Assessment of Paint Coatings on Galvanized Steel

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To extend the life of coil-coated galvanized steel, the zinc coating has to be protected with a chemical- and weather-resistant paint system. Examples of coated galvanized steel range from that used for maritime transport containers and components of Australian army trucks, to cladding on petroleum refinery reactors, structures used in the electric power industry, and communication towers. Painting can also be done for aesthetic reasons. However, the painting of galvanized steel has often given unsatisfactory results because of paint flaking after only a few years. Furthermore, incompatibility problems have been reported between the zinc coating and the paint system.[1-2] The reactivity of the zinc coating as well as the type of corrosion products formed have a great influence on the service life of a protective paint system. If the zinc coating prevents the organic coating from developing its full properties of adhesion and resistance, then the galvanized steel cannot be satisfactorily protected. A well-known example of this reactivity is the following one.[3] Many paint systems are based on drying oil and alkyd binders that, on drying, produce formic acid that immediately reacts with the zinc substrate to form zinc formate [$Zn(HCOO)_2$]. While the film is dry no apparent failure appears, but once water vapor has penetrated the paint film, the zinc formate is dissolved and adhesion is destroyed. This phenomenon usually appears 3 to 12 months after painting.[2,4]

Although the painting of zinc coatings has been considered difficult in the past, numerous studies have demonstrated that galvanized steel is no more difficult to paint than other metal substrates, provided good paint pretreatments procedures are adopted.[5] Selection of appropriate paint and pretreatment is the key to good paintability. The objective of this work was to compare the protective capacity of five paint systems, which are suitable for fresh and weathered galvanized steel, and a common system to paint non-galvanized steel. These paint systems were applied over galvanized steel with six different surface treatments. The surface treatment/paint system combinations were evaluated through laboratory tests and outdoor exposure.

Experimental

Specimens (100 x 150 x 1 mm) were cut from a low carbon steel sheet. They were hot dip galvanized to give a zinc coating with an average thickness of 81 μm (578 g/m^2). After galvanizing, samples were grouped into six batches. Each batch was subjected to a different pretreatment or cleaning action (listed in Table 1) before coating application.

Weathering in a sodium chloride (NaCl) atmosphere was done in a salt fog cabinet per ASTM B 117. For weathering in an atmosphere containing sulfur dioxide (SO_2), a glass cabinet was built in which specimens were exposed to aqueous solutions generating SO_2 (5% sodium thiosulphate and 0.1 N sulfuric acid). An average SO_2 concentration of 0.2% was obtained. Both exposures lasted 24 hours. In no case did corrosion (rust) appear on the base steel. After weathering, corrosion products were removed from the surfaces with a steel wire brush.

In the chromate treatment, specimens were immersed for 20 sec. in an aqueous solution containing 200 g/l potassium dichromate and 6 cc/l sulphuric acid. The specimens turned yellow in the solution. The phosphatizing solution (T-wash) was made up of 9 wt% phosphoric acid (s.g. 1.7), 16.5% ethyl cellusolve, 16.5% ethyl alcohol, 1%

copper carbonate, and 57% water.[3] It was applied by brushing, using an amount of solution just to turn the metal surface black. An ammonia solution was prepared with 5% ammonia, 15% ethyl alcohol, and 80% water. It was applied by brushing until the surface had a dull appearance. All chemical treatments were applied at room temperature.

Sweep shot blasting was achieved by blasting at the lowest possible pressure to produce only light surface roughness for improved coating adhesion. After blasting, specimens were washed with trichloroethylene.

The coating systems were applied by air spray in accordance with the suppliers' instructions. Table 2 identifies the generic types of the systems. The first 5 systems are recommended for galvanized steel, whereas the sixth system is not recommended and was used as control. The coated specimens were then kept in the laboratory for a month to assure complete cure. Afterwards, they were subjected to laboratory tests or outdoor exposure.

The surface treatment/paint system combinations were evaluated through the following laboratory tests. In all cases the experiments were carried out in triplicate.

- Adhesion measurements under dry and wet conditions by the pull-off method (ASTM D 4541)

Aluminum loading fixtures (dollies) having an abrasive-blasted flat base with an area of 2.83 cm^2 were bonded onto the topcoat with a two-component epoxy adhesive and were left to cure overnight. The loading fixtures were then pulled off the specimens using a servohydraulic tensile testing machine at a rate of 3.8 mm/min. For the wet adhesion test, one batch of specimens was immersed in distilled water, while another one was immersed in a 0.5 M NaCl solution for 14 days (336 hours) at room temperature. It was necessary to wait until the adhesive had cured thoroughly overnight and to carry the test out 24 hours after the end of the immersion period.

- Salt spray (ASTM B 117) for 500 hours

Before exposure, each coated specimen was scribed with a single straight line, running vertically along the specimen through the coating and down to the metal substrate.

- Immersion tests in naturally aerated solutions, 0.5 M NaCl or 0.00155 M $FeSO_4 \cdot 7H_2O$, at room temperature during 260 days

Specimens that were exposed outdoors were rack-mounted at a standard 45 degrees south exposure. The condition of the coatings was rated periodically using standard ASTM techniques. Testing was performed for 16 years. In this same test site, the atmospheric corrosion rate of low carbon steel and galvanized steel bare specimens were 51 and 1.86 μm/year, respectively.

Results and Discussion

The results of the pull-off adhesion test in dry condition are shown in Table 3. The prevailing failure of each system is also shown. Values varied considerably among the paint systems. Other authors have also indicated wide variations.[6] The epoxy-polyurethane (3) and one-coat epoxy (4) paint systems showed the highest tensile values when averaged over all 6 types of surface treatments, although within a single type of surface treatment they were not always the two highest ratings. At the other end of the scale was the alkyd (6) system. Not only did the alkyd system have the lowest pull strengths, but also the mode of failure was always adhesive from the galvanized surface. Among the surface treatments, this mode of failure was also present in most of the phosphated specimens, except in those of the chlorinated rubber system (1).

ASTM D 4541 requires the user to estimate the percentage of adhesive failure and the percentage of cohesive failure, according to their respective areas and location on the test specimen. However, in practice, these two types of failure appear to be closely mixed, making it difficult to differentiate one from the other. In systems 1, 3, and 5, types of failures were found mixed. In these systems, intercoat adhesive failure (IAF) was present in most of the tested area, in which only the topcoat detached, showing the primer. Cohesive failure in the primer (CFP) also occurred. In addition, CFP was present in the one-coat epoxy system (4).

Chromating was the treatment that exhibited the highest average. The weathered specimens showed good adhesion, mostly because they were dry when tested; that is, they were not in contact with a liquid that solubilized the salt residues probably remaining on their surface. Conversely, the phosphate treatment showed the lowest values in adhesion. This result is surprising, because several publications have reported good results with the T-wash treatment.[3,5]

Results of the pull-off adhesion test after 24 hours of drying following 14 days of immersion in distilled water or a 0.5 M NaCl aqueous solution (Table 4) showed that, in most of the cases, dry adhesion values decreased after immersion. The most outstanding decreases were found on the epoxy-polyurethane (3) and one-coat epoxy (4) paint systems, which had the highest dry adhesion values. Adhesion measurements were attempted just after removing the specimens from the liquids to avoid drying of the coating and the consequent recovery of adhesion, partial or total. Such recovery of adhesion was present in the vinyl-acrylic (2) and alkyd (6) paint systems, which had the lowest dry adhesion values and in some cases had values that were very close or even equal to the ones determined in dry condition. The chromating again showed the highest adhesion average, but only for specimens that were immersed in the NaCl solution. The chromate-treated specimens showed the lowest adhesion average after their contact with distilled water. With regard to the type of failure in both liquids, there was no change in paint systems 1 and 5 (all failures were CFP/IAF, except in system 5 over T-wash that was AFM), but there were changes of CPF/IAF and CFP to AFM in paint systems 3 and 4, respectively.

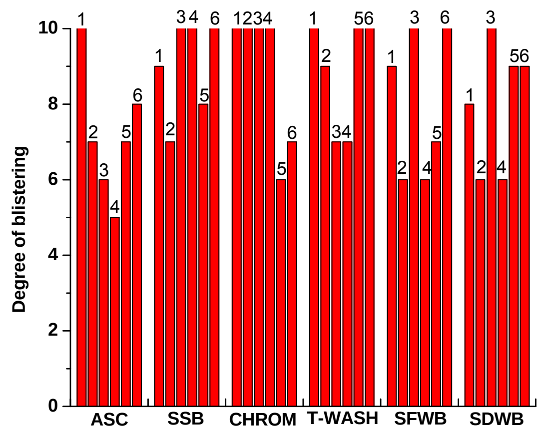
Regarding the influence of the liquid medium in adhesion loss, the majority of adhesion values after immersion in NaCl solution were higher than the corresponding values of immersion in distilled water. In only a few cases, the opposite behavior was observed. Most of the failures in specimens soaked in distilled water could be due to the decreased thermodynamic activity of water in the ionic solutions[7] and/or to a greater quantity of water permeating the coatings by osmosis. In both weathering conditions where water-soluble salts existed, immersion averages in distilled water were the same and lower than those corresponding to the immersion in the NaCl solution.

Figure 1a presents the results obtained in the salt fog cabinet after 500 hours of exposure. In this test, the main damage was the degree of blistering exhibited by the paint systems. There was also delamination due to the formation of blisters close to the scribe. The degree of blistering was evaluated according to ASTM D 714. Blister size and frequency values were converted into numeric values using a conversion table.[8] In this table, 10 indicates no blistering at all, and 0 indicates a total failure.

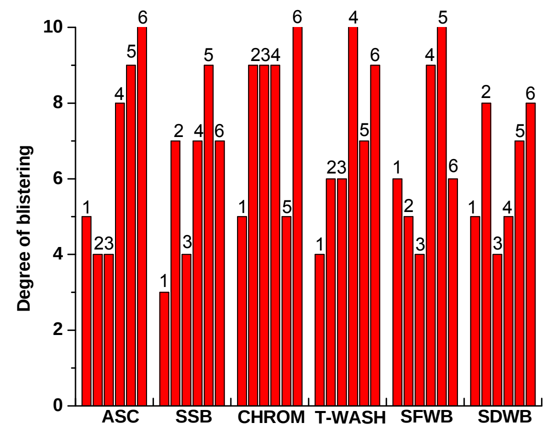
In general terms, the six paint systems withstood the test fairly, with a little more than half of the exposed specimens (52%) blistering slightly. However, at the end of the test, there were neither bursting blisters nor oxidation points over any of the specimens. It is noteworthy to mention the good results of the chlorinated rubber (1), epoxy-polyurethane (3), and alkyd (6) paint systems. The vinyl-acrylic system (2) and the one-coat epoxy (4) obtained the lowest averages. Chromating was the treatment that offered the highest averages on paint systems 1 to 4. The specimens treated with the ammonia solution showed poor results, except for the chlorinated rubber (1) system. The good performance of the alkyd system (6) and of the T-wash treatment in salt fog test is remarkable compared with their defective behaviors in the adhesion test.

In the immersion tests, the coating damage was evaluated visually through the degree of blistering, up to 260 days in the sodium chloride or ferrous sulfate solutions. The results of these evaluations are presented in Figures 1b and 1c, after converting the values of ASTM D 714 to the numeric scale. In the NaCl solution immersion test (Figure 1b), the one-coat epoxy (4), epoxy-polyurethane (5) and alkyd (6) paint systems showed the best general behavior. The chlorinated rubber (1) and epoxy-polyurethane (3) systems performed the worst. The behavior of the alkyd system was comparable to that of the high tensile coatings (4 and 5), despite the alkyd's poor adhesion. With regard to surface treatments, the following should be noted:

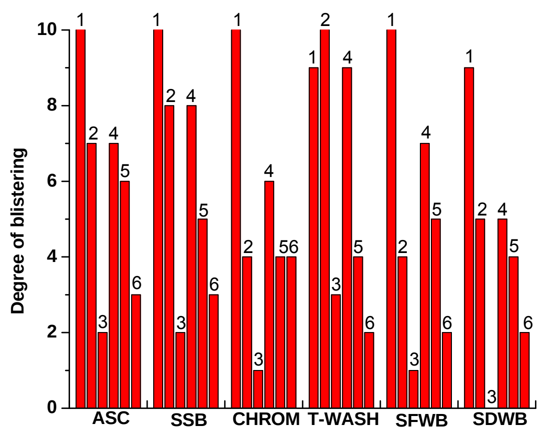
- the effectiveness of chromating as a treatment (with the highest average), except under the chlorinated rubber (1) and epoxy-polyurethane (5) paint systems;
- the effectiveness of T-wash as a treatment in the one-coat epoxy (4) and alkyd (6) systems; and
- sweep blasting, with very good results in the adhesion test, was the worst surface condition under the chlorinated rubber system (1). Sweep blasting and SO_2 weathering treatments had the lowest averages.



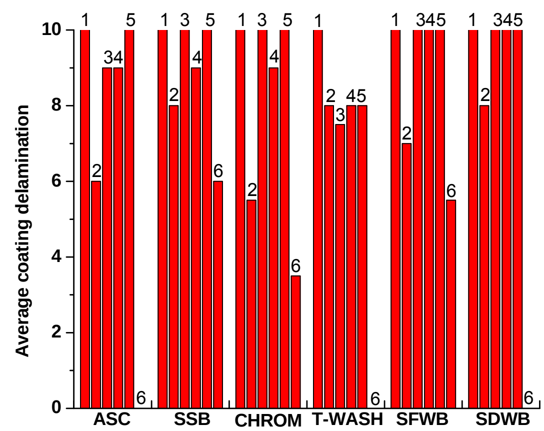
a. Salt fog after 500 h



b. Immersion in a 0.5 M NaCl solution after 260 d



c. Immersion in a 0.00155 M $FeSO_4 \cdot 7H_2O$ solution after 260 d



d. Outdoors exposure after 16 y

Figure 1c shows the results for specimens that were immersed in the $FeSO_4$ solution. Differences among surface treatments were only slight. It is worth noting the following aspects: the good performance of the chlorinated rubber system (1) on all surface conditions; the poor performance of the epoxy-polyurethane system (3), especially on the specimens weathered in SO_2; and the effectiveness of T-wash as treatment in the paint systems 1, 2, and 4. The worst surface treatment was SO_2 weathering. When comparing Figures 1b and 1c, corresponding to the immersion up to

260 days, more damage to the paint systems occurred when in contact with the $FeSO_4$ solution than with the NaCl solution. In addition, the one-coat epoxy (4) better withstood immersion in both solutions, and epoxy-polyurethane (3) showed the highest damage.

The specimens of coated galvanized steel were exposed outdoors in a foundry workshop for 16 years. The six paint systems showed loss of color and gloss but neither blistering nor oxidation over the flat surfaces of the test specimens. According to their overall performance, the six paint systems can be divided in two groups of three systems each: those that withstood the exposure very well and those that had a defective behavior. The first group includes the odd-numbered systems: 1, 5, and 3 (chlorinated rubber, epoxy-polyurethane, and epoxy-polyurethane, respectively), ordered in decreasing performance. Delamination from the scribe was observed in a few specimens of these paint systems (Figure 1d). For instance, none of the specimens coated with the chlorinated rubber system (1) showed delamination; however, they did show erosion. The average delamination from the scribe for each paint system was assessed according to ASTM D 1654.

The defective group is made up of the paint systems 2, 4, and 6 (vinyl-acrylic, one-coat epoxy, and alkyd, respectively). The alkyd system showed the worst paint performance. In fact, specimens treated with the phosphate or the ammonia solutions, or weathered in the SO_2 cabinet and coated with the alkyd system showed complete delamination on wide areas of the surface. This is something that was expected and well known, since this system is not recommended for application on galvanized steel. The one-coat epoxy system showed detachment of the coating in several areas of the tested surfaces (cracking/flaking), mainly of the specimens treated with the ammonia solution or artificially weathered. Because this coating presented chalking from 7 months' exposure, one could think that this deterioration is a consequence of a continuous thinning of the paint film through the 16 years' exposure. To answer this question, the film thickness of the specimens was measured at the end of the exposure. The original thickness was found to have decreased only in approximately 30% of the specimens.

Taking into account the results of coating delamination and the above-mentioned failures, it can be concluded that the chlorinated rubber (1) and epoxy-polyurethane (3) paint systems best endured atmospheric exposure for 16 years. No significant symptoms of degradation were detected for any of the tested conditions on the exposed specimens. The chlorinated rubber paint system (1) only showed cosmetic deterioration from erosion of the binder during 16 years of exposure. The T-wash and the ammonia solution showed the worst behavior of the surface treatments.

Conclusions

- The effect of paint systems on the evaluation tests was much more significant than the effect of surface treatment. None of the surface treatments showed outstanding behavior over the others in all the tests carried out. The most remarkable difference was that exhibited between the T-wash and the other treatments in the dry adhesion test.
- The surface treatments that yielded better results in the tests were chromating and sweep blasting. However, both treatments also had very defective results, the former in the wet adhesion test after immersion in distilled water and the latter in the immersion tests in the two saline solutions.
- There was a coincidence between the dry adhesion and the atmospheric exposure tests, since the vinyl-acrylic (2) and alkyd (6) paint systems and the phosphatizing treatment yielded the worst results in both tests. At the other end of the

scale are the epoxy-polyurethane paint system (3) and the chromating and sweep blasting treatment.

- The chlorinated rubber (1) and the two epoxy-polyurethane (3 and 5) paint systems showed the best results in all the tests that were carried out. The one-coat epoxy (4) system also had very good results in the laboratory tests, but its outdoor behavior was unacceptable.
- The results of the epoxy-polyurethane paint system (3) clearly showed that this system would not be recommended for contact conditions with liquids. In tests including these conditions (wet adhesion and immersion in both saline solutions), this system obtained the lowest values, although in the other tests its performance was of the best.

Acknowledgements

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Table 1: Galvanized steel surface treatments tested

Initial	Weathering	Surface treatment	Designation
Hot-dip galvanized steel	Unweathered	Ammonia solution cleaning	ASC
	Unweathered	Sweep shot blasting	SSB
	Unweathered	Chromate pretreatment	CHROM
	Unweathered	Phosphate pretreatment	T-Wash
	Salt fog chamber	Wire brushing	SFWB
	Moist sulfur dioxide	Wire brushing	SDWB

Table 2: Characteristics of paint systems applied on galvanized steel

System number	Primer	Topcoat	Dry film thickness mils (µm)
1	Chlorinated rubber pigmented with micaceous iron oxide (1st coat)	Chlorinated rubber pigmented with micaceous iron oxide (2nd coat)	5.9 (150)
2	Synthetic resin blend (substantially vinyl) inhibitive primer	Acrylic	6.8 (173)
3	Polyamide–cured epoxy (2 comp.) (supplier 1)	Polyurethane enamel (2 comp.) (supplier 1)	7.5 (192)
4	High-solids epoxy (2 comp.) (1 coat)		5.6 (144)
5	Polyamide–cured epoxy (2 comp.) (supplier 2)	Polyurethane enamel (2 comp.) (supplier 2)	4.1 (104)
6 (NR)*	Alkyd/iron oxide	Alkyd enamel	5.4 (138)

*NR: not recommended

Table 3: Dry adhesion values of paint systems to galvanized steel in kPa

Paint system	Galvanized Steel Treatment*							
	ASC	SSB	CHROM	T-WASH		SFWB	SDWB	Average
1	901(CFP/IAF)	762(CFP/IAF)	866(CFP/IAF)	589(CFP/IAF)		589(CFP/IAF)	901(CFP/IAF)	768
2	520 (AFM)	1039(CFP/IAF)	935 (CFP/IAF)	624 (AFM)		727 (AFM)	554 (CFP/IAF)	733
3	970(CFP/IAF)	1005(CFP/IAF)	1282(CFP/IAF)	727 (AFM)		1455(CFP/IAF)	1212(CFP/IAF)	1109
4	1005 (CFP)	1351 (CFP)	1247 (CFP)	554 (AFM)		1039 (CFP)	1039 (CFP)	1039
5	1074(CFP/IAF)	762(CFP/IAF)	866(CFP/IAF)	554 (AFM)	727(CFP/IAF)	693(CFP/IAF)	779	
6 (N.R.)	208 (AFM)	277 (AFM)	312 (AFM)	242 (AFM)	312 (AFM)	416 (AFM)	294	
Average	779	866	918	549	808	803		

AFM = adhesive failure from metal IAF = intercoat adhesive failure

CFP = cohesive failure in primer

* See table 1 for weathering and surface treatments abbreviations

(N.R.) Not recommended

Table 4: Wet adhesion values of paint systems to galvanized steel in kPa. Immersed 14 days in distilled water or a 0.5 M NaCl solution and then dried 1 day at room temperature

Paint system	Galvanized Steel Treatment*						
	ASC	SSB	CHROM	T-WASH	SFWB	SDWB	Average
	H_2O - NaCl	H_2O - NaCl	H_2O - NaCl	H_2O - NaCl	H_2O - NaCl	H_2O - NaCl	H_2O - NaCl
1	208 --- 554	104 --- 416	346 --- 416	104 --- 520	381 --- 520	346 --- 346	248 --- 462
2	450 --- 381	346 --- 520	69 --- 866	554 --- 416	173 --- 381	104 --- 450	283 --- 502
3	346 --- 381	450 --- 485	173 --- 485	590 --- 381	485 --- 381	450 --- 312	416 --- 404
4	416 --- 416	450 --- 450	138 --- 554	312 --- 381	346 --- 693	450 --- 312	352 --- 479
5	173 --- 589	485 --- 485	485 --- 277	485 --- 381	520 --- 312	658 --- 693	468 --- 456
6 (N.R.)	173 --- 138	277 --- 208	173 --- 173	208 --- 242	242 --- 208	104 --- 381	231 --- 225
Average	294 --- 410	352 --- 427	230 --- 462	375 --- 387	358 --- 416	352 --- 416	

* See table 1 for weathering and surface treatments abbreviations

(N.R.) Not recommended

Scientific Methods for Qualification and Selection of Protective Coatings

by J. Sonke and W.M. Bos

For industrial applications, coatings are typically required to provide excellent corrosion protection for a long time. In case of extreme environmental conditions, it is of utmost importance to select the coating system that is most suitable for site-specific conditions. However, there is no generally accepted method for coating selection. Consequently, improper selection can lead to unexpected coating failure, often with extensive damage as a result.

