry film thickness, topcoat selection criteria, secondary surface preparation, and qualification testing. A summary of the findings from the survey of European shipyards and coating manufacturers also is presented, beginning on p. 38.

**History**

In the 1960s, many American shipyards routinely applied PCP to stock plates and shapes using automatic priming equipment after abrasive blasting. These materials were either proprietary organic coatings or military specification materials. This technique was cost-effective and complemented the shipyard manufacturing methodology. At the discretion of the chief welding engineer, the primer was generally removed for automatic welding processes but normally welded through for stick electrode welding processes.

The PCP—sometimes referred to as a prefabrication primer or shop primer—was only removed from other areas to apply specified coating systems known to be incompatible with the primer. This was the practice in American shipyards into the early 1970s.

Many tank coating systems could be applied over the PCP after using hand tools to repair burned and mechanically cleaned areas. This system worked fairly well as long as the same paint manufacturer supplied both the primer and the tank coating system.

While epoxy primers offered good recoatability for epoxy tank linings, some catastrophic failures resulted from applying epoxy tank
linings over primers based on alkyd or epoxy ester formulations. Standard zinc load (80–85%) inorganic zinc PCPs were used in an attempt to reduce primer failure during the manufacturing cycle. However, applying epoxy tank linings and other immersion-grade coatings over these standard inorganic zinc primers achieved mixed results. Sometimes this approach worked, but many times premature coating failures resulted.

In 1985, the NSRP Panel SP-3

Findings and Conclusions of European Survey on PCP Practices

As part of the MARITECH/ASE research project on retaining rather than removing preconstruction primers from ballast tanks and other immersion areas of ships before application of the full coating system, the author was involved in a survey of standard practices in Europe.

Consequently, in May 1998, he visited five marine coatings manufacturers (International Coatings Ltd., UK; Ameron International, The Netherlands; Sigma Coatings, The Netherlands; Hempel’s Marine Paints, Denmark; and Jotun Paints, Norway); as well as three shipyards (YVC Ysselwerf B.V., The Netherlands; Odense Steel Ship Yard, Denmark; and Howaldtswerke-Deutschse Werft AG, Germany); and one testing institute (MARINTEK, Norway).

Following is a summary of his general observations and information on various aspects of marine coating work that he collected for the study as a result of those visits. (It should be noted that the comments here are limited to the practices found at the places surveyed, and, therefore, they are not necessarily the same throughout Europe.)

General Observations

- None of the shipyards completely remove the low zinc/low alkyl silicate PCP unless contractually required by an owner, nor do any of the coating manufacturers recommend removal.

PCP removal is treated as an extra process.
- The PCP is selected based on shipyard construction parameters for corrosion protection, weld type and speed, etc.
- The PCP is topcoated with a coating system that is qualified by the coating companies for use over the PCP.
- Primed steel is either purchased from French or Swedish steel companies or coated in-house. The PCP is applied in a controlled process with statistical process control (SPC) methodology.
- The minimum PCP thickness is determined based on corrosion prevention performance, and the maximum thickness is based on the cohesion properties of the PCP.
- Primary surface preparation of the steel in the automated abrasive line uses either shot or a shot/grit mix. The process is monitored using SPC techniques. There is a clear understanding of the relationship between profile depth and the required DFT.
- The profile of the steel is measured using replica tape, a profile meter, or a surface profile comparator.
- The PCP-primed steel is colour-coded to distinguish steel types.
- The PCP is welded through or removed before welding based on the shipyard’s construction practice. None of the three shipyards weld through the PCP 100% of the time.
- The PCP (and follow-on coats) are supplied to the shipyards in reusable containers. The PCP is always applied with airless spray equipment.
formulated a test programme (NSRP Report 0248) to determine compatibility of inorganic zinc primers topcoated with epoxy coatings in immersion service. The results were inconclusive. Some systems had good performance, while others failed. No correlation was established between zinc loading and early failure.

The Japanese have used modified organic metallic zinc-containing primers. The zinc loading in these primers is much reduced compared to inorganic zinc primers and probably encapsulates the zinc pigment in an organic matrix. With the progress in paint formulation, some of the present generation zinc-rich PCPs, which contain about half the zinc loading as the standard formulations, might be successfully topcoated with immersion-grade epoxy tank linings.

