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The Future of Ship Painting, Part II

Specs, Standards, Inspections and More

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For anyone in the coatings industry, the criticality of protecting marine vessels from corrosion has been made clear over the years and in the pages of JPCL. In an effort to improve ship coating processes moving into the future, a November 2020 JPCL article discussed the influence various parties have on these processes and how the design of a vessel can affect the work, identifying areas where change is needed. This second part of that covers the coating specifications, standards, inspection methods and products in use today, and what will be necessary in the future.

COATING SPECIFICATIONS

Specifications Today

Many coating specifications in use today have been "grandfathered" in—that is, they have been in use by a company for many years and have never been updated to reflect in-service experience and/or any technological developments.

The current approach to coating specifications is often inadequate. At newbuilding, shipyards use standard specs based on their relationship with their paint supplier and the price of the package offered instead of tailoring the specs to suit their own production preferences.

At maintenance, the usual solution is simply to repair and maintain the newbuilding coating system with the same products that were originally supplied, or the equivalent as recommended by the coating company in the event of a change of supplier. This raises a range of potential problems. For example, if the vessel is built in Asia in the summer and then enters service and/or dry-docks in colder climates, it is possible that the generic newbuild specification may no longer be suitable, as surface preparation would be inferior and application may be by brush and roller as opposed to airless spray. Consequently, there is a great risk in simply adopting the newbuild specification as the standard Maintenance and Repair specification.

In general, when a specification is provided, it usually divides the vessel into 8–10 key areas including the underwater hull, decks, tanks and holds, and the superstructure. It is prescriptive, and it will usually define:

- The total area to be coated (in square feet/meters);
- The product type, and possibly either mention a specific brand or provide a description that tends toward the selection from a limited range of available products; and

- The number of coats of the product to be applied and the nominal dry film thickness, or, in some cases, a minimum/maximum range.

It will then refer to the relevant technical data sheets to enable further details regarding surface preparation and application requirements to be obtained. What it does not generally include is any reference to any specific application guides or procedures that may or may not be available.

However, the main problem hinges around the reference to the technical data sheets. On nearly all technical data sheets there is a stipulation that indicates that the data included in it is a guideline, i.e. it is indicative. The implication is that the exact requirements will vary based on the project type and specific needs. As a result, the requirements on the data sheet are open to interpretation to some extent.

Specifications Tomorrow

The initial change in ship coating specifications is already taking place, as generic specifications are more frequently substituted by functional (goal-based) specifications, and the specification aspect is separated from the product selection aspect. Where functional specifications have been fully deployed on newbuild vessel and repair projects in recent years, significant cost savings have been made in the range of 10–30% against the original budget and scheme selection.[1] Furthermore, through-life needs have been assessed and evaluated to understand how maintenance and repair will be carried out by also considering alternative solutions for these based on planned periods of ownership and operational requirements.

The functional approach breaks down specification into three distinct phases:

- **The Specification:** Understanding the needs of the project through-life area by area, prioritizing the key areas and their required functions, and defining target values for the functions (i.e., life expectancy). The specification does not include the number of coats or type of product or brand, nor does it include dry film thickness. The paint supplier is therefore required to develop a project-specific scheme from its own range of products. The functional specification does, however, include the known application and operational limitations—for example, to be applied in China during winter months.

- **Product Selection:** Based on the functional requirements, a template is issued for tender and paint suppliers are required to match the demands of the functional specification. Each proposed scheme can then be assessed against the required demands, allowing for a best fit to be selected. The benefit of this approach is that while there is unlikely to be a solution that matches 100% of the functional needs, the areas of weakness—and hence, risk—are identified and can therefore be properly assessed in selecting the options. This generates a very transparent product selection regime that is divorced from cost considerations for the paint itself. Once the best technical fits are identified, the costs can be assessed against the perceived added value to the project at newbuild and through-life. While this approach can be resource-demanding for the first project, once the structure is set up, it is not only repeatable, but creates a platform for building knowledge that can inform future decisions.

- **Risk Assessment:** Developing a specification in this manner allows for risks to be assessed and quantification of the impact of any compromises to be made. It also provides a clear link between the needs of the construction process and the in-service performance requirements. Increasingly, specifications will have to also consider interactions with other on-board systems.

COATING STANDARDS

Standards Of Today

Any generic paint specification can list between 10 and 20 standards from different organizations such as ISO, SSPC, NACE and IMO, plus some shipyard- or shipowner-specific standards and the paint manufacturers' guidelines and recommendations.

Usually, little attention is paid to standards until something goes wrong, at which point these serve as a reference for how the project should have been carried out. In marine work, most standards are inadequate as they are generally developed by a committee that could represent a range of industries with different requirements. As a result, the final output is a compromise.