The approach used for the selection of protective coatings is normally based on a wide range of test methods. However, test methods designed for specific applications are often used for applications for which they were not designed. For example, the salt spray test was designed for testing corrosion of metals but is also used for testing of coatings. Visual inspection is the standard method for examination of test results, leading to subjective and inaccurate judgement. Besides this, coatings are frequently selected for specific constituents, because it is believed that the performance of products containing these constituents is similar.

The best method for the development and selection of protective coatings is exposure of coated specimens in the intended environment of application. This testing is very time consuming. As a result, ‘accelerated’ testing of coatings has become very popular. In such tests, parameters that influence coating degradation are amplified. Ideally, the time-to-failure is shortened without changing the degradation mechanism. However, various sources in the literature show that the altered environment introduces different failure mechanisms. A clear example is an attempt to accelerate degradation due to solar radiation by exposure to high-intensity radiation that contains a significant UV energy in wavelengths below 360 nm. However, these short wavelengths cause bond breakage that will not occur in outdoor exposure, thus introducing a failure mechanism that will not occur in normal practice. [1] Another example is the strongly criticized salt spray test. This test does not simulate actual exposure conditions, and the results are not completely independent from the operator.[2] Even when a correlation exists between the results of accelerated tests and the actual in-service performance, one can only conclude that one system is more degraded than the other (*i.e.,* ranking of coatings). The correlation is also often based on how rust spreads from an area of mechanical damage and not based on actual lifetime.[3] Another disadvantage is that these tests do not provide quantitative data. The data can only be used for a limited range of applications. Therefore, different applications require different test methods. Last but not least, results hardly correlate with practice, depend on the operator, and are far from accurate.[1-5]

The basic function of protective coatings is the protection of the substrate against corrosion. Coatings provide corrosion protection by three related mechanisms: the physiochemical (barrier), the electrochemical (inhibition and cathodic protection), and the mechanical (adhesion) mechanisms.[6]

The degradation of coatings can be quantified by measuring the loss of properties providing corrosion protection. In our approach, test methods were selected that provide quantitative data about these properties. A similar approach is already more commonly used for the research of automotive coatings. [7]

There are several conventional tests for the quantification of physical and chemical properties of coatings (*e.g.*, tensile strength, elongation, hardness, and resistance against impact, abrasion, temperature and chemicals). These tests have proven to be useful in determining which coatings are suitable for a specific environment, based on reliable quantitative data.

To obtain insight in the corrosion protective properties of coatings, there is need for a technique that allows the quantification of the relevant parameters. Since corrosion is an electrochemical process, it is logical to use an electrochemical test method to quantify the protective properties.[8]

In the scientific world, electrochemical impedance spectroscopy (EIS) has proven to be a powerful tool for determination of the protective mechanisms of coatings. According to many authors[8-15], even a relatively short period of testing with EIS provides reliable data for long-term behaviour of protective coatings. Currently, its use for practical applications and coating qualification is not common practice. However, because EIS enables the quantification of protective properties, the technique could be very useful for selection of protective coatings. To get a complete picture of coating performance, physical properties must also be quantified by other means besides EIS.[15-17]

Test results from EIS can be interpreted and ranked to different levels of coating performance as shown in Figure 1. Measurement data can be fitted to equivalent circuits to translate the results to physical properties that quantify the level of corrosion protection. (See the section on EIS measurements for protective coatings.)

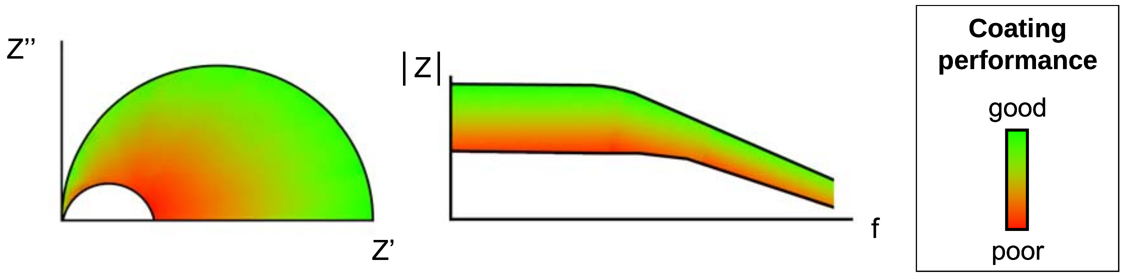

Figure 1 *EIS spectra for different levels of coating performance, left Nyquist plot and right a Bode plot.*

In this article, we will introduce an objective and quantitative method for coating selection, including an electrochemical technique to quantify the properties of protective coatings. With this method, reliable coating selection becomes possible, resulting in less coating failure, longer lifecycles, and less maintenance.

The selection of test methods requires a good understanding of the coating degradation process. Our approach was therefore based on a coating degradation model from which the relevant parameters were derived. Based on these parameters, a test program was composed to enable a more scientific approach for coating selection to be made.

Model of Coating Degradation

Corrosion protection by coatings is initially realised through the function by coatings as a barrier for ions.[18] Additionally, the coating provides resistance inhibition (resistance between anodic and cathodic sites at the interface) as a result of wet adhesion. Throughout the coating's lifetime, inhibiting pigments and extenders can provide active inhibition or cathodic protection.

In this section, we will discuss a general model for degradation of an organic coating as described in various literature sources[6,18-21] and summarised by Nguyen *et al.*[22] It should be noted that several mechanisms of coating degradation could occur, requiring additional tests.

•Step 1: Formation of a Conductive Pathway

In the case of an initially defect-free coating, the first stage of degradation is defined by the formation of conductive pathways in an organic coating. During water uptake, the hydrophilic regions in the coating are attacked by water, followed by interconnection of these regions. (The circled numbers in Fig. 2 indicate the consecutive steps of coating degradation.)

The presence of macroscopic defects, air bubble inclusions, poor wetting between pigment and binder, or mechanical damage accelerates the pathway connections. Swelling and stress relaxation in the coating during exposure all contribute to the formation and enlargement of such pathways.

Hydrophilic regions contain low molecular weight/low cross-linked materials. Ionic groups like soluble pigment components and ionisable resin functional groups facilitate the formation of the conductive pathways.[23] These materials take up large amounts of water, have a low resistance to ion transport, and are susceptible to water attack (*e.g.*, hydrolysis and dissolution).

•Step 2: Ions Migrate to the Substrate

Following the pathway formation, the next step in the degradation of coated steel is the transport of water, oxygen, and ions from the environment to the metal surface. The molecular origin of the direct electrolyte penetration is not entirely clear, but in some cases it has been associated with inhomogeneous cross-linking.[11,20,23,25]

Typical organic coatings are permeable to water and oxygen to such a degree that transport of these materials is not rate controlling.[18] As explained by Leidheiser[21], the transport of ions through coatings takes place in a hydrated configuration through a water phase (pathway) in the coating. The transport rate through coatings depends on the size of the hydrated ion.[21]

In presence of soluble materials (salts) under the coating, water uptake may be accelerated due to osmosis. In this situation, all parameters for corrosion are present, and this will lead to early failure. This example shows the importance of proper preparation of the substrate and removal of salts before coating application. Once conductive pathways are established and ions have reached the metal surface, the degradation of coating systems without apparent defects is believed to be the same as those containing small defects. Also, small defects caused by mechanical load, like micro cracks, directly result in conductive pathways.

•Step 3: Anodes Develop on the Metal Surface

Corrosion cells are formed near conductive pathways and defects. The anodes develop on the bare steel at the base of the pathways, where corrosion takes place. The rate of formation of the first oxidized layer has been found to be orders of magnitude higher in the presence of Cl^- ions. Subsequent oxidation and hydrolysis results in a decrease of pH and formation of complex mixture of hydrated iron oxides (rust).

•Step 4: Cathodic Contacts Develop under the Coating

Under the coating near the defects, cathodes are formed. Electrons produced at the anodic reactions are consumed by the cathodic reactions. Thus, there is a strong electrochemical coupling between the defect (anode) and the cathodic sites under the coating. Underneath a degraded and non-adherent coating, diffusion pathways between anode and cathode are formed.[19,20] The resistance between anodes and cathodes (resistance inhibition) is largely influenced by the adhesion mechanisms.

•Steps 5 and 6: Sodium Ions Migrate to Cathodic Sites

First, the transport of electrons results in the flow of a galvanic current between the defect and the local cathodes. The flow requires transport of cations between the two sites. This transport directly influences the corrosion rate: a low flow results in a low corrosion current and, thus, a slow corrosion process. Blistering or delamination accelerates the cation flow; therefore, the corrosion can continue more freely.

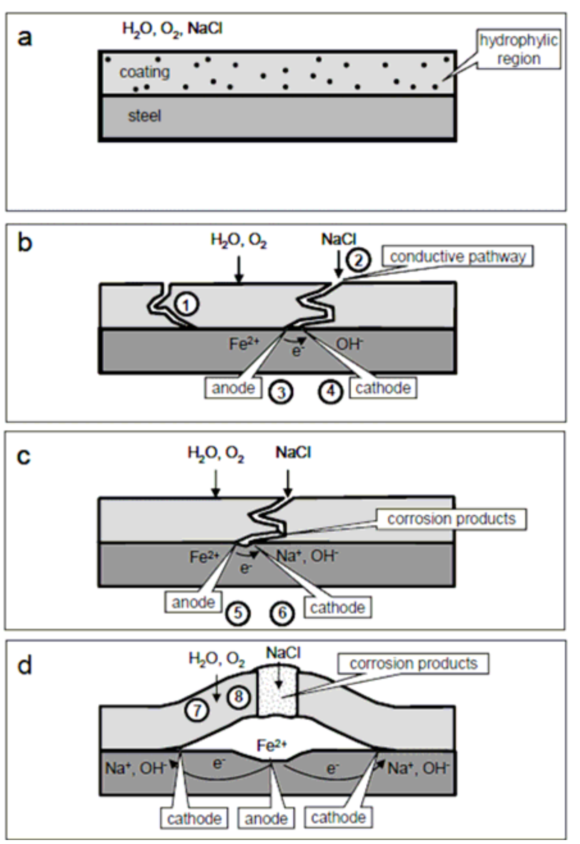

Figure 2 *Four stages of coating degradation [29 and adapted from 22].*

•Steps 7 and 8: Alkalinity at the Cathodic Sites Causes Disbondment

The reaction products at the cathodic sites (NaOH) are alkaline, resulting in an increase of pH. This increase of pH, combined with an osmotic force, results in disbonding of the coating from the substrate. The bonds between the metal and coating are broken by the chemical attack of the NaOH and stimulated by the osmotic pressure of the solution of the cations. In coatings that contain ester bonds and therefore react with NaOH, the resulting saponification will cause disbondment more rapidly than with bonds that are more resistant. For some coatings, blisters develop, enlarge, and eventually coalesce, resulting in total delamination.

Anodic undermining is also accepted as a mechanism for propagation of underfilm corrosion. In the case of steel substrates, cathodic delamination is the most likely mechanism. A corrosion mechanism following anodic undermining is, for example, filliform corrosion of coated aluminium.

EIS Measurements for Protective Coatings[a]

A wide range of protective coatings has been tested according to a standard EIS test method of TNO. All coatings were applied to Q-panels at a thickness of approximately 200 µm. (For a theoretical background on EIS and its use for coatings, the reader is referred to three papers by Loveday[16] and one paper by Gray.[27])

The electrochemical cell and the measurement setup are shown in Fig. 3. The cell is attached to the coated surface. In the cell, a reference electrode and a platinum counter electrode are present. The cell is filled with concentrated artificial rainwater.

Impedance measurements on organic coatings involve an application of an alternating voltage between a counter electrode and a coated (metal) substrate (working electrode) while the response of the system is measured (Fig. 3).

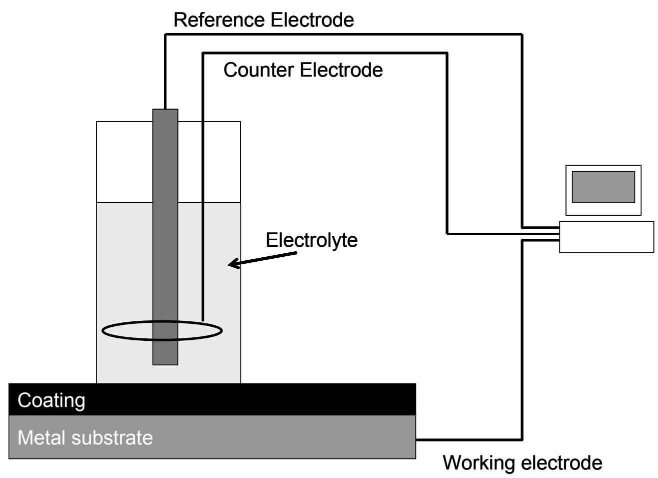

Figure 3 *Setup for an impedance measurement on a coating.*

During the measurement, a sinusoidal perturbation of typically 20 mV (depending on the coating's resistivity) is applied between the steel substrate and the platinum counter electrode. This will result in an alternating current response with a phase shift (φ) (Fig. 4).

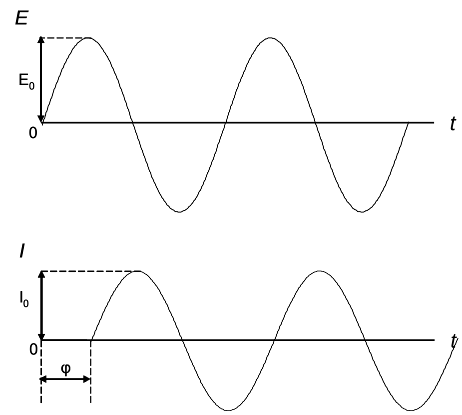

Figure 4 *Current and voltage as a function of time, note the time shift between them.*

Impedance (Z) is the AC equivalent of electrical resistance (R) and can therefore be defined as: $Z(\omega) = E_t / I_t$, where $Z(\omega)$ is the frequency dependant ratio of perturbation over response.

The frequency of the perturbation is changed from 100 kHz to 1 Hz. If required, this range can be extended to 0.01 Hz (increasing duration of measurement).[16]

Since the impedance is frequency dependent, the measurements are executed over a range of frequencies. The test results are often presented in what is called a Bode plot or a Nyquist plot.

A common method to analysing EIS data is to use equivalent (electrical) circuit modelling. In these circuits, elements behave like a resistor, a capacitor, or specialized electrochemical elements such as a CPE (constant phase element). Ideally, each element of the circuit should represent a physical or chemical process.[29]

In general, all data from impedance spectroscopy can be fitted exactly to an equivalent circuit when enough parameters (*i.e.*, elements in the equivalent circuit) are used.[10] The results may, however, be physically meaningless. Therefore, in this case, the data were fitted to most probable impedance equivalent circuits (MPI), according to the following strategy.[27,30]

- The circuit should be as simple as possible.
- Each element added should improve the "goodness of fit" considerably.
- Each element should represent a physical or chemical process and should systematically change in time.
- The configuration of the circuit (*i.e.*, how the elements are relatively positioned) should match the actual situation of the system.

With respect to this strategy, the circuits are based on the process changes according to a unified degradation mechanism model founded on the formation of conductive pathways[16,29] (Fig. 5). A number of equivalent circuits were used to fit the data in our tests.

The parameters that can be derived from these fits include

- electrolyte resistance(R_e),
- constant phase element (CPE, Q_c),
- coating resistance (R_c),
- metal double layer capacitance (CPE, Q_{dl}), and
- charge transfer resistance (R_{ct}).

The constant phase element (CPE) allows for small deviations from ideal capacitance behaviour and is characterised by two parameters, Y_0 and n. Y_0 can be related to coating capacitance if n=1, while n itself represents deviation from ideal coating behaviour. For ideal coatings n=1, while practical systems show a deviation from it, with n values below 1.

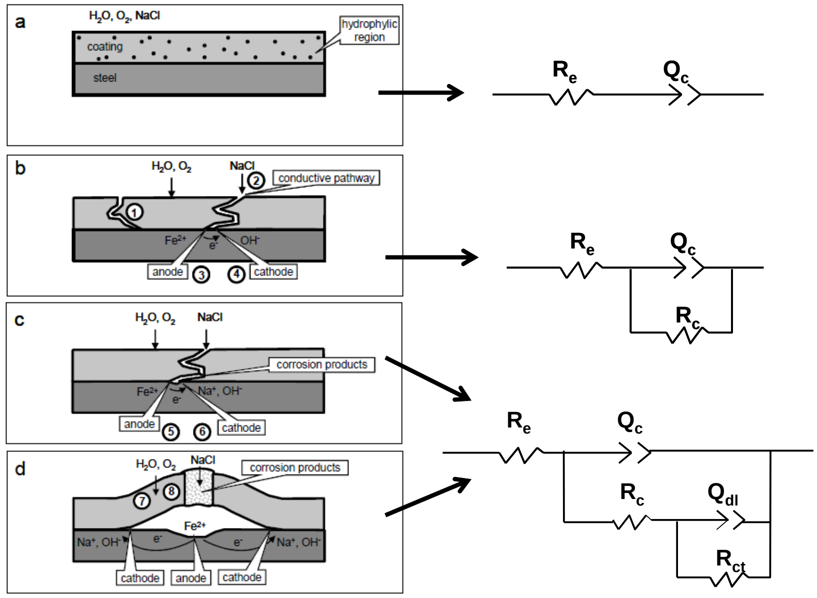

Figure 5 *Most Probable Impedance (MPI) fitting model based on a uniform degradation mechanism [29].*

Parameters Determining Protective Performance

As mentioned in the introduction, the degradation of coatings can be quantified by measuring the loss of the properties providing corrosion protection. Based on this, test methods were selected that provide quantitative data about most of these properties. Therefore, the basic question is which properties should be tested and with what method? In this section, the properties and test methods are distilled from the degradation mechanism.

•Conductive Pathways

The first two steps in coating degradation represent the longest period of the lifecycle of intact coatings. Therefore, the tests that provide information about these stages are very important.

If one looks at the formation of conductive pathways, the process can be measured and quantified by R_c (coating resistance) using EIS. The R_c can be related to the number of pores or capillary channels perpendicular to the substrate surface through which the electrolyte reaches the interface.[11,15,31] The absence of a measurable R_c in the circuit gives indication that no conductive pathways are present. Because this is not the case for most coatings, the R_c can be used for an indication of the amount of conductive pathways that are established.

There are several basic properties retarding the formation of conductive pathways in intact coatings, including the following.

- A uniform composition: no voids and good adhesion between all its ingredients, such as pigments, binder, and extenders
- For non-hydrophilic coating material, EIS can provide information about the amount of polarisable groups (Y_0). From the initial change in capacity or Y_0, the water absorption fraction can be derived[10,11,16,19,34], giving a good indication of the barrier properties.
- Cross-linking, preferably highly functional and with strong chemical bonds, (may be isocyanide-, hydroxyl-, amine-, and epoxy numbers) can give some information. It should be noted that this gives only an indication and no direct link to corrosion protection.
- Chemical resistance: highly chemical resistant for water and specific environments (Good chemical resistance avoids attack at and forming of hydrophilic regions and swelling.)

• Mechanical properties: high tensile strength, elongation, and impact resistance (avoid mechanical damages, micro cracks, and stress relaxation)

For specific industrial applications, chemical and temperature resistance are also very important. Chemical resistance charts from the coating supplier can be used additionally to provide information about specific environments in industrial situations. Besides this, information concerning temperature resistance and temperature change can be obtained using dispersive scanning calometry (DSC). The T_g (glass transition temperature) is a significant parameter that gives information about the coating behaviour for the actual temperature load.

As shown by diverse sources[17,18], the influence of thermal cycles can also be detected with a short thermal EIS test. This kind of test can also contribute to the insight of the behaviour of a protective coating in practice.

Concerning the composition of coatings, flake-shaped pigments and additives can, when totally wetted, result in an elongation of the pathways and thus a delay in the forming of pathways. Also, the type of pigment can influence the inclusion of water in the coating, which will influence the degradation.[32,33]

•Resistance for Starting Corrosion

After conductive pathways are established, the protective properties can be quantified by the R_c, Y_0, and the n-value derived from respective equivalent circuit. These values that can be measured in an early stage are indicative for long-term behaviour [8,11,12,17,31].

R_c is an indication for the resistance of transport of charged species through the conductive pathways, and Y_0 is an indication of the amount of polarisable groups.

After conductive pathways are established, anodes will develop, and this development will be retarded by adhesion, resistance to transport of corrosive species, and a slow development of the conductive pathways.

The formation of the total corrosion cell needs a surface where anodic and cathodic reactions can take place. This development will be retarded by adhesion and inhibition resistance, as well as barrier properties (resistance for transport of ions), and (R_c) the resistance for corrosive species to be transported to the substrate.