As welding speeds increased, some yards switched from pre-

• The thickness of the PCP is measured using both glass panel and smooth steel strip techniques. Two of the coating manufacturers recommend use of smooth steel strips, which allow for the estimation of DFT when coating structural shapes (profiles).
• One of the shipyards performs qualification tests for coatings to ensure compatibility with its construction processes.
• Each shipyard and coating manufacturer has a high degree of understanding of process control. All of the companies have a clear understanding of the need to identify and control PCP application, welding, and coating processes.
• German shipbuilders have joined forces and developed industry-specific standards for many procedures.
• There is a general agreement among coating suppliers that PCPs and coating systems can be interchanged among coating manufacturers. The PCP is considered just another substrate over which coating systems can be successfully applied.
• Selection of the PCP is based on a.) required corrosion protection to match shipyard processes, b.) welding/burning qualifications and speeds, and c.) the ability to develop and control construction processes.

Secondary Surface Preparation
• Weld seams and any physically damaged PCP are blasted to Sa 2½ (except one yard uses power tools—i.e., sanding discs, nonloading rotary discs, and wire brushes—to clean welds made after a ship is in its final configuration).
• Two of the yards have large combination blasting and painting halls with the ability to apply finish coatings to tanks and exterior topsides and underwater hull coatings through the first coat of antifouling.
• The PCP is sweep-blasted before coating, but 50–70% of the PCP is retained. Expendable and reusable grit are used for the sweep-blasting.
• Waterjetting in ballast tanks and confined areas is prohibited at one of the yards because of difficulty in removing moisture from the tanks before coating.

Edge Preparation

No consistency was found in either the need to have cut edges of steel rounded or the method used to round the cut edges. Single and double chamfering, radiusing, or a simple pass with a sander are used. One of the yards is developing a special power tool to radius both edges at one time. In most cases, extruded edges are not radiused but left as manufactured.

Stripe Coating

All of the shipyards stripe coat, and all of the coating manufacturers have procedures for stripe coating that include using contrasting colours. The sequence of stripe coating varies, but all recommend that the first stripe coat be applied after the first coat. Otherwise, the adjacent steel surfaces might become contaminated during the stripe coating process (i.e., by workers touching the bare steel with greasy hands, etc.). It was noted that stripe coating should always be done with a brush and not a roller.

Surface Contamination

Only one yard takes surface contamination readings before coating application, and this is done only for sections delivered via barge from other fabrication sites.

Topcoating

• Topcoats from various coating manufacturers are applied
priming before fabrication to applying the primer in the block stages. (Blasting was also done in the block stages.) At this point, some American yards used PCPs but began the practice of totally removing them before applying inorganic zinc primers and epoxy tank coatings either on blocks or after final erection. Many times, applying Navy-specified coating systems required the complete removal of any PCP before application of inorganic zinc primers. 

This further caused American yards to reduce the use and retention of PCPs in high-performance areas. While yards in the USA were switching from prefabrication priming to block priming, Japanese and other Asian yards and many European yards still used prefabrication primer techniques. Once the primer was applied, it was not removed except when the owner was willing to pay a premium in cost and/or schedule.

Today, the trend in the USA is to return to automatic PCP application, especially in the re-emerging commercial shipbuilding market. The introduction of primers that reportedly can be welded through without detrimental effect increases the attractiveness of this approach. Preconstruction priming is far less expensive than open abrasive blasting and priming on blocks, especially in light of the negative impact of environmental regulations on open blasting.

Findings and Conclusions of European Survey on PCP Practices

over the PCP without regard to the manufacturer of the PCP.
- All topcoats are measured for DFT.
- All topcoats used in ballast tanks are light in colour, based on recommendations by certification/standards agencies. Therefore, use of coal tar epoxies has effectively been discontinued.
- In accordance with recent International Maritime Organization regulations on coating ballast tanks, soft and semi-hard coatings are no longer being applied.
- The number of coats used to meet the specified DFT varies from one to three, depending on the customer.
- 100% solids epoxy tank coatings are not universally used. Some yards use lower solids tank coatings, but all coatings meet local air quality requirements.