Also, the lack of applicability of many standards poses a problem, as do dedicated standards such as the IMO PSPC, which is the result of a negotiation rather than a technical assessment of the situation. For example, coatings can be tested on clean steel coated in laboratory conditions and then approved for real-life application on a salt-contaminated surface.

Standards Of Tomorrow

There is a real need to "marinize" coating standards to make them suitable for these mega-structures and to ensure their technical integrity. There is a lack of a standard body that produces a uniform and comprehensive set of standards for this market, and the consequence is that many disputes arise from conflicting standards that may even be referenced in the same document.[2]

The future requires a uniform set of standards agreed upon across the industry to produce a consistency in approach and to combine the theoretical and practical needs of marine mega-structures.

COATING PRODUCTS

At present, the dominant solutions in the marine market are liquid-based coatings of various limited chemistries (epoxy, alkyd, urethane and copolymer-based systems) that have their origins in technologies developed in the 1960s and 1970s.

Despite attempts to grow the concept of bulk supply, marine paint is overwhelmingly delivered in 5-, 10- and 20-liter cans that contribute to the high waste stream generated by the coating process, both at newbuild and repair. Hence, there is an urgent need for a paradigm shift in how vessels are protected from structural corrosion and fouling, and how cargoes are protected from contamination.

Product Selection Today

Over the last 20 years, there has been an increase in coating manufacturing capacity. This, together with a desire to increase efficiency of the manufacturing and distribution process of coatings for the marine market, has resulted in increased rationalization and a focus on reduction of stock-keeping units (SKUs). This has forced paint suppliers to consolidate their offerings/product range. As a result, newbuild and maintenance and repair products were merged, eliminating aspects of the ranges, and together with a push from shipyards in pursuit of the concept of a universal primer that could be overcoated by any given range of products from either the same supplier or competitor suppliers, has resulted in the number of coatings on offer declining.

What is clear, given the current methods of preparing a coating specification, is that in most cases, selection is finally made on price by both the owner and the shipyard, rather than on technical merit.

Product Selection Tomorrow

While shipyards strive for standardization and simplification,[3] the in-line method of coating manufacture, rather than the batch method, would allow the development of an increased number of SKUs in smaller batches that would reduce the warehousing/distribution issue and allow specialist products to be developed to meet specific area needs. Key areas where specific functionality could be imparted would be for water ballast tanks and cargo hold/tank coatings, and on-board maintenance products/solutions.

Alternative materials could reduce reliance on liquid coatings to some extent, but it is unlikely that one technology can match the flexibility and utility of liquid coatings for all functions and areas. Increased use of plastics is a possibility for some aspects.

Though shipyards are concerned with time, cost and quality, the required speed of production and the quality of application still results in unacceptably high rework levels. *okeyphotos / Getty Images*

THE COATING PROCESS

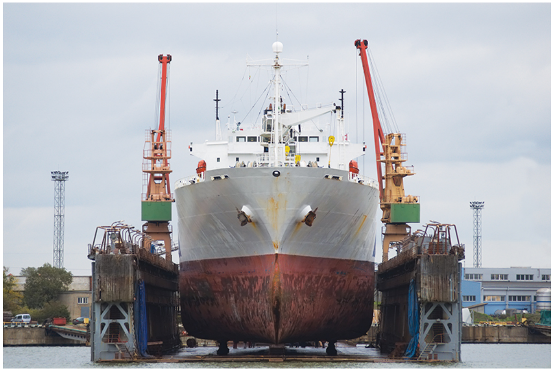
For the most part, the surface preparation and coating application technology in use today has not significantly changed over the past 50 years. The existing processes are under pressure to meet the demands of the market for both newbuilding and subsequent operation/repair and maintenance.

A shipyard has a focus on time, cost and quality.[4] The key paint attributes of drying time and overcoating intervals have not progressed in line with the required speed of production and the quality of application still results in unacceptably high rework levels. Therefore, a review of possible technology solutions that may enable a positive change is worthwhile.

A comprehensive assessment of the coating process was made in the 1990s.[5] This assessment determined the key stages and costs associated with coatings, which during new construction comprise the following steps:

- Primary surface cleaning and preparation;
- Shop primer application;
- Weld line cleaning and coating;
- Secondary surface preparation/cleaning;
- Main coating scheme application at block stage; and
- Erection joints surface preparation/cleaning and coating.