(ss)Retarding the corrosion process

When a corrosion cell is formed by the development of the anodes and cathodes, this eventually results in a measurable, metal double layer capacitance (Q_{dl}) and charge transfer resistance (R_{ct}). From this point on, corrosion progresses at the bare metal substrate at the interface. Q_{dl} provides an indication of the development of the electrochemical double layer, which can be related to the progress of delamination. R_{ct} is the charge transfer resistance and can be related to the corrosion rate. Besides this, adhesion has to be overcome for development of the anodes and cathodes. In this way, especially wet adhesion can also be related to the corrosion processes as measured with EIS.[31]

The rate-determining step in the corrosion process is the transport of ions to the metal surface, causing discharge of the corrosion products. Based on this, the earlier measurable R_c is important, because it is the resistance for ion transport trough the coating.

Oxide formation will result in stresses in the coating material that can result in microcracks.[10] Tensile strength and elongation are parameters that quantify the resistance to cracks.

•Delamination

Because coatings on steel are mostly damaged by cathodic delamination instead of anodic undermining, the transport of cations (sodium) is the rate-determining step for coatings on steel.

To provide information about cathodic delamination besides the EIS measurements, a test was developed according to the ASTM G8. In addition, adhesion is also an important parameter, not only in this phase, but also to avoid osmosis. Dry adhesion can be quantified using a pull-off test. Wet adhesion, however, is hard to measure, but the corrosion processes as measured with EIS (especially Q_{dl}) provides information about it.[31]

The reduction of corrosion by using anti-corrosive additives is by definition temporary, and after these additives are depleted, the substrate will start to corrode anyway. In addition, many anti-corrosive pigments are ionic salts (hygroscopic) and therefore require water to work, thereby accelerating the first steps of degradation.[5,6] For initial impedance measurements at 21 C, these pigments can give a relatively good coating resistance that is caused by the inhibiting effect of the pigment, but this protection will not last for long.[14]

If one uses anti-corrosive pigments, the pigments providing cathodic protection are preferable, in addition to the earlier mentioned flake-shaped additives. However, selection based upon coating ingredients is no guarantee for a good coating.

•Summarising

Based upon the degradation mechanism mentioned before, properties to be tested are selected. The most important functional coating properties are adhesion, tensile strength, elongation, and impact resistance. To quantify corrosion protective properties, EIS provides very useful and reliable information. For more specific circumstances, the abrasion, temperature, hardness, and chemical resistance are important. A selection of several quantifying standard test methods is presented in Table 1.

Table 1 A selection of test methods used in addition to EIS.

Property	**Test Method**
Adhesion	ISO 4624 Pull-off test for adhesion
Tensile strength, Elongation	ASTM D2370 Standard Test Method for Tensile Properties of Organic Coatings
Impact resistance	ASTM D2794 Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
Corrosion resistance	TNO IV-34, Determination of corrosion protective properties of organic coatings using Electrochemical Impedance Spectroscopy (EIS)
Abrasion resistance	D4060-01 Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
Hardness	ASTM D2583, Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor ASTM D2240, Standard test method for rubber property – Durometer hardness.
Temperature resistance (°C)	Information supplied by manufacturer possibly Differential Scanning Calometry(DSC), also Tg can be determined.
Chemical resistance	Information supplied by manufacturer or ASTM C868-85(1995)e1 Standard Test Method for Chemical Resistance of Protective Linings. ASTM G20-88(2002) Standard Test Method for Chemical Resistance of Pipeline Coatings

Besides quantifying corrosion protection, EIS determines the different stages of the lifecycle of protective coatings. In this way, EIS can quantify the condition of weathered protective coatings and, as such, can be used for coating inspection.

Results and Conclusions

Combining EIS measurements with physical and chemical test results enables quantification of the performance of protective coatings. An exemplary qualification based upon first test results of protective coatings is presented in Table 2.

Table 2 *Qualification of physical and chemical properties of protective coatings, the values are typical test results for protective coatings.*

	standard protective coating	heavy duty coating	resistant coating
	3	2	1
Adhesion (ISO 4624)	7 MPa	18 MPa	18 MPa
Tensile strength (ASTM D 2370)	15 MPa	30 MPa	50 MPa
Elongation (ASTM D 2370)	2.5 %	5 %	7 %
Impact resistance (ASTM D2794)	2.5 J	5 J	10 J
Abrasion resistance (ASTM D4060)	150 mg	80 mg	10 mg
Temperature (°C)	80	120	200
Chemical resistance Hydrochloric acid Sulphuric acid Sodium hydroxide	pH 3 - 10	10% 10% 50%	36% 95% 80%
TNO IV-34 EIS results (after 21 days immersion)			
IZI (10^5 Hz)	$2 * 10^4$	$4 * 10^4$	10^5
IZI (10^4 Hz)	$1 * 10^5$	$3 * 10^5$	10^6
OCP (Vs. Ag/AgCl)	n.d.	n.d.	n.d.
Y_0 -value	$5 * 10^{-10}$	$3 * 10^{-11}$	$1* 10^{-11}$
n-value	0,91	0,95	0,98
R_c (Ω)	$1 * 10^7$	$1 * 10^8$	$2* 10^8$
Q_{dl}	n.d.	n.d.	n.d.
R_{ct}	n.d.	n.d.	n.d.

These results show qualification by accurate measurements for coating systems with different levels of performance and corrosion protection. To make a coating selection, the criteria to be judged must be selected upon the actual load of degradation and the protection mechanism.

In other results, shown in Fig. 6, it is seen that a zinc-rich primer can start with a very low n-value and a high Y_0, but a relatively large R_c. After a short period, the n-value and Y_0 start to rise to normal levels, and the R_c decreases to a low value. The inhomogeneous material of such a coating and the different behaviour of metallic ingredients can explain this behaviour. This also shows the importance of considering all the characteristics.

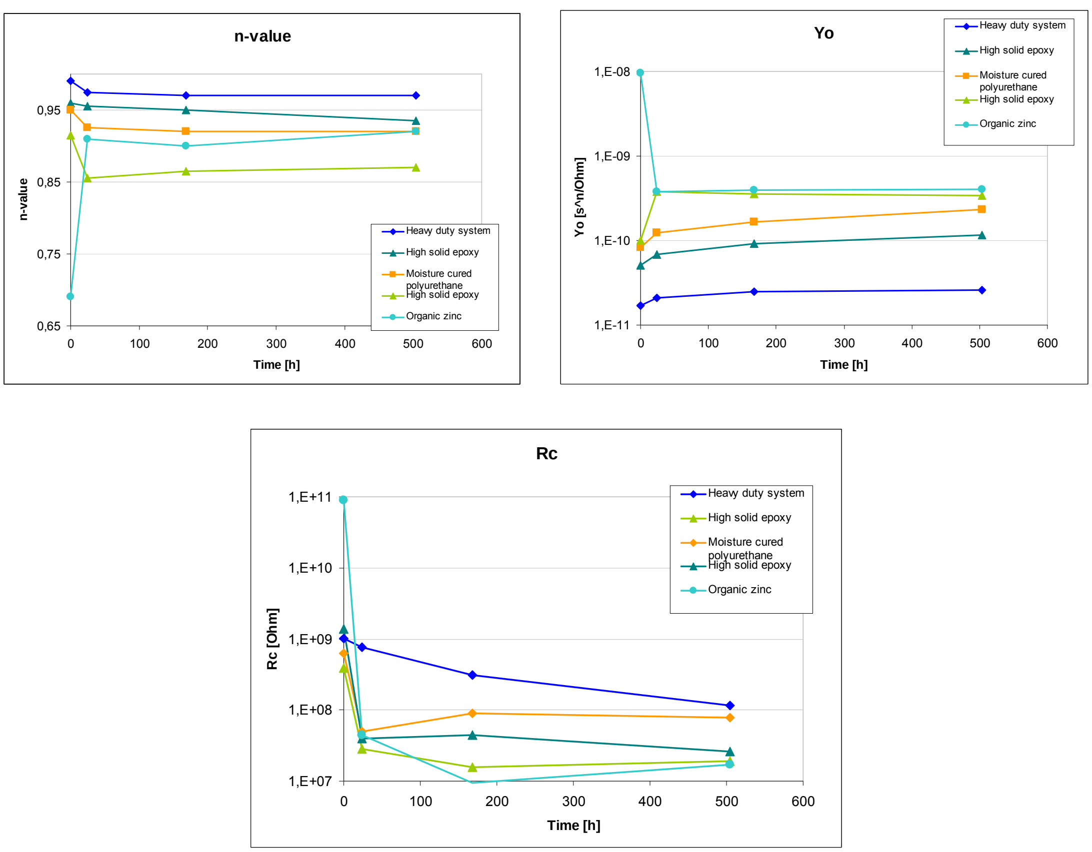

Figure 6 *Exemplary test results from the TNO IV 34 EIS test: the R_c, Y_0 and n-value of a heavy-duty epoxy, two high solid epoxy's a moisture cured polyurethane system and an organic zinc.*

Figure 4 also shows that coatings with different binders and other protective ingredients can perform on the same protective level. For example, two typical heavy-duty coatings are moisture-cured polyurethane coatings and modified epoxies. In addition, similar coating types (*e.g.*, two types of glass flake epoxy) can give totally different results and will perform at different levels. These facts show the necessity for determining products not by their binder or composition but by their level of protection and their chemical and physical properties. In other words, the performance of the coating should be the basis for coating selection.

The test results also show strong fluctuations of high R_c values. This can be explained by the presence of few conductive pathways in the coating and where the closure of one pore can have a large impact on the R_c. If more pores are present, a lower, more stable R_c response was observed.

Selection of coatings based upon accurate information concerning the level of protection and physical and chemical properties results in a more reliable and objective choice. This approach will lead to less coating failure and longer lifecycles.

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The Future of Ballast Tank Coatings

By Johnny Eliasson, Stolt-Nielsen Transportation Group, and Rodney Towers, Safinah Limited

(Based on a presentation the authors gave at a NACE International conference in 2007 in Shanghai)

Introduction

There is a great need for well-performing ballast tank coatings simply because that is what the main stakeholders, the port state control, and the general public demand of the marine industry. This demand in quality is expressed also in the International Association of Classification Societies (IACS) Enhanced Survey Programme (ESP) requiring hard coatings, which must perform to a very high standard. The Oil Majors also have their own stringent quality requirements, whereby cargo and water ballast tanks in ships they use or charter are inspected and scrutinized by other inspecting and surveying organizations. The pattern of raising the quality and performance of coatings in ship's tanks is a continuous challenge and one which the marine industry has taken seriously for many years. But there is a cost to this!

Ships operate in a truly global and very competitive business environment, and they provide an environmentally efficient service at low cost. The beneficiaries of low-cost shipping services ultimately favour the consumer, which few would deny is a good thing! However the cost of stopping an ocean-going ship and putting it into a repair shipyard for the purpose of recoating ballast tanks is phenomenal. Such repair costs have to be recovered and passed on to end users.

New construction shipyards are also working in a cutthroat, competitive business environment and strive well to build ships in a safe and environmentally responsible manner. The shipyards must follow contract specifications to the satisfaction of their customers and adjust to meeting the differing demands of customers and their varied specifications.

To deliver ships built to varying standards within the same yard using the same laborers to different customers will inevitably lead to putting stress on production. Standardization should lead to enhanced productivity, and so the quest of shipyards to standardize working methods and quality is fully understandable.

Could there be a case, therefore, for rethinking certain aspects of current coating practice and application methodology with the objective of further improving performance standards of water ballast (WB) tank coating systems?

All parties in the industry are aware of the need to rise to challenges posed by the IMO Performance Standard for Protective Coatings (PSPC) regulations, and there is common concern about how best these challenges can be met.

In this paper, the authors bring together their views based upon their respective experience in different branches of the industry. They have tried to summarise current industry practice in the coating of WB tanks. They offer some comments upon the IMO PSPC regulations, suggest some consequences for shipbuilders and marine paint manufacturers, and propose some ideas on the way forward.

This paper, therefore, attempts to take a holistic view of the problem and poses certain challenging approaches for both shipbuilders and paint manufacturers, which it is hoped will contribute towards finding new solutions for the industry at reasonable cost. The paper comprises the following four sections.

- Section 1: Current position of WBT coating systems in new construction
- Section 2: Summary of the IMO PSPC regulations
- Section 3: Some consequences of the IMO PSPC regulations
- Section 4: The Way Forward

Section 1: Current position of WBT coating systems in new construction

Shipbuilding output has now become practically dominated by three countries, Korea, Japan and China, to the extent of 75-80% of global tonnage. It is therefore clear that any assessment of the overall performance in service of WB tank coating systems will be heavily influenced by the standards of application, the type of products selected, and the quality control (QC) procedures adopted by shipbuilders in these countries. By the same token, the implementation of any new application methodology, coating system, or QC process is going to depend upon how or the extent to which proposed changes can be integrated into the very high volume construction process, which has become the outstanding feature and economic success of far eastern shipbuilding for some 40 years.

Generic types

Current practice amongst shipbuilders is to broadly offer either modified epoxy systems, or tar-free epoxy systems for ballast tank coating. The terminology of tar-free epoxy can mean any one of three main product types: solvent-borne modified epoxies, solvent-borne pure epoxies, and solvent-free epoxies.

In the general case, modified epoxies are most commonly specified by Chinese and Japanese builders, whereas yard-standard offers from Korean builders are usually pure epoxy systems. Some Korean builders are now specifying solvent-free epoxies for drinking water tanks. Only some European builders specify solvent-free epoxies for full application in WB tanks.

In summary, it appears that some 90 to 95% of WB tank spaces are now coated with either modified epoxy or pure epoxy systems, and probably less than 5% of these with solvent-free epoxy systems.

The term modified epoxy originally referred to technical modifications made to the product binder. The inclusion of some lower cost raw materials was found to improve various properties, such as surface tolerance, adhesion, and flexibility.

Coal tar epoxy became the most widely used modified epoxy in shipbuilding. When applied in WB tanks in two coats to dry film thickness between 300 and 400 microns, with good inspection, such a system could achieve good long-term performance.

However, the intensely competitive nature of the shipbuilding industry led to earlier shipyard specifications of two-coat tar epoxy systems being reduced to one-coat systems. Equally, pressure by shipyards on manufacturers to further reduce costs resulted in the manufacture of some lower cost tar epoxy products, achieved by raising the tar content and lowering the proportion of higher cost epoxy resin. The objective of these actions was essentially to find a minimum specification and cost for painting WB tanks to a standard sufficient enough to avoid claims by owners arising within the shipbuilders 12-month standard warranty.

Following concerns in the 90's about certain raw materials being used in the manufacture of tar epoxies, and in response to the International Association of Classification Societies (IACS) recommendations to use two-coat, light colour, hard coating systems in WB tanks, the industry moved on to use replacement products such as non-tar, bleached tar, epoxy mastic, and pure epoxy systems. Different shipbuilders favoured each of the different product types, and there is evidence of good performance for each type. Recent product developments in both pure epoxy and modified epoxies have been directed towards improving performance.

However, during recent years, it appears that owner preference is moving in favour of pure epoxy products and away from modified epoxies.
The preference for solvent free epoxies by some European shipbuilders is partly driven by their having to comply with the EU Solvent Emissions Directive (SED) and their contribution towards improving health and safety during application in shipyards which, in itself, is a positive development.

Solvent-free epoxies tend to score well technically with characteristics, such as good retention at edge due to slower flow and lower internal stress in some formulations. While both these properties are desirable for long life performance in the WB tank environment, the reduced flow also means less opportunity for surface wetting. Some progress has been made with improving their rather slow curing at low temperatures, but the improvements achieved have, so far, not proved sufficiently attractive for adoption by any of the major far eastern yards. A good coating product, therefore, must meet the needs of both the shipbuilder and the shipowner before it can become a solution.

Secondary surface preparation

A widely recognised and much talked about issue is that of how to treat sharp edges found in tank internal steelwork. Early coating failure has long been observed to begin on sharp edges where paint thickness has been much below the specification thickness on flat surfaces. The purpose of grinding sharp edges and stripe coating, therefore, was to promote the build-up of greater coating thickness over sharp edges, rough welds, and other surface defects.

It has been industry practice for many years to pre-treat steelwork in fully coated cargo tanks in this manner. Sharp edges arise from plates (which have been gas or plasma cut), rough welds, weld undercuts, construction lugs, and the sharp edges of stiffening bars. Steelwork pre-treatment work is usually carried out at the panel assembly stage and does require additional manhours at some yards.

Whilst WB tank coating systems can fail prematurely if such steel pre-treatment work is not carried out, industry practice and indeed performance in WB tanks has varied widely.

The extent to which sharp edge treatment in WB tanks is actually undertaken varies greatly through the industry. Current practice seems to be far removed from any common standard, and whether edge treatment is carried out or not may be dependent upon how the paint specification has been written or acceptance or not of some additional cost by the shipowner in the building contract.

It should therefore come as no real surprise to the industry to find that the IMO PSPC regulation seeks to impose some common standards across the global shipbuilding industry by adopting standards of good coating practice, which have proven beneficial when coating other locations in ships.

Application practice

The major shipbuilders have all constructed large block coating halls during the last 15 years or so. At the present time, the block coating facilities in Korea lead the field in the Far East. In Europe, particularly in Germany, Denmark, and The Netherlands, there are also some excellent block coating facilities. In general, the size and type of ships built in Europe are of smaller deadweight tonnage than in the Far East, and the WB tank spaces tend to be smaller in surface area and harder to access.

Block coating, in both large and small shipyards, is often a bottleneck in the fabrication process and consequently becomes a critical time constraint on overall production. Shipbuilders, therefore, with their primary focus on production, will always seek a coating process that will minimise the cycle time of blocks in the coating cells. Whilst the time to apply and check a typical WB tank 2-coat system will be controlled by the time each coat takes to be dry enough to walk on, the overall application time for a 4- or 5-coat exterior hull system will be limited by minimum overcoating intervals. If application, stripe coating, and QC checking of the WB tank system should take longer than the overall time to apply the exterior hull coating, then the WB tank system becomes more critical, and methods of reducing this critical time will be of interest to shipyards.

Each yard has been free to develop their own system of work that will fit best with their facility and the type of vessels they build. Coating facilities vary greatly in size and capacity. There is no common standard that might describe the extent of application that will be carried out within the block coating facility and how much may be carried out in the open after removal of the block to some intermediate or post-erection storage area.

Application practice of recent years appears to have approached the common standard of a 2 coat epoxy system with a nominal dry film thickness (ndft) of 250 to 300 microns. Common standards for stripe coating practice remain less than clear.

Current shipyard practice is to apply either one or two stripe coats. Despite many advances in industry practice in recent years, there are still some yards that are going to have to seriously upgrade their WB tank coating practice when IMO PSPC comes into full force mid-2008. It is already in force for tankers and bulk ships of specific sizes, under IACS Common Structure Rules (CSR).

Inspection procedures

In a typical application of a 2-coat epoxy system, including 2 stripe coats to WB tank areas at block stage, the following sequence of work is a common practice approach.

New building Shipyards[1]:

- Steel Preparation
- Inspect
- Secondary Surface Preparation
- Clean
- Inspect
- Coat
- Inspect
- Stripe
- Coat
- Stripe
- Inspect

There are four separate stages in the sequence where QC inspections are required. In accordance with the new IMO.215(82) PSPC[2], these inspections must be jointly agreed upon and made by properly approved Inspector/s. This does not mean that other inspectors cannot also be involved.

Current problems in service

The principal failure characteristic of the high-solid type epoxies, currently so widely specified and applied in WB tanks, is one of cracking. Coating cracks are caused by internal stress released by shrinkage. The most common locations to exhibit this problem in WB tank spaces are block joint areas and on butt, seam, and fillet welds.

In the authors' general experience, 70 to 80% of cracking failures will occur within the shipbuilders normal 12-month warranty and so will give rise to a claim against the builder by the ship owner. The shipbuilder will then pass the problem forward to the paint supplier to examine and resolve. Sometimes, such failures take longer to develop and can then become an unanticipated cost problem to be resolved within the owners' maintenance budget.

There can be several causes to the internal strain (stress) causing such cracking to occur, including excessive film thickness, poor surface preparation, poor product formulation, incorrect over-coating intervals, internal stresses, movement of lower scantling high tensile plating, retarded solvent evaporation (poor ventilation or too cold steel), and thermal cycling of structure adjacent to heated cargoes. There may be a combination of these factors.

Block joint areas are the most susceptible to such failure. Cracking around butt, seam and fillet welds, as in photo 1, are other locations for early coating failure. This usually arises from excessive power tool cleaning, which may have polished the metal and left no surface profile.

In a written response[3] to IMO.215(82) on the draft regulations, the following comments summarise the problem: "the cost and difficulty of abrasive blasting at post-erection has meant that power tooling methods have become accepted practice in many major new-building locations," and experience led this party to conclude "that general coating performance is inferior on 'join-up' areas compared to that found on the main body of the tank coated at block stage." The IMO 215.(82) PSPC[2] does allow power tool cleaning of erection join areas since this is the common practice today in most yards around the world. The text does state Sa 2 ½ where practical, indicating that it is aware of the inferiority of power tool cleaning as compared to abrasive blasting in terms of predictable performance.

Photo 1   Typical example of cracking at weld

An important point to note is that most of the cracks run laterally across the weld. This shows that the coating first detached, or became delaminated, from the steel, which is an adhesion failure. In this case, the cracking or cohesive failure of the coating has been a secondary action and occurred after the adhesion failure.

It can be seen how the cracks mostly extend across the typical width of the stripe coat. In this case, high paint thickness may have been a principal contributing factor for the adhesion failure.