Cathodic Protection
- One yard sees no benefit in installing anodes in new construction; another believes it is necessary to install anodes in new construction to evaluate the coating at the initial survey.
- Some coating manufacturers have done extensive cathodic disbondment testing with or without the PCP. The presence of the PCP did not degrade the test results.
- No impressed current cathodic protection systems are used in tanks.

Coatings Materials
- All yards use epoxy tank coatings; however, in the past, some have used full thickness inorganic zinc with success.
- All PCPs are solvent-borne. All paint manufacturers recommend 50% zinc by weight in the DFT to provide necessary protection. One yard is using a 75% zinc coating.

Performance of Coatings
- Two shipyards have tracked performance over an extended period. Coating system performance over the retained PCP has been at least as good as where coatings were applied directly over blast-cleaned steel. No difference in performance has been noted when the PCP is retained.
- At least two of the coating manufacturers have developed a computer database to track coating performance as vessels are surveyed.

Welding
- Submerged arc welding, gas metal arc welding, and flux-cored arc welding are used in the construction processes.
- Two of the yards make extensive use of robotic welding because of its accuracy control.
- One yard has small abrasive blasters installed on robotic welding lines that remove the PCP immediately prior to welding.
- Burn-through and heat-affected PCP are negligible, thereby significantly reducing weld clean-up.
- In all cases, the shipyards are concerned about the health effects of a high zinc-loaded PCP. This concern is expressed by using less zinc in the PCP when possible and providing workers with coveralls that are washed on site.
PCP Selection Criteria

Shop-applied PCPs should be compatible with the manufacturing philosophy. High-performance coating systems selected should be compatible with the PCP to include necessary secondary surface preparation. The steel coated with the PCP should be considered as any other substrate that requires coating.

To reduce total installed costs, PCP selection cannot be driven just by performance of the primer as an undercoat for a high-performance coating system. Instead, PCP selection should be driven primarily by process considerations, including the following criteria:

- protection of the steel substrate during fabrication;
- effect on burning speeds;
- effect on welding speeds, processes, and quality;
- burn-back;
- health and safety considerations;
- effect on the workplace environment from the use of light-colour coatings;
- ability of the PCP to form a film at reduced film thickness;
- suitability for application in automated facilities; and
- performance as the primer in a high-performance coating system.

The PCP formulation determines both long-term corrosion protection and impact on fabrication processes. For example, zinc loading affects corrosion protection. The higher the zinc content, the better the corrosion protection during fabrication. However, the higher the zinc load, the lower the cutting and burning speeds. Health hazards are also increased with high zinc content. Worker exposure and zinc oxide formation (during cutting and burning) become issues. Several coating manufacturers have overcome these challenges and have formulated acceptable materials.

Process Controls for Dry Film Thickness

One of the most important process controls for the use of PCPs is dry film thickness (DFT). For proper performance during cutting and welding, the DFT must be controlled within a very narrow range, such as 12–25 μm. Balanced against this need for low thickness during fabrication is the need to provide corrosion protection during fabrication and erection up to the time that high-performance topcoats can be applied.

One PCP manufacturer reports a reduction in welding speeds of ~9% with a variance in DFT from 12–20 μm. In other words, an increase of 8 μm in thickness reduced the cutting speed from 660 mm per minute to 600 mm per minute. Likewise, in another example, welding speeds for double fillet flux-cored arc welding went from 500 mm per minute down to 460 mm per minute with essentially the same variance in film thickness.

Since DFT is a critical control parameter, how can it be assured that the correct thickness has been achieved?

In Europe, there has been no uniform method of measuring film thickness on blast-cleaned steel. However, the latest version of ISO 2808, Paints and Varnishes—Determination of Film Thickness, includes a standard method for measuring dry film thickness. In addition, a CEN standard on this topic is being prepared.

In the USA, SSPC-PA 2, Measurement of Dry Paint Thickness with Magnetic Gages, includes a generally accepted practice for measuring DFT. This procedure requires that the profile of the prepared substrate be measured using the same instrument used to measure the applied DFT.