The relative cost of the coating process increases as it progresses through the production process. Therefore, the cost of coating application for work carried out after the main scheme application can range from 6 to 14 times costlier per square foot/meter than at the block stage. This shows that coating strategy and planning are critical to ensure that the coating work is integrated into the production process—and that the specification should focus on, among other things, attributes of the coating that enable it to best survive the production process.



While surface prep and application technology has not significantly changed in the last 50 years, the existing processes are under pressure to meet the higher demands of today. *spet / Getty Images*

COATING TECHNOLOGY

Needs Today

Today, most construction facilities would identify the following as key attributes that they would target:

- Minimal surface preparation;
- Minimum number of coats;
- Speed of cure (at practical DFT);
- Over-coating intervals (both minimum and maximum) at practical DFT;
- Low temperature workability; and
- Low environmental impact.

The shipowner is generally looking for longevity of the coating, with anti-corrosive protection for 15 years, antifouling for 10 years and chemical tank lining resistance of 10–12 years, as well as attributes such as color match, ease of maintenance, universal application (one product for all areas) and anti-abrasion/toughness. The shipyard is generally interested in the achieving the 12-month warranty requirements, while the shipowner is generally interested in attributes through life of ownership.

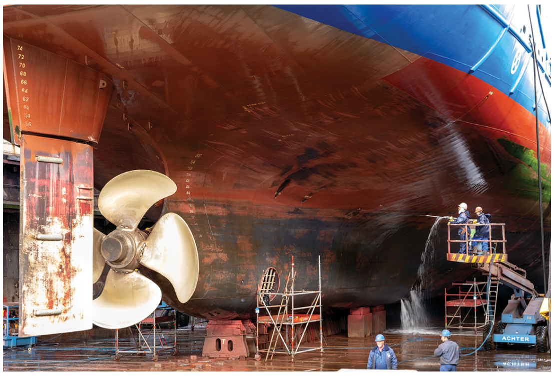
Needs Of Tomorrow

There are several features that are required in the future for new products and technologies. Perhaps the strongest driver for technological change in the future will be regulatory requirements. These have increased since the organo-tin ban of the 1990s[6] that resulted in a dramatic change in fouling prevention technology solutions. The REACH directive[7] has had an ongoing impact on the chemical products that are considered safe to use, and other legislation will cause further challenges, such as the BWT Convention,[8] which has raised issues of compatibility between the treatment methods and the ballast tank coatings.

With this said, the key feature required of coatings is that of "predictability of performance." The biggest challenge today is to get the coatings to perform in a predictable manner to allow newbuild and operating costs to be reliably accounted for. If the time to failure of a coating was understood, then owners could plan and manage the costs of operation effectively, and if the relevant performance criteria for new construction (drying time, overcoating intervals, etc.) were predictable, then production could also be optimized.

Progress on any of the required attributes is essential in the future, and some suggestions about technology developments required at the different stages include:

- **At New Construction:** The use of UHP water (wet blast technology) to prepare steel surfaces could be adapted to produce a surface profile, as well as the use of lasers to remove paint for subsequent hot work, and use of localized chemical treatment for erection joints and seams.
- **Through-Life:** Laminates for color match and improved barrier properties, self-healing coatings using bacteria technology,[9] microencapsulation, or polymer memory, and antifouling based on living organisms or microstructured surfaces.[10]



The use of UHP waterjetting to prepare steel surfaces could be adapted to produce a surface profile for newbuilding applications. *VanderWolf-Images / Getty Images*

INSPECTION FOR QUALITY CONTROL AND ASSURANCE

The current approach to coating work for ships appears to hinge around answering the question, "Have we done it correctly?" While some shipyards do attempt to answer the question, "Can we do it better, and how?", their efforts are often restricted by the provision of a 12-month warranty and with little interest in through life performance.

Given the rate of ownership change of many ships, it is the classification societies who are perhaps best placed to assess through-life coating behavior and performance. Sadly, to date, they have more often tended to focus on ensuring that documentation is audited and correct, rather than ensuring that the engineering of the coating system is carried out properly to match the build and operational needs of the vessel.

Inspection Today

The current industry inspector qualification is based around a two-week course, and the inspector gains experience either working contract-to-contract, or in some cases, through a further on-the-job training program.

In recent years, paint companies have taken to contracting out their paint inspectors (technical service representatives) to clients as a way of mitigating the cost of having this group of people to monitor coating application and to protect the paint company interests—thus raising the issue of potential inspector loyalty.

At newbuilding, there can be several inspectors—the shipowner's inspector, the shipyard production inspector/foreman, the shipyard QC inspector and the paint company inspector—in attendance. In addition, for ballast water and crude oil tanks, a classification society inspector may be present for verification purposes.