Photo 2

Photo 3

There has also been a lot of discussion and research into the way structural movement may act as a contributor to the cracking of internal coatings, but, so far, the results of laboratory simulations have not been able to show that structural movement is a primary contributing factor. Photo 3 is notable because it also shows some cracking in the coating near the angular corner of the vertical stiffening, and yet at this point in the structure there will be virtually no movement.

Cracking is also often found in corners and other local areas where the sprayer has had physical difficulty in laying down an even coat and has overcompensated from some awkward position. These situations can easily result in raising dry film thickness to levels that raise the risk of solvent entrapment and consequential stress cracking at some later period.

Further, the lower the temperature the slower the solvent evaporation, and this will give rise to increased solvent retention in the coating when cured.

Current performance

Over the years, there have been quite a few case histories where certain ship-owners, who, recognising the importance of good WB tank protection, wrote and contracted for their own high standard specifications at new building. They accepted some additional cost, budgeted for regular coating maintenance in WB tanks, and have achieved 15 years and more performance in service.

However, the fact is that current performance of WB tank coatings in general is still falling short of the forthcoming IMO 15-year target life for these areas.

Learning from the manner of current coating performance in WB tanks, there appear to be four main issues.

1. Raising the general standard of WB tank coating practice in some shipyards, and in particular the standards of secondary surface preparation and application
2. Researching new coating products to improve performance, achieve better resistance to cracking, and that will remain manageable by the applicator.
3. Changing the general approach of some ship-owners to accepting the need for some planned and regular WB tank coating maintenance and to cost this into their repair budgets
4. Providing easier, more objective methods of inspection

The best of past practice in the industry certainly suggests that IMO's 15 year performance target objective is entirely realistic, but to raise the general level of coating performance still requires good specification, good work, and good maintenance to achieve the "GOOD" standard required by the IMO 215(82)[2] PSPC.

Section 2: Summary of the IMO PSPC regulations

The IMO document is long and detailed. It is in the public domain and can be referenced easily. This paper will now summarise some of the main requirements for coating systems.

Primary aims

The primary aims[1] of the PSPC are the following.

- To achieve a 15-year target life performance for ballast tank coating systems, after which time the overall condition of the coating system can be surveyed and described as being 'Good,' where 'Good' condition is defined in resolution A.744(18) and is "minor rust spotting affecting < 3% of flat plate surfaces, and < 20% of welds and edges"

- To influence the wider adoption of better coating systems with reduced maintenance

- To improve safety at sea through better structural protection of WB tank steelwork and reduction in steel wastage

- To highlight the need for good coating system maintenance supported by an appropriate costing system to achieve the 15-year target performance condition

- To make the ballast tank application more transparent

In a nutshell, the aim is to achieve a better level of protection performance than the coating system in photo 4.

Photo 4 Typical condition of tar epoxy system in topside WB tank after 7 – 8 years, using present methods and coatings.

Principal requirements[1] of WB tank coating systems
Principal requirements of WB tank coating systems shall be the following.

- Selection of the coating system shall take into account the in-service conditions and planned maintenance.

- All coatings shall be epoxy based or equivalent and consist of multi-coat layers of contrasting colour.

- The top coat shall be a light colour

- All coatings shall have a Statement of Compliance or Type Approval Certificate issued by a third-party independent of the coating manufacturer.

Principal requirements[1] for coating system approval

- Epoxy coatings or equivalent shall be allowed

- Testing must have been carried out to the defined standard in Annex 1 of the PSPC or equivalent (e.g. Marintek B1).

- Epoxy-based systems in existence before the entry into force of these new standards and new alternative systems shall require documented field exposure for 5 years, with a final coating condition of not less than "Good," or laboratory testing.

- All independent test laboratories must meet requirements set out in International Association of Classification Societies (IACS) Uniform Recommendation (UR) Z17[4].

Most coatings used today have already passed Marintek tests with a B1 rating.

For block stage application
Secondary surface preparation shall be the following.

- Sa2½ standard of preparation on welds and damaged shop primer

- Sa2 standard, removing at least 70% of intact shop primer if the shop primer has not passed a pre-qualification test as part of the applied scheme

- Water-soluble salt levels on the steel after surface preparation, but before painting, are specified to be less than or equal to 50 mg/m² sodium chloride. Conductivity is measured in accordance with ISO 8502-9.

Steel profile shall be 30 to 75 microns or that recommended by the coating manufacturer and is according to ISO 8503-1/3 as per the shop primer specification

Paint thickness and number of coats are specified as follows.

- Nominal system dft to be 320 microns in total with inspection following the 90/10 rule.

- Paint thickness should beachieved in a minimum of 2 coats and 2 stripe coats

- Typical specifications will be 2 x 160 microns, but coats of differing thicknesses are allowed.

- It is understood by most observers that the stripe coats shall be carried out by brush to edges and welds, and roller to be used in scallops, etc., only. The text is, however, ambiguous, and IMO will be required to clarify this at an upcoming conference.

- The second stripe coat may be omitted on welds if the ndft can be met by the coats applied.

Photo 5 Typical example of good stripe coating. Note the care employed not to over build.

For block joint areas and damage repairs
Steel profile is not specific, and the regulations essentially avoid the issue.

Secondary surface preparation shall include the following.

- Butts ('join ups') should be prepared prior to coating to "St3 or better or Sa2½ where practical," as per ISO 8501-1. The text says "or better," which indicates that IMO were not only concerned but expects improvements. IMO concluded that it was not ready to mandate a higher standard at this point.

- Small damages, up to 2% of the total area, are to be prepared to St3 standard prior to coating.

- Contiguous damage over 25 m² or over 2% of the total area of the tank should be prepared to Sa2½. Care is to be taken not to damage surrounding areas.

- All coating repairs are to be feathered in the overlap

Paint thickness and number of coats shall be the same as for the block stage application.

This is essentially the common practice in most shipyards today!

The Coating Technical File[1] (CTF)
This composite record of all data relating to the WB tank coating system and its application during new construction, must be compiled by the shipbuilder. A fully complete and audited version must be handed to owners on delivery of the vessel. This is an entirely new requirement for WB tanks, and the responsibility for it has now been properly placed with the shipbuilder.
The Coating Technical File will contain the following documents.

- Statement of compliance or Type approval of coating
- Documented performance records of the coating and criteria for selection
- Specification
- Technical data sheet supplying all data needed
- Shipyard work (and owner) records: location, times, surface preparation, environmental conditions, etc.
- Inspection procedures and repair of coating during construction (and also in-service maintenance)
- Coating log issued by the coating inspector
- Shipyards inspection report

All of the above information must be brought together, and it will help all parties if the format can be such that the information therein can be easy to access, easy to understand, and user-friendly for the ship owner to maintain what should increasingly become a really useful onboard database for each ship to guide future maintenance to keep the tanks in “good” condition.

It is the authors hope, therefore, that detailed attention will be given to these points, because the alternative might be that CTFs could become just an unused document, containing a massive amount of useful data which the ship just carries on board for its entire life.

Section 3: Some consequences of the IMO PSPC regulations

For Shipbuilders[1]

– Many yards will have increased QC work to do during both block stage and *in situ* applications of WB tank coatings. Whether this work is done by the painting subcontractor or by the yard’s own team manpower, there will be an increase in inspection man hours. Increased inspection time may lead to some addition to the coating cell cycle time for each block. Some relatively minor increases in QC costs seem a likely consequence.

– Lead QC personnel are required to have qualifications to Frosio level 3, NACE level 2, or equivalent. A surge in demand for the training of such personnel can therefore be expected in all shipbuilding countries. There will be both an initial and an ongoing additional cost of training personnel to these standards.
In fact, the Inspector charged with validating the IMO 215(82)[2] compliance has to be certified. Other inspectors do not.

– Yards are responsible for compiling the CTF. The systematic collection and assembly of the necessary information will therefore be a yard cost.

- Some yards may have to consider the investment cost in new or additional coating facilities, something that progressive shipyards have been doing for years, simply because of the gains in productivity and financial returns which may follow.

For Marine Paint Manufacturers[1]

There will be additional costs arising from the following factors.

– The need to outsource independent testing of new coating products and systems to obtain mandatory approvals

– The need for these independent test laboratories to meet requirements set out in IACS UR Z17[4] will create its own additional cost of testing fees these labs will charge paint manufacturers

- The coating manufacturer having to meet the requirements of

IACS UR Z17[4] at all of their overseas factory locations manufacturing ballast tank coatings

- Identical Products manufactured at different locations must be shown by infra red and specific gravity measurements that they are identical to that tested, or individual approval tests will be required from each location.

– Preparation of new data sheets

– Training of some Field Technical inspection personnel to the same Frosio, NACE, or equivalent levels as for shipbuilders. It shall be noted that it is the agreed person in charge with the validation of the standard who must by Certified. Other persons can perform inspections as well.

– The need to supply personnel with higher levels of qualification than hitherto. Higher levels of qualification usually carry an expectation of higher salaries. In addition, more personnel might be required.

- Less failures and claims can be expected as a result.

A general consequence of raising the cost of the whole inspection process to all parties will create a new business environment in which the cost of inspection services becomes a more visible cost for all parties.

Some other consequences of this huge testing regime seem likely to make coating manufacturers carry out more exhaustive in-house testing of WB tank coating systems before committing to expensive third-party testing.

However, whilst the cost of system testing is viewed by manufacturers as expensive, it is useful to give this matter some perspective by considering the following.

The cost of a full ship supply of all WB tank coatings for a VLCC newbuilding is in the region of $1.5 million. The cost of testing one WB tank coating system over one shop primer is about $6000 or 0.4% of the WB tank coating supply value for one ship. However, the coating system may have to be tested over 10 to 20 leading shop primers, and so the total testing cost might be as high as 4% - 8% of the supply value. If the shipyard application cost were to be added, then the total cost of the WB tank coating installation may be in excess of $5,000,000. Wwhilst the relative cost of the testing falls, it could still be in the range 0.1% - 2.4% of the value of the installation cost.

If the WB tank coating should fail and the WB tanks were to be recoated, the total cost for supply of coating material and application would be in the region of $20,000,000. The cost of testing would then be in a range of 0.03% - 0.6% of the total recoating work.

For smaller ships, such comparison of the cost of testing will appear proportionately higher. However, in practice the paint manufacturers will need to defray these costs across their total new construction supplies.

***For Shipowners*[1]**

Shipowners and operators of large tankers and bulkers, especially for ships in which the WB tank areas are large, can expect the following.

- New building prices will increase.

- Ship owners will have to maintain the ballast tank coating

- Coating Technical File (CTF) will be on board each new ship. The format of this document should allow subsequent records of coating maintenance carried out to be entered and maintained.

- Ship owners will see considerable financial benefit from the reduced costs of recoating, which should feed into lower through life costs. (If not a considerable improvement why do it.)

Section 4: The Way Forward

The IMO PSPC regulations

Initially, these new regulations seem certain to result in some additional costs for both shipbuilders and paint manufacturers, which builders and paint manufacturers can be expected to try and recover through price increases.

The regulations mandate a new requirement for higher standards of steelwork preparation than some yards are used to, more product testing and laboratory approvals, training of personnel to higher levels of inspection competence, and additional documentation and record keeping.

The cracking problems being experienced with both modified and pure epoxy-type products when sprayed cold or over-thick, and with regard to adhesion in the block joint areas, are occurring because of technical characteristics of such products. These problems are not likely to be eliminated by these regulations, but since the suppliers are in fact required to supply product systems for 15-year performance, it might help. This is particularly interesting in the block joint areas, where the regulations leave the surface profile specification out of step with that specified for the main block areas.

The problems of secondary surface preparation on the block joint areas are essentially of a practical nature. There is no easy way to achieve an even surface profile in the range of 35 to 75 microns in these interior spaces, due to an industry reluctance to develop a more productive, portable vacuum blasting or Sponge-Jet type technology, which can deal with the structural profiles used in shipbuilding construction. The power tool option is therefore used, and the tendency is to polish and eliminate the original surface profile to give a bright ST3 finish, which is clean and looks good visually, but in fact a rougher surface is needed to promote paint adhesion. It is common practice to use higher texture grinding discs to enhance the situation, albeit not generating an equivalent surface profile to that achieved by grit blasting.

For Shipbuilders

This is a time for a lot of new thinking on how to manage the new requirements arising from the IMO PSPC regulations. However, shipbuilders should not feel locked into a box of current products and standards, because it is stated several times within the IMO PSPC regulations that alternative products and innovation are encouraged.

If current estimates of consequent loss in productivity and additional costs are even remotely found to be correct, the major shipbuilders are likely to react and disallow such productivity loss to become permanent. This will stimulate more intensive research by shipbuilders into alternative and faster methods of application of WB tank coating systems. The objectives of such research will be about how to gain productivity and reduce costs as a consequence of the new IMO regulations. The directions of shipyard research might therefore focus upon the following points.

- **Block coating**

  Find products and methodology which could speed up the processes of paint curing and QC procedures. This might allow blocks to be moved more quickly from coating cells and might be a counter action against loss of productivity.

  Find new coating materials with tolerance to higher relative humidity than the current norm of 85% and lower temperature curing than the +5 deg C limit of many epoxies. Such wider application limits might enable shipyards to make some cost savings in their operation of environmental controls used in block coating cells during application.

- **After erection**

  Consider the possibility of using alternative coating materials in these areas. Waiting for new technologies to become more acceptable, the shipyards have only limited practical options for carrying out secondary surface preparation in these locations, and they seem likely to continue with the general use of power tools. In that case, varying standards of surface finish will continue to be the norm in practice. Therefore, a different type of coating might be better suited to the conditions of application in these areas. The coating overlap adhesion and likely in-service performance would clearly have to be tested.

With productivity being shipyards' primary issue and if shipyards should conclude that some innovative coating process and material, could reduce coating cycle times, improve productivity, and yet deliver a better performing, long life WB tank coating system, then they could decide to treat the application process as a shipyard engineering issue. If the potential benefits from such a change should be found important enough, shipbuilders may conclude that it would be in their best interests to exercise more control over the process, even to the extent whereby yards will specify the WB system(s) they will provide. The authors have learned that at least one major Korean shipbuilder has taken the first steps in this direction. This would also mean that the yards would assume more responsibility for the performance of the coatings.

Shop primer has long been a shipyard supply item because of its impact on construction processes. Similarly, in the auto industry, the customer can choose the colour and kind of finish, but they have no say in the primer process and product selection. Such decisions are part of the engineering process, fundamental for guaranteeing better performance, and selected by the manufacturer. Likewise, coating performance expectations in the auto industry are much longer than the 1-year warranty typically given by shipbuilders.

•Inspection and data management
Develop better and faster systems for inspection and collection and collation of data to generate the required CTF documentation and speed up the inspection process.

For instance, if one dft reading is taken every $5m^2$, across 250,000 m^2 of WBT area in a VLCC, this means 50,000 readings will need to be recorded. A system for processing this data to meaningful conclusion, formatting for entry to the CTF and retrieval for audit purposes and to feed into the future planned maintenance through life, is clearly going to be required. With the objective of minimising total time and effort, a number of such systems are now being developed to help shipyards compile the initial CTF and then help owners continue with the appropriate entry of coating maintenance data during the vessel's service life.

For Marine Paint Manufacturers

Following on from the previous section, where some perceived needs of shipbuilders have been suggested, this could now become a time of great opportunity for marine paint manufacturers.

It will be very surprising if, in 15 to 20 years' time, major shipbuilders are still applying two-coat epoxy systems in WB tanks according to coating methodology generally in use today.

WB tank areas are just too big in terms of square metres for shipyard painting and too important in terms of the structural integrity of the hull for the industry to accept the status quo to continue with regard to both product and methodology. Essentially, the industry is still geared to coating technologies pioneered in the 1940's and significantly re-engineered in the 1960's. However, cost and productivity issues, which are being triggered by the new IMO PSPC regulations, are of a magnitude sufficient to initiate a major drive for change in shipyard coating methodology.

Marine paint manufacturers are well aware of their need to follow and satisfy the demands of their shipyard customers, and there can be little doubt that important research projects will already be in the pipeline. Coating manufacturers must now also focus more on performance, with a 15-year life demand – a positive change.

Short to near term view: 1 – 5 years

•Solvent-borne epoxy systems

Efforts will likely be concentrated upon the improvement of existing epoxy products already accepted by the market. Primary effort to reduce internal stress and thus improve flexibility in existing WB tank products seems probable. Internal stress in coatings has been one characteristic attributed to some cracking failures in recent years, and so improving on that, and thus lowering the propensity to crack, should contribute to better longer-term performance. Any modification should not negatively alter other vital characteristics such as water resistance (vapour transmission rates, etc.).

It is worth restating that not only is the cohesive strength important, but also the adhesive strength, and these strengths must be matched. To have a fully cohesively intact coating not adhering because it has been pulled off by shrinkage does not help much.

There are also some new products in the market that claim to have improved resistance to cracking. Information on one of these, described as fibre reinforced, was presented at PCE Marine[5] 2006. It is still too early to review in-service feedback reports.

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In recent years, other manufacturers have made improvements to the edge retention characteristics of some epoxy products, and research in this area will no doubt continue. This must, however, not come at the expense of other vital characteristics, such as flow and wetting. Raising the volume solids content has been another general and ongoing development.

•Solvent-free epoxies

Solvent-free epoxies, in general, do have far better flexibility. They offer the best environmental response in terms of future pressures on shipyard painting practice, and further product development of this type can be expected. However, at present, some solvent-free epoxies have other characteristics that are not so user friendly for yards with high rates of block throughput. For example, drying times are sometimes slower, which impedes walk-on QC inspection; low temperature curing versions are still in general slower than with normal epoxies; and there is concern about their surface wetting ability because such products do not flow much after surface contact. They have in general, however, better edge retention as a result. There are also very fast curing solvent-free epoxies on the market, and new curing agents have made faster and lower temperature cure possible and much safer than with solvent-borne epoxies. The solvent-free systems generally require application by plural-component pumps for proper control of the mixing and spraying process. This type of pump is more expensive than the standard airless spray type widely favoured by shipyards for many years.

Some yards are specifying this kind of product for application in relatively small tanks which are spray applied *in situ*. Drinking water tanks are an obvious choice. Some Japanese yards have been using this kind of product for this purpose for many years, and more recently some Korean builders have begun to favour these products for the same purpose.

•Rapid cure systems

Interestingly, in the United States the NSRP Technical Panel[6] SP-3 reported in 2005 that Navsea was researching technologies for single-coat, multi-pass, rapid cure systems in tanks with the purpose of improving application productivity by eliminating two stripe coats and all the associated QC inspection work. If such an innovative approach can confirm good performance, then the applications engineering aspect of such technology must be of serious interest to commercial shipyards. The authors understand that this research has recently reached the stage where some poly-novo, solvent-free system will undergo shipyard application trials shortly.

If such tests should prove satisfactory for the block coating process, and if a practical application solution for block joint areas can be found, there will still be the issue of establishing customer confidence in such technology in what has long been a traditional and cautious market.

If this US technology, mentioned above, does prove manageable by shipyards and can be shown to reduce the block coating cycle time for WB tank areas, then a challenging scenario might develop. A successful outcome of this work might lead logically towards the development of a whole new range of products based on this rapid cure technology. Such products might be technically suitable for use on other locations, such as on decks, in cargo holds, or on the exterior hull above the waterline.

•The Dual Bonding Mechanism (DBM) approach
The marine paint majors have long been aware of the differences in standards of secondary surface preparation, physical access, and degree of environmental control with which they have to contend between blocks coated in a purpose built painting cell and block joint areas coated inside the ship structure. Since this part of the modern ship construction process is a fact of shipbuilding life and unlikely to change, why not recognise this major difference in application conditions between block and block joint areas?

Instead of having to use the same product for the total internal WB tank area, why not consider developing a block stage product with the primary need of aiding shipyard productivity and an associated objective of countering the potential loss in productivity that some shipbuilders are currently predicting? Of course, this will result in additional testing requirements.

•Main coating applied in block coating facility
The constant demand on block coating cell space points to the need for a product that will greatly speed up the drying process so that walkover QC checks can be made very soon after application. Yet, the product should retain a maximum overcoating capability, so that a second full coat application can be made within hours. This idea envisages that two full coats, and stripe coats, can all be applied, QC checked. and the block complete its full WB tank coating cycle in 24 to 48 hours. This should go a long way towards helping shipbuilders gain productivity above the present situation. How shipbuilders then decide to balance or integrate the block coating of the external hull will become another issue. It is, however, quite possible that solvent-free systems of similar characteristics can be used on other areas, reducing the number of coats and application time.

•Coating of block joint areas in the ship
As explained earlier, surface preparation standards in the block joint areas are generally lower than for the main block. Therefore, why not consider a separate technical approach towards better product performance when application must be done under these different conditions?

The primary requirements suggested are good adhesion, low internal stress, and good flexibility. However, the most important difference between the *in situ* application and the coating cell application is that the secondary surface preparation of the block joint area, carried out in the ship, can often remove the surface profile. This therefore raises the question about whether it might be better to consider a coating for block joint areas that can develop its adhesion to ‘ smooth’ steel by a chemical process rather than by mechanical adhesion, which the surface profile provides, and that is what the coating cell enables?

The chemical process would mean stimulating some reaction between the wet paint and the steel surface. There may be several technical routes through which such a chemical bond might be achieved.

This approach would use two different products, each of which gain adhesion by different principles. These actions might therefore be described as ‘dual bonding mechanisms’ or the DBM approach.