Examples of the size distribution of the measured profile and the DFT of an applied PCP are given in Figures 1–6, which are based on the measurement method in SSPC-PA 2. Figures 1 and 3 are graphs of actual measurements using a fixed-probe gauge over bare blast-cleaned steel (Fig. 1) and the same steel coated with a PCP (Fig. 3). Figure 5 combines both sets of raw measurements. As can be seen, the size distribution for profile and DFT overlap. Figures 2 and 4 are graphs of these same measurements sorted by size. Figure 6 is a combination of these profile and DFT sorts. In this graph, a difference between profile and DFT can be distinguished. This difference approximately equals the difference between mean values of the two measurement sets.

Assuming the measuring device has a 10% margin of accuracy, the actual thickness of the applied PCP cannot be readily determined, even though a difference between the mean value of profile and the mean value of measured DFT can be demonstrated. This result presents a challenge to develop a new method of measuring the DFT of thinly applied coatings over the rough surface topography of blast-cleaned steel.
Topcoat Selection Criteria

In the USA, most high-performance immersion-grade coating and lining systems are recommended for use over bare steel substrates prepared by abrasive blast cleaning. In Europe and Asia, it is common practice to retain and coat the PCP. It essentially is just another substrate to coat.

The selection criteria for topcoats to be applied over retained PCP should be essentially the same as the procedure normally followed when selecting any immersion-grade coating material, with one major exception.

Exposure conditions, temperature, cycling, ease of use, and health and safety aspects are all important. However, for a coating system formulated for application over a PCP, there should be objective evidence either in the form of service history or actual marine immersion exposure history that it will perform satisfactorily over the PCP.

Dry film thickness control of the PCP again becomes important. The internal tensile strength of an alkyl-silicate zinc-rich PCP is much weaker than for most high-performance epoxy topcoats. This characteristic or limitation is amplified as the DFT increases. The wetting ability of the epoxy and the degree of shrinkage during cure are other important attributes.

The important point is to select a coating system formulated to be applied over the PCP. In Europe, several coating suppliers have cross-qualified coating systems.
using PCPs from different suppliers. This practice has been necessary because many of the shipyards purchase PCP-primed steel plates directly from the steel supplier.

Secondary Surface Preparation

Any surface preparation performed after the initial abrasive blast cleaning and PCP application is called secondary surface preparation. It can vary from complete removal of the PCP to extensive use of hand and power tool cleaning. The general practice in Europe is to clean welded and mechanically damaged areas with power tools. Blast cleaning for secondary surface preparation is used in only a few shipyards.

Because of the harsh winters in
parts of Europe, pre-erection assemblies (large block units) are processed inside large, environmentally controlled paint halls.

A stripe coat is generally applied by brush to all sharp edges, welds, and cut-outs after application of the first coat of the lining system. The stripe coat is not applied first because of the potential for flash rusting and recontamination of the adjacent blast-cleaned flat areas during stripe coat application and cure.

Following assembly of the main ship configuration, major erection welds are power tool cleaned to bright metal using composition wheels and sanding discs to re-establish surface roughness.

Qualification Testing
Qualification testing, in lieu of long-term service histories in similar service conditions, is used by European coating manufacturers to establish confidence in the material selection process.

There are two general types of proof testing of coating and lining systems. One is laboratory immersion testing using techniques such as NACE TM 01-74, Laboratory Methods for Evaluation of Protective Coatings Used as Lining Materials in Immersion Service. The second is to perform mock-up testing using simulated conditions.

While neither of these approaches exactly duplicates service conditions, both can provide valuable performance data, especially the mock-up testing technique. In the MARITECH/ASE test, mock-up ballast tanks are being used to compare and verify performance.

In Europe, many shipyards, coating suppliers, ship owners, and regulatory agencies recognise the value of mock-up testing. MARINTEK, a marine research centre in Sandefjord, Norway, has developed a test protocol using mock-up ballast tanks. It has been used to test and qualify numerous European coating and lining systems for use over various PCPs. In fact, early in the programme, many of the coatings were qualified over a generic PCP.

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