If the current belief that coatings fail because of poor surface preparation and application is true, then the conclusion must be that the current methods of inspection and assessment are inadequate. However, this is not the root cause of failure (as this is not driven by these factors alone), but merely symptomatic of a poor engineering solution to the problem.

One major challenge of inspection today is the assessment of when a coating system has failed, using the IACS classification of 'Good,' Fair' and 'Poor.' Thus, even with a degree of defects where 20–50% of edges are showing corrosion and up to 20% of flat surfaces showing signs of corrosion (both classified as 'Fair'), the coating system would not necessarily be considered to have failed.

Given that these are complex spaces and large areas, this judgement as to percentage is made by eye and is thus truly subjective. As ballast tanks must be in good condition after 15 years, there is a potential for considerable argument/dispute as to this subjective assessment of the degree of failure that could result in costly unnecessary repairs at one extreme, and loss of through-life structural integrity at the other.

Inspection Tomorrow

Safety of shipping operations is reliant on an effective maintenance policy. Inspections today come at a high cost and are often perceived by owners as onerous and inefficient. Shipping is slowly starting to embrace the idea of predictive/risk-based maintenance, and remote inspection solutions equipped with various sensors are being developed and tested by major companies. For example, the drone industry is booming, and since 2018 the R&D efforts have focused on innovations in autonomous flight, utilizing big data, machine learning and computer vision. In terms of coating-related applications, drones can be adapted to carry out visual inspections of external structures or enclosed spaces in a pre-planned, efficient and repeatable way. The capability of drones goes beyond visual inspection and extends to more complex tests such as thickness measurements by using ultrasound probes, for example. The presence of surveyors is still necessary, but with the advances in virtual and augmented reality technology, this may not be a requirement in the near future.

The challenge of inspection is not only what data is recorded, but what is presented and how it is presented, as well as repeatability of inspections to allow subsequent follow-up to be meaningful. Reporting should include not only close-up photographs of issues, but also fuller views to allow the extent and severity of an area under consideration to be assessed. However, more detailed representations are required that not only identify the areas being inspected, but also the location of defects and such to allow subsequent follow-up.

To remove subjectivity in the assessment of coatings, there is a need for the development of through-life performance data that could be presented as degradation curves to enable preventative maintenance to be conducted to prevent system failure. The industry must also consider if the current levels of failure acceptable under the Good-Fair-Poor assessment approach is meaningful and appropriate.

The delivery of inspection services will also change, with paint companies taking a more commercial approach to the supply of inspectors and the need from the market shifting more toward better coating work supervision and planning at both newbuild and dry-dock, which will likely be suited to be delivered by independent third parties. There is already evidence in some market sectors of this approach being increasingly adopted.

MAINTENANCE AND REPAIRS

Maintenance Today

Maintenance is defined as the ability to maintain a given area in its present condition. For example, if it is in 'Fair' condition, all maintenance can do is sustain it in that condition, while a repair would be able to restore the area to a 'Good' condition. While dry-dock work is generally considered repair work, work carried out by the crew is usually considered as maintenance. For maintenance to be effective, then, the crew needs to be trained accordingly. There is considerable in-house evidence that a properly trained crew uses less paint and performs better repairs, reducing costs.[11]

Maintenance Tomorrow

Significant challenges will be faced to maintain vessels and minimize down time, resulting from repairs while in-service, and there are several possible scenarios.

1. Coatings, coating processes or alternative technologies will need to be improved or will be required to provide a 25-year life.
2. Vessel life will be reduced because of lack of maintenance, or increased off-hire periods will be required to address all issues at dry-dock.
3. Riding crews will be required on the unmanned ship to minimize downtime, and hence, vessels will be part-time manned.

CONCLUSIONS

As discussed in both parts of this article, there is no doubt that given the stagnation of the process technology and the increased regulatory burden, cost and time pressures on new construction, as well as the increased number of vessels that require drydocking as the fleet grows, it is unlikely that the current approach to coatings will remain sustainable, and is likely to be an increasingly significant cost driver for shipowners/operators and a significant man-hour and cost burden on shipbuilders and repair yards.

The challenge is that the cost of development against the market persistence of driving prices down to commodity levels as the added value that coatings can provide is not clearly defined or accessible to all. This limits the ability to increase revenues sufficiently to develop new technologies. Similarly, the dominant coatings companies are largely wedded to the supply of paint, meaning that novel solutions will likely emerge from smaller and more dynamic companies either alone or in collaboration with the established players. This will raise significant challenges to the current business model and may result in novel approaches (already being trialed) where in effect the underwater hull or ballast tanks etc. are rented by the owner from the paint company as long as they deliver the required performance and the through-life maintenance will rest with the paint company or suitable third. The range of ship owner types however will likely preclude a "one size fits all" solution.