The concept of using two different products to form one system with the first coat of the system acting as a ‘glue‘ coat is not that new. Remember the old T-wash to make vinyl coatings stick. Of course if a ’glue’ coat should be developed and prove successful in the WB tank environment, then this might open the door for a much wider application of the concept.

A solvent-free product that maintains a safer working environment within WB tanks would be a bonus but is not essential. Colour matching would be , but some shade difference might actually be an advantage in a WB tank, if two different suppliers were being used.

Good adhesion across the overlap with the block coating would be fundamental, and the question inevitably arises, “over what?,” if one manufacturer was unable to supply approved products for both the block coating and the block joint area. There would therefore be issues about testing for the parties to resolve. Clearly, it will also be very important to gain owners confidence. Whilst this hybrid approach might be unusual, it could be technically possible.

WB tank areas of large, double hull tankers can typically be 280,000 to 300,000 m2 per ship. Therefore, if block joint areas and damages totalled 5%, this would mean 14,000 - 15,000 m2 per ship. This is no small area, and would actually be a large supply contract for a small manufacturer holding some special technologies in maintenance, assuming the manufacturer could obtain PSPC approval for their product. If such a product were to be used in the block joint areas, then it would become first choice for any ongoing maintenance and coating repair for the ship’s WB tanks once in service.

Shipyards’ normal procurement policies are to limit suppliers to one or two manufacturers per ship. However, if any products should be found by the shipbuilder to be particularly suitable for use in block joint areas, and the manufacturer was not the same as that favoured for the main block coating supply, then this hybrid approach, using best technologies from two different manufacturers, might be workable. The shipbuilder will always be in a position to pull such concepts together within the terms of their Shipbuilders Warranty, but it will be the performance of the products and systems themselves that will have to generate sufficient confidence with shipbuilders to convince them to take such steps.

Mid term view: 3 - 8 years

•Innovative primer system
There were big problems in the auto industry some 15 to 20 years ago when bodywork paint systems were found to be generally deteriorating after even 2 or 3 years, a situation that customers found unacceptable.

One manufacturer researched the situation and came up with a completely innovative methodology and product type for priming the steel bodywork. This resulted in far superior performance and has subsequently been wholly adopted by the auto industry. The consequence of adopting this technology enabled auto manufacturers to work out a new deal for customers, where success of the process has led to bodywork perforation warranties these days of 5 to 7 years. Against a shipbuilder's standard 12-month guarantee for a WB tank coating system, the marine industry offer is miserable by comparison.

Is there therefore something the marine industry can learn from the auto industry's approach? It will be healthy development if the IMO PSPC regulation can stimulate rethinking about the WB tank requirement in conjunction with the ship construction process, and the primary interest of the shipyard in fabrication and block production.

•The 'glue coat' primer proposition
Two questions are now posed.
1. Why should the first coat and second coat have to be of the same material?
2. Can some technical combination of different coating products produce a system suitable for 15 or even 25 years performance in the WB tank environment?

We will look further at both questions.

The history of WB tank coatings is remarkably simple and uncomplicated. Hand-applied grease coatings first became available around 1910. These were low-tech products, inexpensive, highly effective, and they often lasted the life of the ship. They were mainly applied as an owners' extra in UK shipyards when the UK was a major world shipbuilder. Their disadvantage was that WB tank special survey inspections were a hazardous nightmare.

Then one-coat applications of cement wash or bitumastic were adopted by shipyards during the 30's and 40's, these being cheaper and cleaner systems for both application by shipyards and subsequent tank inspections. Both coating types were of a brittle nature and their useful lifetime was far inferior to the performance of grease paints. Both systems were still being offered in yard-standard specifications during the 50’s and 60’s.

The big ships, which began emerging in the 60’s, had greatly increased WB tank areas to protect, and hand-applied coatings became utterly impractical. The response of manufacturers was to either ‘hot’ spray *in situ* a new type of grease paint or cold spray the new tar epoxy hard coatings. Grease paint applications were wholly impracticable for block application. As yard preference for block coating grew, tar epoxy systems, in either one or two coats, became the global WB tank coating standard until the IACS recommendations of the 90’s.

Some owners, mostly American, had a preference for one-coat zinc silicate systems instead of tar epoxies. Zinc silicates gave good mid-term protection but brought other problems in initial application and maintenance. Their use did not become widespread.

The authors view on question 1 is that because there is virtually no historical precedent for the use of any mix of coating products in WB tanks, the issue has not really been fully addressed.

The authors are, however, aware of a small number of exceptions to this norm. During the 80’s, a few progressive owners chose to meet the additional cost of applying a zinc silicate primer, and then overcoating this with two coats of tar epoxy. There are examples of very satisfactory performance of this type of mixed coating system still afloat today after more than 20 years in service, which therefore goes some way towards answering question 2 above.

This leads directly to the question of whether such a system could be successfully formulated to meet the needs of today’s high steel throughput shipbuilding. What if, therefore, the first coat was designed primarily to maximize adhesion to the zinc silicate shop primers generally favoured in ship construction today? The function of such a first coat would then essentially be that of a ‘glue coat.’ The second coat would then be formulated to form the anticorrosive “barrier.” It is envisioned that the following application cycle for such a system might then be possible.

Example; block of about 1000 m2

1	***Blast and clean***	***(No change)***
2	***Apply Glue Primer***	***Will need to be hard dry for QC inspections, not touch dry***
3	***Stripe coat****	
4	***Apply Main Coating***	***wet on wet to achieve film build in one process Will need to have fast cure characteristic***
5	***Wet Film Thickness control and spray correction by QC team***	***Floors will be coated after other work completed in main areas***
7	***Block Confirmation Inspection***	***Next day***

*The striping could be done with normal high quality, solvent based paint. The same can also be used for erection seams and damages

The challenge would be how to achieve a target time of 24 hours for the completion of the above procedures on a WB tank block.

•Application equipment
Spray pump manufacturers are usually consulted early on in the development of new technology systems because workability and application properties of the product are essential practical issues to confirm. The range of spray pumps continues to grow and requires specialist engineering in certain product areas such as the application of passive fire protection systems.

Rapid cure materials require plural-component pumps with impingement mixing for materials of short pot life. If the loss of productivity due to IMO PSPC is as real as shipyards are maintaining, and if new product technology can help speed up the application of WB tank coating systems, then the shipyards will change their methodology and gain in the process. This could, , lead to a considerable programme of spray pump re-equipment by shipyards, who might choose to go forward this way.

Summary

Ships need to have good ballast tank coating during the entire ship's service life. This will contribute towards lowering operational cost, be beneficial for the environment, be beneficial to the ship's customers, and will be overall good economy. To change steel is expensive and time consuming.

Ships also need predictable coating performance to enable proper planning and budgeting of coating maintenance.

Marine paint manufacturers have developed the specialist coating technology to protect water ballast tanks for long-term periods and have the capability to supply various products that can meet the new performance standards, as set out by IMO to satisfy the rightful demands of the primary stake holders and their various representatives; Class, Port State Control, IACS, CDI.

The challenges for the future will be about how to employ new technologies and develop new products that can assist shipyards achieve both a higher quality of initial application and longer term performance in service. Coating technologies have entered a new dynamic phase and the IMO PSPC regulations seem certain to stimulate a substantial re-thinking of the whole methodology of painting WB tanks. In most commercial ship types, the WB tank spaces are, and will remain, the largest single location in any new ship, which the shipbuilder is required to paint. It follows that R&D effort in this area should be treated with similar importance to that traditionally given to anti-fouling. The authors anticipate that the result of such research effort should lead to something more than a one-product, one-technology solution.

Shipyards, for their part, will always seek to perform at maximum efficiency and lowest cost to enhance their competitiveness and profitability. Predictable production will therefore assist shipyards in their planning, scheduling, and costing of new ships. In this way, shipyards strive to be evermore efficient and keep their prices internationally competitive. The IMO PSPC is a challenge to shipbuilders. The authors anticipate that shipyards will now be ready to explore new options in WB tank painting more than ever before. The possibility of their adopting some major changes in methodology should not be discounted.

It is the global consumer who is the ultimate end user and beneficiary of improved efficiency and lower costs in both ship production and operation. Shipping and transport remain a small but important element in the cost of all manufactured and processed goods, and it is therefore in the interests of all countries to support any new initiative that may contribute towards the maintenance of a low-cost shipping industry. There is, in fact, no other lower cost way of transporting large volumes of food, commodities, fuels, chemicals, raw materials, and manufactured goods other than by ocean shipping services. We should never, therefore, take such services for granted.

Improving long term coating performance in WB tanks has become a major issue for the industry to resolve. The marine coatings industry may be entering an exciting time for both new product and application technologies, some consequences of which may initiate substantial change in established practices and bring some positive surprises in their train for all involved parties.

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Do the Right Thing

There is a commercial on television that really makes you think. Its theme is that everyday, millions of people do the right thing, and there is a company out there doing the same. The ad is for Liberty Mutual Insurance Company. One version of the ad shows a person doing a small act of kindness such as helping an elderly person cross the street, while a third person observes that act of kindness. That observation inspires that other person to also perform an act of kindness, and the process continues throughout the entire ad. Version two of their ad campaign shows a lady in her wheelchair going down the street in the pouring rain and boarding a bus. She arrives at her location and has to go under a locked pipe gate to go into a building. You then realize that she has arrived at her destination and it is where she votes. It ends with her going to the cubicle to fill out her ballot. Again the theme is that everyday, millions of people do the right thing.

I also remember in December 2005 hearing the news about how the Iraqi people went to the polls to elect a 275-person parliament, forming a new government after the fall of Saddam Hussein. The photographs and news footage show people standing in long lines to vote and coming out with a purple dye on their finger, showing their willingness to exercise their right to self determination even under the threat of violence.

I feel that we in America take that privilege of self-determination for granted. Right now we are involved in one of the most closely contested Democratic primaries that I can remember. I live in Pennsylvania, which has one of the latest primaries in the election year. Before our primary occurs, a candidate usually has the number of delegates needed for the nomination. This year we were a battleground state, and many who normally do not go to the polls felt that they finally had a say in the process. We should not feel that way. On November 4th, we all have a say in our democratic process, and hopefully we all take advantage of that right that is protected for us by those who have sacrificed the most through our nation's history.

I know I have written editorials in the past that have urged people to vote. The insurance company commercials and the Iraqi elections make me think of how I have been taking the democratic process for granted for so many years. It just makes me appreciate the privilege I have even more. In November, I hope you join the millions of people who will do the right thing, at least for this one day, because this determines the course this great nation will take for the next four years.

Bill Shoup
Executive Director, SSPC

Finishing Contractors Name New CEO

A veteran industry executive will become the next Chief Executive Officer of the Finishing Contractors Association. The association's board of directors unanimously approved Stuart Binstock's appointment. He will join FCA on June 16.

Binstock brings two decades of senior-level construction association management experience to his new role. Most recently, he was executive director of the Management Education Institute of the National Association of Electrical Contractors, headquartered in Bethesda, Maryland. He managed a $2 million dollar budget, and supervised 40 adjunct professors and a staff of four.


Stuart Binstock

"Stuart's recent experience will be of particular benefit to our association as our plans evolve to conduct education programs to benefit our contractors," said Edward Z. Zaucha, chairman of FCA's board of directors.

Binstock said his appointment is the culmination of 20 years of experience in working for associations in the construction industry.

"My goal is to work with the board and members, to continue to work collaboratively with the [International Union of Painters and Allied Trades] and to provide products and services that will show the value of membership that will give current and future members an outstanding return on their investment," Binstock said.

Binstock previously held executive positions with the Associated General Contractors of America and the American Institute of Architects. He was an attorney for the U.S. Department of Labor with OSHA and the National Labor Relations Board.

Binstock succeeds Vince Sandusky, whose five-year tenure ended in March.

The Finishing Contractors Association, based in Vienna, VA, was formed by union finishing contractors in 1997.

Senior Leaders Announced at Hexion

Hexion Specialty Chemicals Inc. has announced the post-merger senior leaders for the company, contingent on the close of its acquisition of Huntsman Corporation.


Peter Huntsman

According to Hexion, Peter Huntsman, president and CEO of Huntsman Corp., will become chairman of the Board for the combined company. Craig Morrison, chairman, CEO, and president of Hexion, will become president and CEO. Donald Stanutz, division president, Performance Products of Huntsman, will become COO, and William Carter, executive VP and CFO for Hexion, will assume that role in the new company.


Donald Stanutz


Craig Morrison

Based in Columbus, OH, Hexion Specialty Chemicals manufactures thermoset resins. It serves the global industrial and wood markets through a broad range of thermoset technologies, specialty products, and technical support. Huntsman, headquartered in The Woodlands, TX, is a global manufacturer and marketer of products for a variety of industries, including paints and coatings, construction, chemicals, and textiles.

Sika Acquires ICS Garland Flooring Business

Sika AG's U.S. subsidiary, Sika Corp., has acquired the commercial and industrial polymer flooring business of ICS Garland Inc., a producer of epoxy, polyurethane, and ESD materials. Terms were not disclosed. Revenues for the acquired business totaled approximately $14 million for the fiscal year ending Dec. 31, 2007.

Sika, which recently acquired Valspar Corp.'s polymer flooring business, called the ICS Garland flooring business "an excellent fit for Sika's focused growth strategy for North America," and said the business "greatly enhances and complements Sika's fast-growing position in this key market."

Sika is a major manufacturer of construction chemicals including adhesives and sealants, concrete admixtures, and repair and strengthening products. Sika Corp. is based in Lyndhurst, NJ.

FSCT Members, Board Greenlight NPCA Merger

The National Paint and Coatings Association (NPCA) and the Federation of Societies for Coatings Technology (FSCT) are moving forward with a merger of the two organizations following a majority vote by FSCT members endorsing the merger plan. The FSCT Board of Directors certified the vote at its May 11 meeting, verifying that 84% of those members who participated in the process voted to approve the Bylaws changes necessary for the merger.

In February, NPCA and FSCT signed a Memorandum of Agreement outlining the details of a prospective merger of the two organizations. The agreement framed a “governance merger” that will consolidate the governance, management, and administrative functions of both groups under NPCA, while preserving each organization’s separate identities, operations, functions and member services. NPCA and FSCT will remain as separate organizations managed through a common governing structure.

The May 11 vote on changes to its bylaws was a step in the merger process.

As part of the merger, FSCT and NPCA agreed to combine the International Coatings Expo (ICE) with the American Coatings Show and Conference (ACS), to be held on June 2-5, 2008, in Charlotte, N.C. With the combination of ICE and ACS, ICE 2008 in Chicago has been cancelled. NPCA and FSCT have fully endorsed and support the American Coatings Show as the premier industry exhibition for the coatings industry. In addition, NPCA and FSCT are endorsing and supporting the FSCT’s international technology conference, FutureCoat!.

All aspects of the merger should be completed by June 3, 2008, at which time the new FSCT Board of Directors will convene for its first meeting.

NPCA is a voluntary, nonprofit trade association representing paint and coatings manufacturers, raw materials suppliers and distributors. Its primary role is to serve as ally and advocate on legislative, regulatory, and judicial issues at the federal, state, and local levels.

The Federation of Societies for Coatings Technology is the leader in technical education and professional development for the international coatings industry. FSCT publishes the *Journal of Coatings Technology and Research* and *JCT CoatingsTech*.

Cook Composites and Polymers Names CEO

Paul H. Colonna has been named chief executive officer for Cook Composites and Polymers (CCP; Kansas City, MO), effective July 1, 2008. He will succeed Charles E. Bennett, who has served as CEO since February 1998, and has announced his retirement.


Paul H. Colonna

Colonna, 47, has more than 20 years as a business management professional, including the position of vice president of Composites with CCP, which he has held since April 2004. Just before joining CCP, Mr. Colonna was with Composites One, LLC for over 10 years, most recently as general manager of their West region.

Cook Composites and Polymers produces and distributes polyester gel coats and resins. CCP has manufacturing facilities throughout the U.S., Canada, and Mexico.

CCP affiliate companies include TOTAL, Cray Valley, Sartomer Reacciones Quimicas, Composites One, and Progress Plastiques.

Jet Edge Appoints New Corporate Sales Manager

Jet Edge, Inc. (St. Michael, MN) has appointed Robert Bangasser as its new corporate sales manager.

In his new position, Mr. Bangasser is responsible for Jet Edge’s worldwide sales activities. He has previous experience in various sales management roles at all levels of the selling process and in business development. He most recently provided custom-fabricated capital equipment solutions to major OEM manufacturers as a manufacturer’s representative. He is a graduate of St. Mary’s University in Winona, MN.

Established in 1984, Jet Edge is a global designer and manufacturer of waterjet systems for precision cutting, surface preparation, and coating removal. Jet Edge systems are used in a range of industries, including industrial, airlines, automotive, and aerospace.


Robert Bangasser

Polyurea for Potable Water

Overcoming Structural Challenges for a Successful Waterproof Lining System

by Michael C. Durbin, The Sherwin-Williams Company

In the early 1900s, a small community in the mountains of western Maryland installed two below-grade potable water tanks that were open topped. Over the years, the tanks began leaking water into the basements of nearby residences; therefore, the community planned several upgrades to the tanks. The upgrades included the addition of metal dome roofs, electronic security systems with fencing, and a waterproof lining system. Contractors were invited to view the facility and bid the lining system while the tanks were still in service. Coatings work began in August 2005 and concluded in May 2006.

Fig. 1: The problematic uncapped water tank before work was done
Photos courtesy of the author

In hindsight, the inability to see the tanks empty at the bidding stage was the catalyst of many problems encountered later in the project. Many problems were hidden when the job was bid because the tanks were full, and the contractors couldn't anticipate or prepare for them. Some of the unforeseen problems included groundwater migrating through the floor and walls of the tanks, expansion joints in excess of 2 in. (5 cm) wide and 8 in. (20 cm) deep on the floor of one of the tanks, and the questionable structural integrity of the tanks themselves.

Another issue the contractor had to overcome was the timetable for the installation of the lining system: the first tank was to be lined in the summer, while the second tank was to be done in the winter. Most of the year, western Maryland has weather that is suitable for most painting projects; however, winter in the mountains of Maryland can be severe, and the 2005–2006 winter was no exception. In spite all of the problems encountered along the way, a pure polyurea lining system was installed successfully.

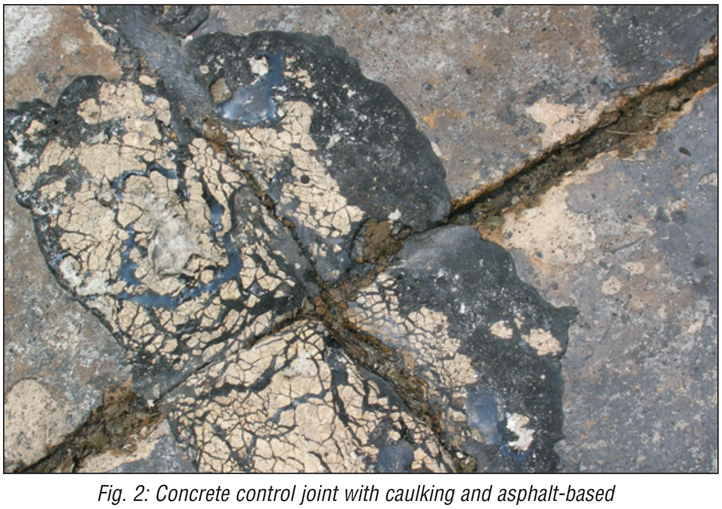


Fig. 2: Concrete control joint with caulking and asphalt-based patching material, later removed

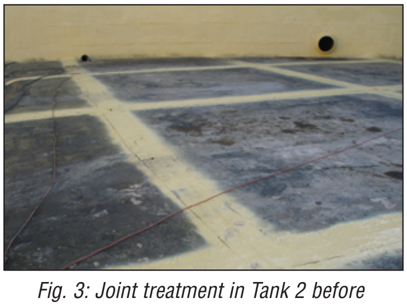


Fig. 3: Joint treatment in Tank 2 before final lining application

Continued

History of the Tanks

Tank 1, built around 1910, is approximately 40 ft (12 m) deep and 118 ft (36 m) in diameter. It had been upgraded in the early 1960s with the application of gunite to its interior walls and floor.

Tank 2 was built in the 1930s and was also around 40 ft deep, but with a diameter of 168 ft (51 m). The floor of this tank consisted of multiple concrete pads that were approximately 15 ft by 15 ft (4.6 by 4.6 m). The control joints between these pads averaged 2 in. wide by 4 in. (5 cm by 10 cm) deep, with many in excess of 8 in. (20 cm) deep. It was clear that attempts to fill these joints had been made in the past using a variety of caulking and asphalt-based materials, which now had to be removed before abrasive blasting.

As soon as both tanks were drained, it became immediately clear that water was leaking into them from the groundwater supply. Water ingress problems would have to be addressed if the contractor was to prevent the tanks from leaking into the residences.

"Water ingress problems would have to be addressed if the contractor was to prevent the tanks from leaking into the residences."

The Specification Called for Multi-Functional Lining

A consulting engineering firm was used for the project, and the specification the firm wrote was for a potable water lining system, using 100% pure polyurea approved to NSF Standard 61. That system consisted of surface preparation in accordance with SSPC-SP 13, Surface Preparation of Concrete, followed by the application of 100% solids epoxy to fill all surface irregularities and bugholes. The primer consisted of a solvent-borne, 72% solids epoxy primer applied at 3 to 4 mils' (75 to 100 microns) dry film thickness (DFT). The final coat was an NSF Standard 61-approved 100% pure polyurea applied at 80 to 100 mils' (2 to 2.5 mm) DFT.

The choice to use a 100% pure polyurea lining system was made based on several product characteristics. The specified product was a 100% solids, spray-applied aromatic polyurea, which is tough and flexible. It can be applied at the specified thickness of 80 to 100 mils in a single application using multiple passes, and it has the ability to bridge moving cracks up to ⅛ in. (3 mm) in the concrete substrate, due in part to its tensile elongation of 520%. It also offers excellent tear strength of 400 psi and tensile strength of 2,500 psi (172 bar). These values were important due to the potentially unsound substrate to which the polyurea would be applied. If there were areas where the substrate failed, the cohesive strength of the coating was required to maintain integrity. In essence, the coating system would act like a giant bag inside of the concrete tank. As events unfolded, this attribute would prove to be essential to the success of the project.

Tank 1 Work Starts with Unexpected Challenge at the Bottom

To start the project, excavation was performed around the outside walls of the tank to try to determine the areas of moisture ingress. It was quickly apparent that digging up the ground against the outer walls was not an option, because the walls were constructed of stone set upon stone with no mortar between the joints. Basically, the ground around the tank supported the entire structure and held it in place. The excavation was stopped before further damage was done.

The contractor then trowel-applied a fast-setting, hydraulic cement product to stop the water, with little success. The water continued to seep into the tank. A urethane injection product was then used to stop the leaking on the walls. When the urethane injection was completed and no water was visible, the rest of the surface preparation resumed. The floor of this tank had been sprayed with gunite and had large areas of loose concrete that had to be removed before coating. The contractor used chipping hammers to remove all loose concrete and reach a sound substrate that would be strong enough for the proper adhesion of the polyurea. Abrasive blasting and power washing followed this procedure.

The final step before the polyurea application was the fairing out of the chine angle around the bottom of the tank where the walls and the floor come together. The contractor applied a 100% solids epoxy patching and fairing compound to radius this area to create a smooth transition. Creating this radius helps to prevent cracking of the polyurea in this area due to insufficient film build in the 90-degree angle. At this time, the contractor also filled bugholes in the concrete. An epoxy primer was then applied using airless spray and backrolling.

Approximately one half of the floor was coated on the first day of the polyurea application. The contractor saw multiple areas of large, fluid-filled blisters on the floor when work resumed the next day. It was quickly determined that these blisters were filled with water, and the problem had to be addressed before the project could continue. A core drill was used to remove an 18-inch by 24-inch (46- by

Continued

61-centimeter) core. The hole that it left behind filled with water in less than 5 minutes, and it would continue to refill each time it was bailed out. Since the dome roof had already been installed, it was obvious that groundwater was still seeping in.

Calcium chloride testing in accordance with ASTM F-1869 was conducted on the floor of this tank to assess the severity of the problem. Anhydrous calcium chloride tests were performed for a period of 72 hours. The results of those tests showed moisture vapor emission (MVE) rates ranging between 10 and 12 lbs. (MVE refers to the movement of water vapor through a concrete slab.) The maximum recommended MVE for the specified polyurea system was 3 lbs. Something had to be done to address the flow of groundwater, so that it would not enter the tank. Coating operations were again suspended, and plans were made to put an irrigation trench around the tank (dug several yards away from the structure) to divert the natural water flow away from the tank. Once this was completed, the coating operations resumed, and the tank was completed without further problems.

Tank 2 Work Starts with Unexpected Challenge at the Top

Tank 2 offered many problems of its own. The original scope of work called for the metal dome roof to be installed before the installation of the lining system. One of the delays involved how to build the dome. The original plan called for building the dome on site and then using a crane to lift it into place. However, at over 168 ft (51 m) in diameter, the dome required a large crane that was not readily available. In addition, the site was not sufficiently large to accommodate the crane and the completed dome at the same time. Due to these limitations, it was determined that the dome would have to be built in place on top of the tank. While the general contractor geared up to perform that task, the decision was made to install the liner before the installation of the dome.

The other critical issue to overcome on Tank 2 was that the project budget was exhausted due to the urethane injection and drainage trench dug for Tank 1. The township had little funding left to address these same problems in the much larger Tank 2. On top of the moisture ingress through cracks in the walls, Tank 2 had the excessive control joints previously mentioned: A total of 2,200 linear ft (751 m) of control joints had to be addressed.

The first order of business was to remove all of the caulking and asphalt

Continued

materials from these joints. Additionally, the contractor performed the same surface preparation as in the first tank, including chipping, abrasive blasting, power washing, bughole filling, and priming with the epoxy primer. As the joints were being prepared, their size was recognized to be a serious problem. While polyurea is exceptionally strong and able to bridge cracks, it cannot bridge control joints, especially when they average 2 in. (5 cm) wide. The depth of the joints also had to be addressed. Sand was added to decrease the depth from around 8 in. (20 cm) to less than 2 in. (5 cm). Next, a backer rod was inserted, and then a two-component, self-leveling caulking material was poured into the joints. These actions filled the joints and prepared them to be coated; however, joint movement had to be addressed, as well.

If side-by-side concrete slabs were to move in different directions, the polyurea would be stressed and perhaps split. The solution was to use geotextile fabric strips over the joints for additional reinforcement. Strips of geotextile fabric 6 in. (15 cm) wide were cut to go over the joints. A small bead of acrylic latex caulk was applied the length of each side of the joints, and then the geotextile strips were applied into the wet caulking material. The caulk acted as a temporary glue to hold the geotextile strips in place so that the polyurea could be spray applied onto the strips without blowing them away with the spray gun pressure. Next, 15 to 20 mils (375 to 500 microns) of polyurea were applied to the strips to saturate the geotextile and provide support for the final polyurea application to the floor of the tank.

While the joint treatments were being done, two leaking cracks on the wall were injected with hydrophobic urethane to stop leaking into the tank. This stopped the leaking in those areas; however, there were many other areas around the lower chine of the tank that continued to leak extremely slowly. The decision was made to ignore these leaks based on a lack of funding for any further urethane injection. The slow leaks created water puddles on the floor of the tank. Polyurea, like most coatings, should not be applied over water puddles. Once again, geotextile fabric was used as the solution.

First, the walls of the tank were coated with the polyurea lining system to slow the moisture ingress in the leaking areas. Next, the puddles were dried as much as possible with fans and towels. Then sheets of geotextile fabric were laid over these areas and secured in place with mechanical fasteners. Again, 15 to 20 mils (375 to 500 microns) of polyurea were sprayed onto the geotextile fabric in those areas. Once this process was completed, the fairing of the chine angle was done in the same manner as in the first tank. Finally, the entire floor of the tank was sprayed with the polyurea.

Once the lining system was finished, the tank dome was installed in place. The steelworkers and other trades were all able to build scaffolds and work with the lining in place, using only plywood sheets to protect the coating. Despite this abuse, the lining system needed only one small repair on the floor after one year of service. That repair was performed, and the tank was refilled the same day.

Hannahoe Painting of Reading, PA, performed the surface preparation and coating application on the tanks. Carl Belt Inc. (Cumberland, MD) was the general contractor.

Conclusion

Spray-applied, 100% solids pure polyurea was an exceptional choice for this project. Its combination of low permeability and crack-bridging properties sealed the tanks and ended the leaking problems. Tensile elongation and tensile strength allowed the coating to be applied over the massive control joints and the geotextile fabric in the wet areas with little fear of tearing or cracking. Another benefit of using polyurea in the mountains of western Maryland was that it could be applied all year due to its wide application temperature range.

While repairing these tanks exceeded the budget the township had allocated, the cost of replacing them with new tanks would have been exorbitant. The 100% solids pure polyurea added many years of life to these tanks.

Mike C. Durbin is a corrosion specification specialist for the Sherwin-Williams Company. He has worked for the company's Industrial and Marine Division since 1987, providing inspection, specification, and troubleshooting of coatings. Durbin is a NACE-certified coatings inspector and is an instructor for the Sherwin-Williams Industrial & Marine Coatings Course. A graduate of James Madison University with a BS in science, he is active in NACE International, ASTM, SSPC, and ICRI.

Developments in High-Performance Waterbornes: A Review of Recent Literature

By Cynthia Challener, Ph.D.

Steel and concrete used for the construction of bridges, offshore oil platforms, chemical storage tanks, and other demanding industrial and marine applications must provide superior performance even when exposed to very harsh environments. Properly designed coatings offer an effective means for protecting the surfaces of these structures from corrosion, weathering, chemical attack, and other aggressive conditions.

Solvent-borne formulations have been the preference in these applications, but increasingly strict limitations on volatile organic compound (VOC) content have led to developments in high-solids coatings and waterborne coatings over the past three decades. This article focuses on recent developments in low VOC, waterborne coatings. Developments in raw material for high-performance, low VOC, high-solids coatings were the subject of an April 2008 article "O. Brown, "Coatings Materials Update for 2008," pp. 73–80.

Many early product introductions met VOC requirements but fell short on performance. In more recent years, technological innovation has resulted in new resins and additives that enable waterborne alternatives to equal or exceed the performance of traditional solvent-borne coatings.

This review discusses recently reported developments in waterborne coatings technology for use in the protection of steel and concrete in industrial, bridge, and marine settings. The new developments have been discussed in trade journals or conference presentations within the past year. For each of these papers, the new technology and its benefits are summarized and potential applications highlighted. A list of conference and journal sources is also provided. The review is not comprehensive. Claims made in the papers are those of their authors, not *JPCL*, and *JPCL* made no attempt to verify product claims.

Epoxies

Waterborne epoxy coatings have gone through several development stages. A recent advance for direct-to-metal applications has been the introduction of a low VOC, epoxy-amine dispersion binder system known as NEW GEN™ waterborne technology developed by Hexion Specialty Chemicals. According to Vandenberghe *et al.*[1] and Heine *et al.*,[2] both a bisphenol-A based solid epoxy resin and hydrophobic amine adduct hardener are pre-reacted with a proprietary surfactant and then pre-dispersed into water. The system has been shown to perform as well as or better than solvent-borne coatings, particularly for drying behavior, corrosion resistance, and adhesion to difficult substrates. By carefully selecting the binder and resin and adjusting the formulation, formulators can develop very-high-performance waterborne epoxy coatings for demanding conditions such as marine environments. Low-temperature cure formulations are also possible with the NEW GEN™ waterborne technology.

Cytec Surface Specialities has developed a two-component (2K) epoxy system based on a new, internally flexibilized epoxy dispersion that can be formulated without zinc-based anticorrosive pigments, according to Grasböck and Geisberger.[3] The coatings are high-performance, low-VOC anticorrosive primers that, when properly formulated, outperform solvent-borne systems.

New amine curing agents have led to the improved performance of 2K waterborne epoxy coatings. At Cardolite Corporation, phenalkamines produced

Strong resistance to marine environments is among the properties being pursued for waterborne epoxies. Photographer: mikeuk

from cardanol, the main constituent of cashew nutshell liquid (CNSL), a renewable resource, allow production of low-VOC coatings that tolerate poorly prepared surfaces, cure at very low temperatures, and provide excellent water resistance and corrosion protection.[4] Dallons reports that the phenalkamines can cure different types of epoxy resins, both solid and liquid, while keeping a workable pot life.

EPIKURE™ Curing Agent 8547-W-60 from Hexion Specialty Chemicals is designed for use in coatings for concrete and enables formulation of high-performance, ultra-low VOC systems with superior handling and application properties and visible end of pot life; other properties are improved chemical and stain resistance and easy water cleanup.[5] Fernee *et al.* established design criteria for the waterborne curing agent through interviews with end users, specifiers, and owners.

A modified amine curing agent has been used by The Sherwin-Williams Company for developing a 2K zero-VOC waterborne epoxy topcoat based on a new bisphenol-A "1"-type solid epoxy resin dispersion.[6] According to Wendy Zhao, the coating offers performance comparable to that of solvent-borne products. A surfactant is pre-reacted into the backbone of the epoxy polymer, which is dispersed with a patented high-speed dispersion process that requires no added solvents or reactive diluents. The coating has good storage stability and offers high gloss, fast cure, long pot life, and excellent resistance to water, humidity, chemicals, and corrosion on metal, concrete, and primed surfaces.

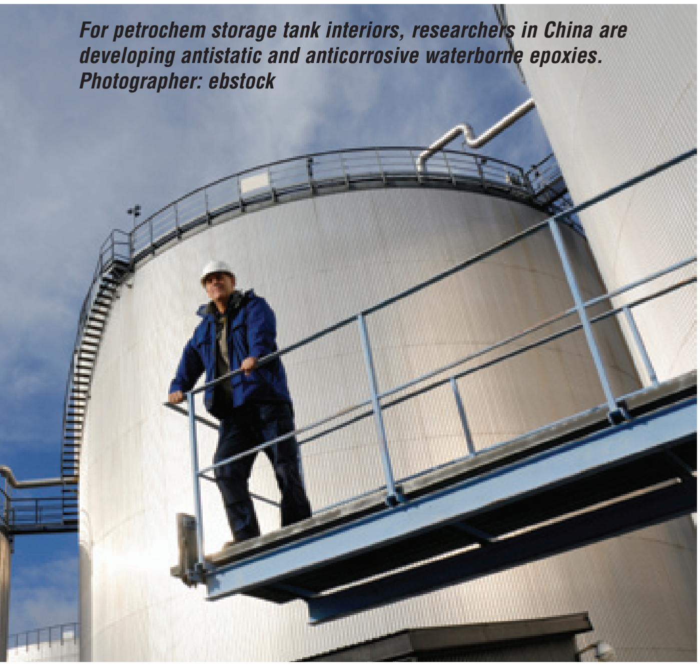
Waterborne epoxy resins have also been used by researchers at Guangdong G&P New Materials Co., Ltd. and the College of Material Science and Engineering at the South China University of Technology in light color, antistatic, and anticorrosive coatings formulations for use on the inner walls of oil tanks to provide protection against corrosion and the generation and release of static charges.[7] Chen *et al.* report that the type and amount of conductive and anti-corrosive pigments, film thickness, and curing temperature as well as time affect the performance of these coatings. A system based on two coats of primer and two coats of topcoat, all with a waterborne epoxy resin as the main film forming material, was shown to be effective.

Scientists at the Institute for Colorants, Paint and Coatings in Tehran evaluated ten waterborne epoxy coatings with respect to their anticorrosion protection. Using design of experiment software, Ranjbar *et al.* found that coatings with higher levels of zinc phosphate and resin performed the best.[8] Higher resin content led to better film formation and greater adhesion. The mechanism of zinc phosphate action is not well understood, the authors said.

The behavior of different anticorrosive pigments was evaluated in a water-reducible epoxy ester coating, and the results were reported by Gichuhi and Novelli of HALOX.[9] A greater availability of free zinc oxide correlated well with better corrosion resistance. Zinc-containing pigments also provided better rub resistance than non-zinc-containing chemistries. Purity, solubility, morphology, type of ions, pigment-polymer interactions, pigment volume concentration, and the environment of the substrate also play a role. A variety of electrochemical techniques can be used to elucidate these properties, but multiple methods are recommended when qualifying coatings.

Polyurethanes

Two-component waterborne polyurethane (PU) coatings are becoming increasingly popular. Having a better understanding of film formation mechanisms can help aid in formulation development.[10] With non-invasive inverse microwave Raman spectroscopy (IMRS), Olier *et al.* of Rhodia determined that formulations incorporating a well emulsified, pre-diluted polyol (36% w/w) produce a uniform film with polyol and polyisocyanate fully dispersed. These coatings also exhibit improved gloss.



For petrochem storage tank interiors, researchers in China are developing antistatic and anticorrosive waterborne epoxies. Photographer: ebstock

Properties of low VOC 2K waterborne polyurethanes can be improved with new hydrophilic polyisocyanates, according to Wu *et al.*, also from Rhodia.[11] Rhodocoat™ hydrophobically modified aliphatic polyisocyanates self-emulsify in water and provide extended pot lives of 5–6 hours, making them easy to use. Coatings designed for protecting concrete were prepared and shown to exhibit excellent hardness and chemical resistance. Abrasion resistance was increased by using a mixture of acrylic and polyester polyols.

New liquid aliphatic polycarbonate macrodiols with MW 1000 g/mol have also been shown to improve the performance of waterborne PU coatings.[12] Oxymer® diols from Perstorp Speciality Chemiclas AB impart hardness and flexibility while offering excellent adhesion to aluminum, according to Bernquist *et al.* Chemical resistance is improved over more traditional polyols. Depending upon the polycarbonate, the abrasion resistance and surface energy can be improved as well.

Incorporation of silicon and fluorine atoms can also be achieved with waterborne PU coatings. When used to produce 2K waterborne polyurethane coatings, silicone-modified acrylic emulsions were found to improve water and chemical resistance, according to Chang and Yu of the Department of Material and Chemical Engineering at the Guilin University of Technology.[13] Scientists from the Department of Polymer Science and Engineering at the University of Science and Technology of China reported that water and oil repellency of aqueous acrylic-polyurethane dispersions are improved for a novel core-shell type fluorinated acrylic and siliconated polyurethane (FSiPUA) hybrid emulsion.[14] The best properties, according to Zhang et al., were achieved with 20% fluorine and 12% siloxane.

Fluorine-containing coatings are also known to have increased ease-of-cleaning properties. Based on this understanding, scientists at Rhodia have developed a low-VOC, low-odor 2K waterborne polyurethane anti-graffiti coating.[15] Wu and Rosen report that selection of the appropriate blend of fluorinated polyols and hydrophobically-modified polyisocyanate led to the right balance of coating properties: the desired level of barrier protection and release properties combined with the ability to recoat the surface.

Stewart at Bayer MaterialScience reported that 2K clear waterborne PU coatings formed from a blend of polyacrylate dispersions and a hydrophilic polyisocyanate perform well as anti-graffiti coatings.[16] The coatings were tested according to ASTM D6578 and the TL 918300, Blatt 39° visual rating system from railroad company Deutsche Bahn AG. With the appropriate choice of polyacrylate and polyisocaynate chemistry, waterborne coatings that outperform their solvent-borne counterparts can be prepared.

Acrylics

Low-VOC waterborne acrylic binders generally find use in light- and medium-duty industrial maintenance applications. New technology that leads to improved pigment distribution in both the wet paint and dry film enables the formulation of high-performance acrylic latex paints, according to Procopio *et al.* from Rohm and Haas Company.[17,18,19,20] The new resin forms polymer-pigment composite particles and self-crosslinks upon exposure to UV light. It can be formulated into primers, topcoats and direct-to-metal finishes with VOC levels at or below 100 g/l, and as low as 50 g/L. It offers higher gloss potential, better durability and corrosion resistance, improved adhesion to metal substrates, more effi-

Waterborne polyurethanes that can be easily cleaned to remove graffiti are in the works. Photographer: istockphoto cient hiding, and improved solvent and dirt pickup resistance.

Researchers at Rohm & Haas also investigated the use of clear, waterborne acrylic coatings to enhance the gloss and durability of underlying pigmented basecoats in industrial settings.[19,20,21] A new all-acrylic, self-crosslinking waterborne latex polymer was designed as a low-VOC alternative to 2K polyurethanes. Use of this clearcoat, whether applied to a newly painted surface or weathered coatings, may extend painting cycles and the overall lifetime of the coating system, thereby decreasing overall maintenance costs.

A new low-VOC waterborne elastomeric acrylic resin from Rohm and Haas has also been developed to formulate thick-film, surface-tolerant coatings said to outperform traditional waterborne acrylic and solvent-borne systems, even when applied over a rusted surface.[20] Andrew Trapani reports that, in addition to its great flexibility over a range of temperatures, the resin also provides excellent corrosion resistance, dirt pickup resistance, and adhesion to various metal surfaces.

Copolymerization of acrylic monomers with a new vegetable oil macromonomer (VOMM) has enabled the production of low VOC acrylic copolymer latexes that incorporate renewable resources.[22] Rawlins *et al.* from the University of Southern Mississippi School of Polymers and High Performance Materials report that VOMMs are excellent plasticizing monomers that are incorporated into the final polymer. They also undergo auto-oxidation during drying and contribute to improved hardness. SoyAA-1 is a soybean oil-based macromonomer designed to produce optimum emulsions and has potential for use in industrial coatings, textile finishes, and many others applications.

Fluoropolymers

New low-VOC, waterborne fluoro-olefin vinyl ether (FEVE) copolymers from Asahi Glass Co., Ltd. have been prepared

Acrylic latex and fluoropolymer waterbornes with enhanced UV protection are being formulated Photo: Getty Images

Selecting a Low-VOC Waterborne Coating Replacement for Bridges

VOC regulations in Southern California are among the strictest in the United States. In preparation for new VOC requirements (100 g/L VOC) for industrial maintenance coatings issued by the South Coast Air Quality Management District (SCAQMD) in 2006, the California Department of Transportation (Caltrans) evaluated single-component waterborne resins to identify a suitable replacement for higher-VOC bridge coatings.[29] According to Associate Chemical Testing Engineer Barry Marcks, criteria included low toxicity; corrosion, chemical and UV resistance; hardness; extended shelf life; and adhesion to a variety of substrates and primers.

The high-VOC coating to be replaced was based on a high gloss styrenated acrylic latex resin and formulated for 250 g/L VOCs. Several acrylic-type resins designed for low-VOC formulations were chosen for the study. Selection of suitable pigments and colorants (light-fast, glycol- and heavy metal-free, and alkali-resistant) was also necessary to meet the color specifications for the coatings. Additives investigated included dispersants, thickeners, surfactants, defoamers, grinding aids, plasticizers and biocides. Quantities and combinations of latex resin, coalescent solvents, additives and pigments, as well as the order of addition of ingredients, had an impact on the performance of the coatings.