Solvent-Free Epoxies for the Marine Market

By Michael Aamodt, Alan Guy and Raouf Kattan, Safinah Group

There is currently no clear universal definition of what a "solvent-free epoxy coating" is in the market today. The generic name indicates that the epoxy coating should be "solvent-free," but when looking at solvent-free epoxy coatings currently available, we see that that is not always the case.

To be able to spray apply such a solvent-free coating through single-feed airless spray equipment, the viscosity needs to be low enough to get a good spray pattern without the need for thinning with solvents. A very common formulation approach for solvent-free epoxies is to use low-viscosity liquid Bisphenol A or Bisphenol A/F epoxies that have been modified with reactive diluents. The epoxy binder is cured with low-viscosity polyamine or polyamide curing agents that can be delivered with 30% benzyl alcohol as a solvent to further lower viscosity, work as a good epoxy compatibilizer and accelerate the cure. In many cases, the viscosity needs further reduction to reach optimal application properties, so 10% weight or more benzyl alcohol solvent can be added as a non-reactive epoxy resin diluent.

Without any scientific proof (that we are aware of), benzyl alcohol has been claimed to remain as a solid in epoxy coatings, but benzyl alcohol is an aromatic alcohol with a boiling point temperature of 205 C and should strictly speaking (in the authors' opinion) be classed as a solvent and contribute to the coatings volatile organic compound content. Some argue that due to benzyl alcohol's high boiling point temperature most of it will not evaporate or diffuse out of the coating film. There is, however, a reason why we over the last two decades we have seen solvent free epoxy coatings for potable water tanks move towards benzyl alcohol-free formulations as it has been observed that over time the solvent diffuses out of the coating film giving taste and smell to the potable water. The significantly lower, practically determined volume solids compared to the values calculated treating benzyl alcohol as a non-volatile, is a strong indication that it is in fact volatile and should be classified as a solvent.

In **Table 1**, benzyl alcohol contents in the epoxy base and curing agent part of solvent-free epoxy marine tank coatings have been taken from the coating manufacturers material safety data sheets.
From the table, it is clear that not all paint manufacturers count benzyl alcohol as a solvent that increases VOC content and lowers volume solids of the coating, so we get the unfortunate situation that solvent-free coatings that should have very close to 100% volume solids and 0 g/l of VOCs can vary anywhere between 95–100% solids and 0–180 g/l in VOC. Considering that ultra-high solids epoxy coatings can have up to 97% VS and down to 50 g/l in VOC, a universal common definition of solvent-free epoxy needs to be made so that users can clearly distinguish between solvent free and ultra-high solids epoxy coatings. In addition, the main advantages of solvent free epoxy coatings are very low or no VOC emissions, the possibility to apply thick coating films with little or no film shrinkage and lower film formation stress.

Based on this, the authors would propose the following universal definition for a solvent free epoxy coating:

> "A 'solvent free epoxy' coating can be defined as an epoxy paint where all of the non-reactive components of the formulation have an initial boiling point greater than 250 C at an atmospheric pressure of 101.3kPa. Benzyl Alcohol added to epoxy coatings should be counted as a volatile since it is not reactive and falls within the definition of a solvent according to EU Paint Directive 2004/42/CE. Benzyl alcohol will also lower the practical volume solids compared to that calculated and often stated on data sheets, when assuming it is non-volatile. At the same time its inclusion increases the volatile organic compound (VOC) content of the coating."

Hopefully, this proposed definition for solvent free epoxy coatings will start a discussion among relevant stakeholders to agree on a common clear and universal definition.

Table 1: Benzyl alcohol (BA) content in some typical marine solvent free epoxy cargo and potable water tank coatings.

PRODUCER	SOLVENT FREE EPOXY COATING	VOLUME SOLIDS %	VOC G/L	WT % BA IN PART A	WT % BA IN PART B	MIXING RATIO A : B	OTHER SOLVENTS ADDED %
A	1	100	125	3	0	2 : 1	
	2	100	70	0	< 10	2 : 1	In part B: MEK < 10
B	1	98	22	3	25 – 50	2 : 1	
	2	98	140	0	25 - 36	2 : 1	In part B: Xylene 0.8
	3	99	180	< 5	10 - 25	3 : 1	
	4	100	70	< 3	10 - 21	2 : 1	
	5	97	39	0	0	2.5 : 1	
C	1	100	142	10-15	10-15	4 : 1	
	2	100	20	10 - 25	10 - 20	4 : 1	
D	1	98	22	5-10	5-10	3 : 1	

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