This extensive testing program resulted in the identification of two waterborne bridge coating formulations (dark green and light green) based on a styrenated acrylic resin with excellent “in-can” color stability, gloss retention, resistance to corrosion and UV light, and weatherability. A third, white tintable formulation based on a new self-crosslinking, aqueous acrylic emulsion was also developed for use as a finish coat on prepared metal surfaces.

In this evaluation process, the Caltrans team also discovered that the use of tighter specifications, including a larger number of physical property parameters and associated testing methods, ensures better and more consistent performance characteristics for low VOC latex industrial maintenance coatings.

and formulated into coatings with weatherability, resistance to water and solvents, durability, and gloss comparable to the same properties in solvent-borne fluorourethane systems.[23] The coatings are formed from the reaction of a stable FEVE dispersion with water-dispersible aliphatic isocyanates, according to Sumi *et al.* Heat-cured coatings are also possible if blocked isocyanates or melamine resins are utilized. Applications exist in the architectural, industrial maintenance, automotive, and aerospace sectors.

Siloxanes

Waterborne siloxane emulsions are well suited for protecting concrete because they provide both water repellency and vapor permeability, preventing penetration of exterior water and chloride ions while allowing internal water vapor to escape. A silane-siloxane resin (Silblock WA) from Momentive Performance Materials has been shown to comply with both U.S. and European standards for concrete.[24] Kaesler reports that the oligomeric siloxane penetrates the pores, forming durable bonds with the minerals in the substrate without changing the surface appearance. It can be used alone for protection or as a primer for other coatings.

Sol-gel coatings

Sol-gel coatings, formed through the transformation of a liquid solution (sol) into a solid gel through a series of reactions, show promise as an effective means for protecting lightweight materials such as aluminum, magnesium, and their alloys from corrosion damage. Sol-gel coatings are a more environmentally friendly alternative to heavy metal coating systems. Based on organosilanes, these coatings exhibit high hardness while maintaining flexibility. They also show good thermal stability and weathering resistance. Limitations include high cost, low storage stability, and the need for special application equipment.

To address the cost issue, it is possible to incorporate a certain level of conventional organic polymer, according to Pathak and Khanna of the Department of Metallurgical Engineering and Materials Science at the Indian Institute of Technology. After formation of the primary sol by mixing of appropriate silanes in the presence of an acid catalyst, either polyester[25] or alkyd[26] resin is added and the curing completed. Substrates were cleaned and then dipped into the sol. The new coatings were found to be continuous and crack-free and exhibited good adhesion and flexibility. Excellent corrosion resistance was achieved for certain concentrations of organic polymer.

A modular aqueous sol-gel system has been developed by Evonik Degussa GmbH to address storage stability and application issues.[27] Borup *et al.* found that the very-low-VOC waterborne binder forms a transparent, flexible thin film with high hardness that is dry to the touch after 10 minutes. Different pH additives are designed to give storage-stable solutions. Other additives make it possible to produce coatings that repel various liquids and exhibit increased weatherability. The coatings can be applied by spraying, dipping, or doctor blade depending on the substrate. A powder coating can be added before curing at 200 C, or the coating can be cured directly if easy-clean properties are desired.

Novel epoxy-functionalized organofunctional silanes developed by Momentive Performance Materials can also be added to a resin emulsion to provide enhanced adhesion to the substrate and improved water, chemical,

Offshore Platform Testing of Waterborne Coating Alternatives

New restrictions on VOCs became valid in the European Union in 2007 and will be fully implemented by 2010. To identify effective waterborne protective coatings for its North Sea offshore platform and coastal oil terminal applications, Hydro Oil and Energy began testing commercial coating systems in 2000. Jan Ivar Skar and Per G. Lunde reported the results of this investigation.[30]

Both purely waterborne and hybrid solvent/water-mixed systems, all with zinc-rich primers, were included in this study. Pre-treatment and coating application were completed by professional contractors according to manufacturer specifications. While the waterborne coatings were easy to work with, their different nature required excellent communication among the paint manufacturer, Hydro, and the contractor to ensure successful application.

It was found that three-layer systems perform better than two-layer systems for all types of coatings, with hybrid systems exhibiting the best characteristics. Disbonding and cracking were the two common mechanisms of failure.

A system comprised of a 2K zinc epoxy primer, 2K waterborne epoxy mid-coat, and waterborne acrylic emulsion topcoat exhibited cracking of the topcoat. The cracking, however, was an appearance issue only and did not influence the corrosion protection of the system. After four years, a section of the outer perimeter of the oil platform coated with this system did exhibit some flaking and cracking. Overall, however, the hybrid system was found to be adequate for severe corrosive conditions.

A steel pipeline coated by the prefabrication contractor with a system made up of a waterborne zinc epoxy primer, waterborne epoxy midcoat, and 2K solvent-borne acrylic topcoat remained in good condition after five years in service at the offshore location.

and stain resistance.[28] Dhanabalan *et al.* also reported that glycolic silanes are currently being investigated that could lead to formulations with even lower VOCs.

Conclusion

Full details on obtaining further information on the papers described are given in the references below and the accompanying box.

Cynthia Challener holds a Ph.D. in chemistry from the University of Chicago. She writes widely for the coatings industry.

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Waterborne and High-Solids Symposium, March 2008
PRA
Janet Saraty, Event Manager
14 Castle Mews
High Street
Hampton
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tel: +44 20 8487 0811
fax: +44 20 8487 0801
conferences@pra-world.com
www.pra-world.com

Annual International Waterborne Coating Symposium, January 2008
The University of Southern Mississippi (USM)
Laura M Fosselman, Waterborne Coordinator
Polymer Science Research Center
118 College Drive #10063
Hattiesburg, MS 39406
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Fax: 601-266-6265
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NACE Corrosion 2008 Conference & Expo, March 2008
NACE International
NACE FirstService
Tel: 281-228-6223
Fax: 281-228-6329
firstservice@nace.org

The Paint and Coatings EXPO (PACE), (Joint show of SSPC and PDCA)
January 2008
Society for Protective Coatings (SSPC)
Lorena Walker
Phone: 412-281-2331 Ext. 2215
Fax: 412-281-9993
walker@sspc.org
www.pace2008.com/

Protective Coatings: Protecting the Substrate & the Environment, October 2007
PRA, *The Journal of Protective Coatings & Linings* (JPCL) and SSPC Co-sponsored Conference (PRA-SSPC)
Janet Saraty, Event Manager
14 Castle Mews
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conferences@pra-world.com

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Philadelphia Society for Coatings Technology Inc. (PSCT)
Steve Schmidt, President
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1320 Industrial Blvd.
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www.psct.org/asp/officers.asp

Journal of Coatings Technology Research (J. Coat. Technol. Res.)
JCT CoatingsTech
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editors@coatings.de
www.coatings.de

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The Future *of* Ballast Tank Coatings

The main stakeholders in the marine industry, the port state control, and the general public demand ballast tank coatings that perform well. The International Association of Classification Societies' (IACS) Enhanced Survey Programme (ESP) also demands quality by requiring hard coatings that must perform to a very high standard. The pattern of raising the quality and performance of coatings in ships' tanks is a continuous challenge.

The IMO PSPC regulations will put stringent demands on the service life of a water ballast tank coating. Photos courtesy of the authors

There are no requirements that ships must be built having good coatings in the ballast tanks, but there is a requirement that such a coating must be in place when a ship is delivered. This requirement will change on July 1, 2008, with the implementation of the International Maritime Organization (IMO) Performance Standard for Protective Coatings (PSPC) for ballast tanks, MSC215, (82).

As it is today, the coating in the worst "area under consideration" (part of a tank) must be at least "Good" as defined under IACS rules. That not being the case results in a class notation for that area. Class notations are not acceptable by many high-quality customers, meaning the ship cannot trade properly. The tanks must remain "Good" not for a few years, or 15 years, but for the life of the ship—that is a true challenge.

Ships operate in a truly global and very competitive business environment, and provide an environmentally efficient service at a very low cost. The beneficiaries of the low cost shipping services ultimately favor the consumer, which few would deny is a good thing. However, the cost of stopping an oceangoing ship, and putting it into a repair shipyard to recoat ballast tanks is phenomenal. The costs have to be recovered and passed on to end users.

While working in a cutthroat business, new construction shipyards strive hard to build ships in a safe and environmentally responsible way. They must follow contract specifications to the satisfaction of their customers, and adjust to meeting their differing demands and specifications.

When the same yard using the same laborers delivers to different customers ships built to varying standards, stress on production is inevitable. Standardizing of building practices should lead to enhanced productivity; hence, the quest of shipyards to standardize working methods and quality is fully understandable. Could there be a case, therefore, for rethinking certain aspects of current coating practice and application methodology in order to further improve performance standards of water ballast (WB) tank coating systems?

All parties in the industry are aware of the need to rise to challenges that the IMO PSPC regulations pose, and all parties share concerns about how best to meet these challenges.

This article is a condensed version of a

Editor's Note: This article is based on a presentation the authors gave at a conference NACE International sponsored in Shanghai in 2007.

By Johnny Eliasson, Stolt-Nielsen Transportation Group, and Rodney Towers, Safinah Limited

paper in which the authors bring together their views based upon their respective experience in different branches of the industry. They summarize current industry practice in the coating of WB tanks; comment briefly on the IMO PSPC regulations; suggest some consequences for shipbuilders and marine paint manufacturers; and propose some ideas on the way forward. The full paper can be viewed at www.paintsquare.com.

Current Position of WB Tank Coating Systems in New Construction

Three countries— Korea, Japan, and China—practically dominate shipbuilding output, accounting for 75–80% of global tonnage. Thus, the standards of application, the type of products selected, and the QC procedures that shipbuilders in these countries adopt will heavily influence any assessment of the overall performance in the service of WB tank coating systems. Similarly, the implementation of any new technology will depend on how or to what extent proposed changes can be integrated into the very high-volume construction process.

Generic Types

Current practice among shipbuilders is to broadly offer either modified epoxy systems or tar-free epoxy systems for coating ballast tanks. The terminology of tar-free epoxy can mean any of three main product types: solvent-borne modified epoxies, solvent-borne pure epoxies, and solvent-free epoxies.

In general, Chinese and Japanese builders most commonly specify modified epoxies, whereas yard standard offers from Korean builders usually specify pure epoxy systems. Only some European builders specify solvent-free epoxies for full application in WB tanks.

"Modified-epoxy" originally referred to technical changes to the product binder. Adding some lower cost raw materials improved properties such as surface tolerance, adhesion, and flexibility. Coal tar epoxy became the most widely used modified epoxy in shipbuilding.

However, the intensely competitive nature of the shipbuilding industry led to reducing earlier shipyard specifications of two-coat tar epoxy systems to one-coat systems. Shipyards then pressured manufacturers to further reduce costs, resulting in the manufacture of some lower-cost tar epoxy products. The objective of these actions was to find a minimum specification and cost for painting WB tanks to a standard sufficient to avoid owners' claims within a shipbuilder's 12-month standard warranty.

Following concerns in the 90s about certain raw materials used to manufacture tar epoxies, and in response to the IMO A798 recommendations to use two-coat, light-color, hard coating systems in WB tanks, the industry switched to products such as non-tar, bleached tar, epoxy mastic, and pure epoxy.

Different shipbuilders favored each of the different product types, and all evidenced good performance. However, recently, owner preference seems to be moving toward pure epoxy products and away from modified epoxies. Some European shipbuilders' preference for solvent-free epoxies is driven partly by having to comply with the EU Solvent Emissions Directive, SED, and the contribution to improving health and safety during application in shipyards—in itself, a positive development.

Solvent-free epoxies tend to score well technically with characteristics such as good retention at edges due to slower flow, and lower internal stress in some formulations. While both properties are desirable for long-term performance in the WB tank environment, the reduced flow also means less opportunity for surface wetting. Some progress has been made with improving the rather slow cure of solvent-free epoxies at low temperatures, but the improvements have, so far, not proved sufficiently attractive for any of the major Asian yards to adopt the products. A good coating, therefore, must meet the needs of the shipbuilder and the ship owner before it can become a solution.

Secondary Surface Preparation

A widely discussed issue is how to treat sharp edges in tanks' internal steelwork. Early coating failure has long been observed to begin on sharp edges where paint thickness has been much below the specification thickness on flat surfaces. The purpose of grinding sharp edges and stripe coating, therefore, was to promote the build-up of greater coating thickness over sharp edges, rough welds, and other surface defects.

It should come as no surprise to find that the IMO PSPC regulation seeks to impose common standards across the global shipbuilding industry by adopting standards of good coating practice that have proven beneficial when coating other locations in ships.

Application Practice

The major shipbuilders have all constructed large block coating halls. The block coating facilities in Korea lead the field in Asia. In Europe, particularly in Germany, Denmark, and The Netherlands, some excellent block coating facilities exist, but, in general, the size and type of ships built in Europe are of smaller deadweight tonnage than those in Asia.

Block coating in large and small shipyards is often a bottleneck in the fabrication process and consequently becomes a critical time constraint on overall production. Shipbuilders, therefore, with their primary focus on production, will always seek a coating process that will minimize the cycle time of blocks in the coating cells.

In recent years, application practice appears to have approached the common standard of a two-coat epoxy system with nominal dry film thickness of 250–300 microns. Common standards for stripe coating practice remain less than clear. Current shipyard practice is to apply either one or two stripe coats. Thus, despite many advances in industry practice in recent years, some yards will still have to seriously upgrade their WB tank coating practice when IMO PSPC comes into full force mid-2008. It is already in force for tankers and bulk ships of specific sizes, under IACS Common Structure Rules (CSR).

Inspection Procedures

In a typical application of a two-coat epoxy system, including two stripe coats to WB tank areas at block stage, four separate stages in the sequence require QC inspections. In accordance with the new IMO.215(82) PSPC[2], these inspections must be jointly agreed upon and made by properly approved inspector(s). Other inspectors can also be involved.

Current Problems in Service

Cracking is the principal failure characteristic of high-solids epoxies, currently widely specified and applied in WB tanks. Internal stress released by shrinkage causes cracks.[6] The most common locations exhibiting this problem in WB tanks are in block joint areas and on butt, seam, and fillet welds (Fig. 1).

In the authors' general experience, 70–80% of cracking failures occur within the shipbuilder's normal 12-month warranty and so will give rise to a shipowner's claim against the builder. The shipbuilder will then pass the problem to the paint supplier to examine and resolve. Often, though, such failures take longer than a year to develop and can become unanticipated cost problems to be resolved within the owner's maintenance budget.

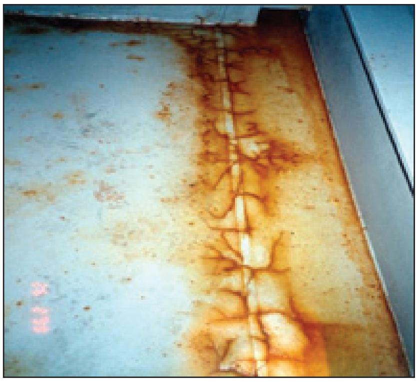


Fig. 1: Typical example of cracking at the weld

Several causes of the internal strain (stress) can lead to cracking: Excessive film thickness, poor surface preparation, poor product formulation, incorrect overcoating intervals, internal stresses, movement of lower scantling high tensile plating, retarded solvent evaporation (poor ventilation or overly cold steel), and thermal cycling of a structure adjacent to heated cargoes. A combination of these factors may cause cracking.

Current Performance

Over the years, in quite a few case histories, certain shipowners have recognized the importance of good WB tank protection, then wrote and contracted for their own high standard specifications at new building. They accepted some additional cost and budgeted for regular coating maintenance in WB tanks, which have achieved 15 years or more of performance in service. However, current performance of WB tank coatings in general is still falling short of the IMO 15-year target life.

A major classification society made a statistical analysis of its data on ESP evaluations and found that the average ship age at which time the coating went from "Good" to "Fair" was 8–10 years—hardly satisfactory! Ballast tank coatings on ships built to a higher coating standard, recognized by this classification society, on the average reached an age of nearly 15 before the condition reached "Fair." This finding says that 15 years is achievable, as proposed in the IMO PSPC, and that a better job done at new construction pays off later.

Based on current coating performance in WB tanks, four main issues appear to be involved.

- Raising the general standard of WB tank coating practice in some shipyards, in particular, standards for secondary surface preparation and application
- Researching new coating products to improve performance, achieve better resistance to cracking, and remain manageable by the applicator
- Changing the general approach of some shipowners to accepting the need for some planned and regular WB tank coating maintenance and to include the cost in their repair budgets
- Providing easier, more objective methods of inspection

The best of past practice in the industry suggests that IMO's 15-year performance target objective is entirely realistic, but raising the general level of coating performance to achieve the "Good" standard required by the IMO 215(82)[2] PSPC still requires good specification, good work, and good maintenance.

Summary of the IMO PSPC Regs

The IMO document is long and detailed. It has been reported on in several papers and can be referenced easily. Apart from summarizing some of the main requirements for coating systems, this article will not discuss the document further.

The primary aims[1] of the PSPC are

- to achieve a 15-year target life performance for ballast tank coating systems, after which time the overall condition of the coating system can be surveyed and described as being 'Good,' where 'Good' condition is defined in resolution A.744(18) as " minor rust spotting affecting <3% of flat plate surfaces, and <20%

of welds and edges”;

- to influence the wider adoption of better coating systems with reduced maintenance;
- to improve safety at sea through better structural protection of WB tank steelwork and reduction in steel wastage;
- to highlight the need for good coating system maintenance supported by an appropriate costing system to achieve the 15-year target performance condition; and
- to make the ballast tank application process more transparent.

Meeting the requirements of the PSPC and raising the performance of WB tank coatings will go a long way to alleviating the trading problems of ship owners today (Fig. 2). The problems include the cost of additional inspections required by the Class Societies and Port State authorities due to poor coating condition, notwithstanding the costs of coating repairs. These trading problems increase operating costs and reduce operating time and profits. Moreover, the added costs must be passed on to the customers, making the owner less competitive.

However, these aims will have consequences for shipbuilders, marine paint manufacturers, and ship owners, and, again, these have been reported in detail. The ship owner can expect, among other consequences, the following.

- New building prices will increase. Due to increased inspection time, during both block and in-situ coating application, cycle time for painting operations will also increase, thus reducing overall productivity at yard. The cost of training inspectors will also rise.
- Owners will have to maintain the ballast tank coating, although this cost could be offset somewhat by the considerable financial benefit gained from the reduced costs of recoating due to better initial coating application. That is, better initial application should feed into lower through-life costs. (Otherwise, why do it?)

The Way Forward

Initially, the IMO PSPC regulations seem certain to result in more costs for shipbuilders and paint manufacturers, costs that both groups can be expected to try to recover through price increases. This section will look at the way forward for shipbuilders and paint manufacturers, concentrating on the latter.

For Shipbuilders

This is a time for a lot of new thinking on how to manage the new requirements arising from the IMO PSPC regulations. However, shipbuilders should not feel locked into a box of current products and standards: The IMO PSPC regulations repeatedly encourage alternative products and innovation.

The directions of shipyard research might therefore focus on the need to find products and methodologies to accelerate paint curing and QC procedures during block coating. Needed are new coating materials tolerant to relative humidity higher than the current norm of 85% and capable of curing at temperatures below the +5 C limit of many epoxies. Shipyards should also consider using alternative coating materials after erection.

Productivity is primary to shipyards. If they should conclude that an innovative coating process and material could reduce coating cycle times, improve productivity, and yet deliver a better performing, long-life WB tank coating system, then they could decide to treat the application process as a shipyard engineering issue. If the potential benefits from such a change should be found important enough, shipbuilders may conclude that it would be in their best interests to exercise more control over the process, even to the extent that yards will specify the WB system(s) the builders will provide. The authors have learned that at least one major Korean shipbuilder has taken the first steps in this direction. This would also mean that the yards would assume more responsibility for the performance of the coatings.

For Marine Paint Manufacturers

This time could be one of great opportunity for marine paint manufacturers. It will be surprising if, in 15–20 years, major shipbuilders are still applying two-coat epoxy systems in WB tanks with the method generally used today.

WB tank areas are just too big in terms of square metres for shipyard painting and too important in terms of the structural integrity of the hull for the industry to let the status quo continue for the product and the methodology. Essentially, the industry is still geared to coating technologies pioneered in the 1940s and significantly re-engineered in the 1960s. But the cost and productivity issues being triggered by the IMO PSPC regulations are of sufficient magnitude to initiate a major drive for change in shipyard coating methodology.

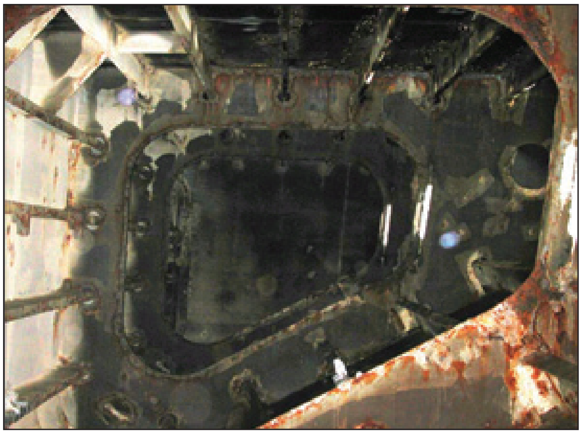


Fig. 2: Typical condition of tar epoxy system in topside WB tank after 7-8 years, using present methods and coatings

Short- to Near-Term View: 1–5 Years

• **Solvent-Borne Epoxy Systems:** Efforts will likely concentrate on improving existing epoxy products already on the market. A primary effort to reduce internal stress and thus improve flexibility in existing WB tank products seems probable. Any modification should not negatively alter other vital coating characteristics such as water resistance (vapor transmission rates, etc.).

It is worth restating that not only is the cohesive strength important, but so also is the adhesive strength, and both strengths must be matched.

Some new products also on the market are said to have improved resistance to cracking. Information on one of these, described as fibre-reinforced, was presented at the PCE Marine Coating Conference[4] 2006. It is still too early to review in-service feedback reports. Also, in recent years some manufacturers have improved the edge retention characteristics of some epoxies, and research in this area will no doubt continue. But improved edge retentions must not come at the expense of other vital characteristics, such as flow and wetting.

• **Solvent-Free Epoxies:** Solvent-free epoxies, in general, have far better flexibility than solvent-borne epoxies; solvent-free products also offer the best environmental response to future pressures expected on shipyard painting practice. Further product development of this type of coating can be expected. However, at present, some solvent-free epoxies have other characteristics that are not so user friendly for yards with high rates of block throughput. For example, drying times are sometimes slower, which impedes walk-on QC inspection; low-temperature curing versions are still in general slower than with normal epoxies; and there is concern about their surface wetting ability because such products do not flow much after surface contact. They have, in general, however, better edge retention as a result. There are also very fast-curing, solvent-free epoxies on the market; new curing agents have made faster and lower temperature cure possible and much safer than with solvent-borne epoxies. The solvent-free systems generally require spray application by plural-component pumps for proper control of the mixing and spraying, and this type of pump is more expensive than the standard airless spray type that shipyards have widely favored for many years.

• **Rapid-Cure Systems:** Interestingly, in the U.S., the NSRP Technical Panel[5] SP-3 reported in 2005 that NAVSEA was researching technologies for single-coat, multi-pass, rapid-cure systems in tanks. The purpose was to improve application productivity by eliminating two stripe coats and all the associated QC inspection work. If such an innovative approach can confirm good performance, then the applications engineering aspect of such technology must be of serious interest to commercial shipyards. The authors understand that in this research, some novel, solvent-free systems will undergo shipyard application trials shortly.

If this US technology proves manageable by shipyards, and can be shown to reduce the block coating cycle time for WB tank areas, then a challenging scenario might develop. A successful outcome to this work might lead to the development of a new range of products based on the rapid cure technology.

•**The Dual Bonding Mechanism (DBM) Approach:** The marine paint majors have long been aware of the differences in standards of secondary surface preparation, physical access and degree of environmental control with which they have to contend between blocks coated in a purpose built painting cell and block joint areas coated inside the ship structure. Since the conditions and standards of the modern ship construction process are unlikely to change, why not recognize the major difference in application conditions between block and block joint areas?

Instead of having to use the same product for the total internal WB tank area, why not consider developing a block stage product with the primary need of aiding shipyard productivity and an associated objective of countering the potential loss in productivity that some shipbuilders are predicting? Of course, the product development will result in additional testing requirements.

• **Main Coating Applied in Block Coating Facility:** The constant demand on block coating cell space points to the need for a product that will greatly accelerate drying so that walkover QC checks can be made very soon after application. Yet the product should also retain a maximum overcoating capability so that a second full coat can be applied within hours. This idea envisages that two full coats and stripe coats can all be applied,

Fig. 3: Typical example of good stripe coating. Note the care employed not to overbuild

QC can be checked, and the block can complete its full WB tank coating cycle in 24–48 hours (Fig. 3). This kind of product should go a long way towards helping shipbuilders increase productivity beyond the present situation.

• **Coating of Block Joint Areas in the Ship:** Because surface preparation standards in the block joint areas are generally lower than those for the main block, why not consider a separate technical approach towards better product performance when application must be done under these different conditions?

One approach could be to use two different products, each gaining adhesion by different principles. The principles might be described as dual bonding mechanisms or the DBM approach.

Using two different products to form one system with the first coat of the system acting as a glue coat is not new. The old T-wash made vinyl coatings stick. If a glue coat should be developed and prove successful in the WB tank environment, the concept might open the door for a much wider application.

Good adhesion across the overlap with the block coating would be fundamental, and the question, "over what?" inevitably arises if one manufacturer is unable to supply approved products for both the block coating and the block joint area. If a painter is using two products, the block joint coating would need good adhesion to the main block coating at the overcoated edge areas. If products are from different manufacturers, then the adhesion level between the joint coating and the main block coating would be unknown. The parties would have to resolve testing issues. It will be important also to gain owners' confidence. The hybrid approach might be unusual but technically possible.

Mid-Term View: 3–8 Years

• **Innovative Primer System:** The auto industry had big problems 15—20 years ago when bodywork paint systems were found to be generally deteriorating after even 2 or 3 years, which customers found unacceptable. One manufacturer researched the situation and came up with a completely innovative methodology and product type for priming the steel bodywork. This innovation resulted in far superior performance and has subsequently been wholly adopted by the auto industry. Can the marine industry learn something from the auto industry's approach?

• **The 'Glue Coat' Primer Proposition:** Two questions are now posed.

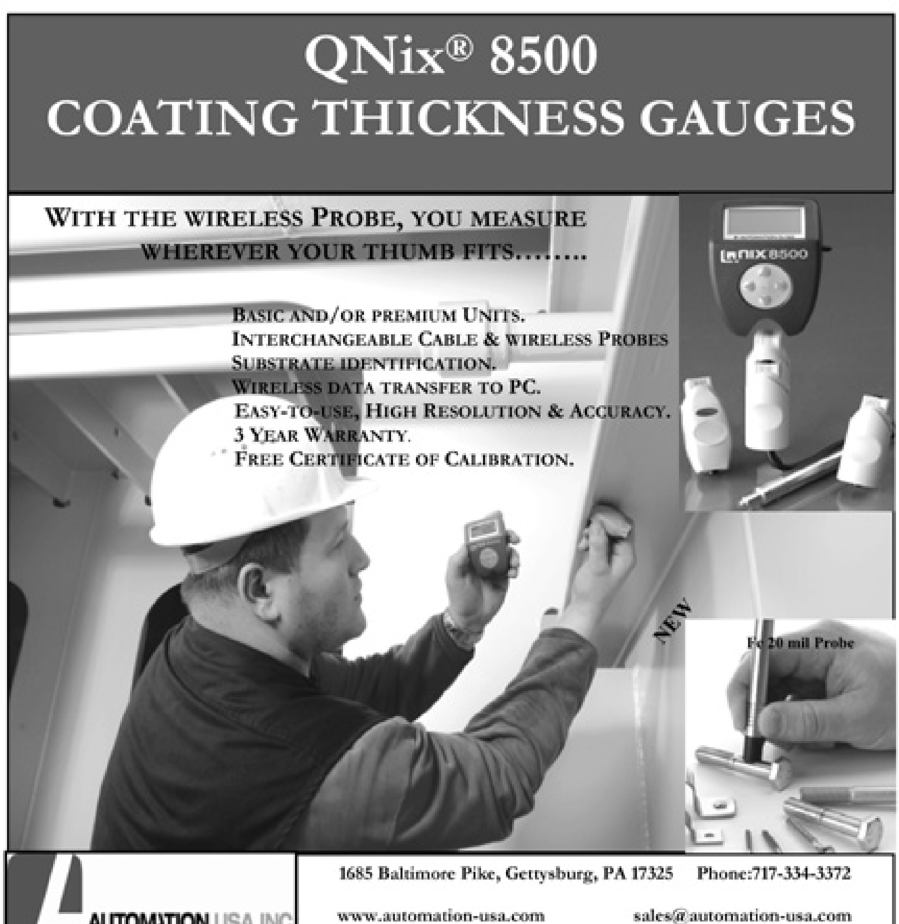
1.Why should the first coat and second coat have to be of the same material?

2. Can some technical combination of different coating products produce a system suitable for 15 or even 25 years' performance in the WB tank?

The authors' view on question 1 is that because there is virtually no historical precedent for the use of any mix of coating products in WB tanks, the issue has not been fully addressed. The authors are, however, aware of a small number of exceptions to this norm. During the 80s, a few progressive owners chose to meet the additional cost of applying a zinc silicate primer, and then overcoating it with two coats of tar epoxy. Examples of very satisfactory performance of this type of mixed coating system are still afloat after more than 20 years in service, which helps answer question 2.

The examples of successful performance above lead directly to the question of whether such a system could be successfully formulated to meet the needs of today's high steel throughput shipbuilding. What if, therefore, the first coat was designed primarily to maximize adhesion to the zinc silicate shop primers generally favored in ship construction? The function of such a first coat would essentially be that of a glue coat. The second coat would be formulated to form the anticorrosive barrier.

The challenge would be how to complete the above procedures on a WB tank block in a target time of 24 hours.



Summary

Ships need a good ballast tank coating during the ship's entire service life. A good WB tank coating will help lower operational costs, benefit the environment and the ship's customers, and be overall good economics. To change steel is expensive and time consuming.

Ships also need predictable coating performance to enable proper planning and budgeting of coating maintenance.

Marine paint manufacturers have developed the specialist coating technology to protect water ballast tanks for long periods and have the capability to supply various products that can meet the new performance standards set out by IMO to satisfy the rightful demands of the primary stake holders. The challenges for the future will be about how to employ new technologies and develop new products that can help shipyards achieve both a higher quality of initial application and longer service life.

Coating technologies have entered a new, dynamic phase. The IMO PSPC regulations seem certain to stimulate substantial rethinking of the whole methodology of painting WB tanks. The authors anticipate that the result of such research should lead to more than a one-product, one-technology solution.

Shipyards, for their part, will always seek to perform at maximum efficiency and lowest cost to enhance their competitiveness and profitability. Predictable production will assist shipyards in their planning, scheduling, and costing of new ships. The IMO PSPC is a challenge to shipbuilders; the authors anticipate that shipyards will now be ready to explore new options in WB tank painting more than ever before.

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What's New with Regs for Surface Prep?

By Alison Kaelin and Dan O'Malley, KTA-Tator, Inc.

Surface preparation operations could be subject to proposed and current federal regulations on emissions of lead, particulate matter, and hazardous air pollutants (HAPs). Here is a review of some recent activity from the U.S. Environmental Protection Agency (EPA).

EPA Proposes New National Ambient Air Quality Standard for Lead

The Clean Air Act requires the EPA to set National Ambient Air Quality Standards (NAAQS) for criteria pollutants (e.g., lead); to periodically review the standards to ensure that they provide adequate health and environmental protection; and to update them as necessary. (EPA defines "criteria" air pollutants as ones it regulates by developing human health-based and/or environmentally based criteria [science-based guidelines] for setting permissible levels.) On May 20, 2008, EPA issued a proposed revision of its existing NAAQS for lead that could change monitoring equipment and practices, among other aspects of surface preparation operations.

History of Current Proposed Rule (PR)

A September 2005 U.S. District Court decision ordered EPA to implement steps to assess and revise the NAAQS for lead. On October 1, 2006, EPA issued an Air Quality Criteria Document for Lead discussing several topics, including

- concentrations of lead in the environment;
- multimedia lead exposure (via air, food, water, etc.);
- characterization of lead health effects and associated exposure response relationships; and
- delineation of environmental (ecological) effects of lead.

EPA then issued a Draft Staff Paper for Lead on December 5, 2006, followed by a final staff paper and a "Final Human Exposure & Health Risk Assessment" issued on November 1, 2007.

The staff papers recommended retaining lead as a criteria pollutant with primary and secondary standard limits and reducing current primary and secondary NAAQS levels for lead.

On December 17, 2007, EPA issued an Advanced Notice of Proposed Rulemaking (ANPR) supporting the staff paper recommendations and requesting comments on the ANPR.

The Current Proposed Rule (PR) at a Glance

On May 20, 2008, EPA published its PR to revise the primary NAAQS for lead. The agency concurrently set a public hearing for June 16, 2008. Written comments to EPA are due July 21, 2008. The final rule is expected by September 2008.

If adopted, the PR will substantially reduce the NAAQS

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limits for lead and will dramatically change the coatings industry approach to ambient monitoring. Key components of the PR include the following.

NAAQS Limits

• Reduce the current 1.5 µg/m^3 NAAQS level to within the range of 0.10 to 0.30 µg/m^3 when monitored in the form of lead as total suspended particulate (TSP-lead).

• EPA seeks comments on an alternative NAAQS level of 0.10 to 0.50 µg/m^3.

• EPA has also requested comments on when, if ever, it would be appropriate to set a NAAQS for lead at zero.

• EPA proposes to make the secondary standard identical in all respects to the proposed primary standard.

Sampling and Analytical Methods

• EPA proposes that monitoring continue to be performed in accordance with 40 CFR 50, Appendix G, Determination of Lead in Suspended Particulate Matter. However, EPA has also introduced a new Appendix Q that would establish a Reference Method for Determination of Lead in Particulate Matter as PM10. Note: Appendix Q would allow the sample to be collected using a low-volume air monitor (i.e., 17 liters per minute) with a size selective head and two-inch diameter filter operated over a 24-hour period. Appendix Q also requires laboratory analysis using energy-dispersive X-ray fluorescence (EDXRF) spectrometry for analysis. Appendix Q is very similar to the Appendices (L and O) addressing PM 2.5 monitoring.

• EPA is soliciting comments on shifting from measuring lead in TSP (App G) to measuring lead as PM10 (App Q).

Calculation of Results

• EPA proposes that monitoring results be compared to the NAAQS levels as an arithmetic mean concentration average of a calendar quarter (what is done currently) or as the 2nd highest arithmetic mean concentration averaged over a calendar month.

Monitor Siting

• EPA proposes changes siting criteria recommendations for lead monitoring (40 CFR 58, Appendix D) within state and local monitoring stations. The proposal appears to suggest that monitor siting should focus on a microscale scale based on dispersion modeling; a middle scale based on proximity of sensitive receptors with 328 to 1,640 feet; and a neighborhood scale measuring concentrations at a distance of 1,640 feet up to 2.5 miles.

Potential Effects on the Painting Industry

A reduction of the NAAQS for lead to the recommended levels can have several effects on the painting industry's current approach to ambient air monitoring.

In order to achieve detection levels at the proposed NAAQS values of 0.1 to 0.5 µg/m^3 using TSP-lead ambient air monitors, the monitors would likely need to operate for a full 24 hours (as opposed to the current practice of monitoring only during emission producing operations). The laboratory analysis of the filter may need to be performed using inductively coupled plasma atomic emission spectroscopy, or ICP (versus atomic absorption spectroscopy, or AAS) to achieve lower detection levels of lead on the filter.

If the "Lead in PM10" method is used, it involves different monitors (low-volume vs. high-volume), different filters (cassettes vs. filter paper), and PM10 adapters (to remove particles above 10 microns). The laboratory analysis for this method would require EDXRF.

A brief review of background monitoring data (conducted prior to paint removal) that the authors' company performed appears to indicate that in some urban areas, background values would already exceed the proposed limits, prior to any paint removal operations. Because many specifications rely on the NAAQS TSP-level of 1.5 µg/m^3 as a 90-day average and NAAQS monitoring and analytical methods as the basis to establish that project activities are not adversely affecting the public and environment, the industry may have to reconsider its approach to ambient air monitoring as a whole. The industry is encouraged to comment on and monitor the impact of this rulemaking process.

EPA Revises Rule for Meeting NAAQS for PM2.5

The 2006 CAA revisions for the NAAQS for PM2.5 reduced the 24-hour concentration to 35 µg/m^3 but retained the annual limit of 15 µg/m^3. 40 CFR Part 51, Clean Air Fine Particle Implementation Rule became final in May 2007. This final revision added "Subpart Z—Provisions for Implementation of PM2.5 National Ambient Air Quality Standards." Subpart Z requires "non-attainment" (i.e., exceed NAAQS for PM2.5) to revise their State Implementation Plans (SIPs) to meet the PM2.5 standard. Previously, EPA enforced the standard by fining states which could not meet the NAAQS for PM2.5.

The Problem with PM2.5 Emissions

Most stationary sources (such as steel mills) that emit PM2.5 are already regulated by the state. So to meet the 2006 PM2.5 emission levels, non-attainment states must seek to control other sources of emissions. PM2.5 comes from a wide range of sources, including cars, trucks, industrial and construction sources (e.g., painting and surface preparation), and other burning or combustion-related activities. But many of these sources, notably the mobile ones, are difficult to regulate. Their PM2.5 emissions are primarily "fugitive" emissions, that is, not associated with a particular source or industry.

EPA has stated "We believe that to attain the PM2.5 standards, it is important to pursue emissions reductions simultaneously on the local, regional, and national levels."

How to Reduce PM2.5?

Reductions have begun on the Federal level through the Volatile Organic Compound (VOC) standards and standards related to vehicle and fuel emissions. On state and local levels, further reduction of PM2.5 is being accomplished through SIPs indicating how it will reduce PM2.5 emissions in areas of non-attainment.

Discussion with several state agencies and reviews of draft state SIPs indicate that some states intend to meet EPA PM2.5 requirements by regulating sources of fugitive emissions that have previously not been regulated, such as non-permitted blasting and painting facilities, mobile abrasive blast cleaning operations (i.e., field painting), and non-road engines and equipment, such as compressors and generators. Some states, such as New York and California, have already proposed or initiated regulations targeting non-road equipment.

It is reasonable to expect that there will be an increase in local regulations related to control and reduction of PM2.5 emissions and all types of surface preparation, especially abrasive blast cleaning, over the next several years.

EPA Proposal Could Affect Shop Blasting, Painting

The EPA announced on April 3, 2008, that it is proposing national emission standards for controlling HAPs for abrasive blasting, spray painting, and other operations that take place in nine metal fabrication and finishing area source categories included in the proposal.

Among the other affected new and existing operations are machining, dry grinding and dry polishing with machines, and welding operations.

The emission standards that EPA is proposing are in the form of management practices and equipment standards, says the Agency.

According to EPA, comments on the proposed rule were required to be submitted on or before May 5, 2008.

Conclusion

To read the proposed and final rules described above, go to http://www.epa.gov. ■

New OSHA Program Targets Silica, Other Blast Cleaning Hazards

By Alison B. Kaelin, CQA, and Stan Liang, CIH, CSP, KTA-Tator

On January 24, 2008, OSHA issued directive number CPL 03-00-007, National Emphasis Program—Crystalline Silica, which will, at a minimum, change OSHA's approach to inspections of projects involving abrasive blasting with sand and, at the most, could affect virtually all types of abrasive blasting. The National Emphasis Program (NEP) establishes policies and procedures for inspection. Its stated purpose is "to significantly reduce/eliminate employee overexposures to crystalline silica and, therefore, control the health hazards associated with such exposures." Inspections are to be targeted to work sites that likely create high silica exposures, and the inspections must comprise 2% of each OSHA Region's annual inspections. The NEP specifically "targets" employer classifications such as the following.

- Painting and paper hanging
- General contractors
- Highway and street construction
- Bridge and tunnel construction
- Heavy construction
- Concrete work
- Wrecking and demolition

Appendix B of the NEP provides a comprehensive list of industries by SIC/NAICS codes that have been identified by OSHA as having potential exposures to elevated levels of crystalline silica.

After giving background on reasons for regulating crystalline silica exposure, this article outlines key components of the NEP, provisions specific to abrasive blasting of all types, and pointers on managing worker exposures during blast cleaning in light of the NEP.

What Is Crystalline Silica?

Silica is a broad term referring to the mineral compound silicon dioxide (SiO_2). Silica can be either crystalline or amorphous. Crystalline silica, often called free silica, is a basic component of most rocks, soil, sand, granite, and many other minerals. Quartz (i.e., sand) is the most common form of crystalline silica. Cristobalite and tridymite are other forms of crystalline silica. Crystalline silica is significantly more hazardous than amorphous silica. Amorphous silica, which can be synthetic or naturally occurring, is typically in a glassy state. Silicates, which are minerals composed of silicon dioxide bonded to something else, are also a source of silica, though usually in amounts less than 1% by weight.

Crystalline silica has long been recognized as a respiratory health hazard and is classified as a human carcinogen. Occupational exposures to silica are associated with silicosis, lung cancer, tuberculosis, and airway diseases. Recent studies have also indicated it is associated with pulmonary disease, renal disease, and stomach and other cancers. Appendix A of the NEP summarizes the health effects of crystalline silica exposure. Silica has the potential to be present in any of the following materials and others discussed in the NEP.

- Abrasives such as mineral slags as well as sand
- Paints
- Concrete
- Portland cement
- Silicates
- Soil

Isn't Crystalline Silica Already Regulated?

OSHA regulates silica in construction under 29 CFR 1926.55, Gases, Vapors, Dusts and Mists and the in the general industry under 29 CFR 1910.1000. Essentially this is a "catch-all" regulation that states if you exceed the Permissible Exposure Limit (PEL), you must implement administrative and engineering controls followed by respiratory protection to reduce occupational exposures below the PEL. Silica is also referenced in 29 CFR 1926.57, Ventilation, which requires the use of an abrasive-blasting respirator when abrasive blasting with silica.

Moreover, since 1979, NIOSH has recommended that silica sand or other material containing greater than 1.0% crystalline silica (quartz) be prohibited as a media for abrasive blasting. Some state and local governments and DOTs have adopted these limits related to abrasive blast cleaning.

However, while the above regulations and recommendations have long been in place, they have typically not been enforced or treated by employers with the same level of detail as comprehensive regulations such as the lead or cadmium standards. OSHA began to focus on silica in 1996 through its Special Emphasis Program (SEP) on silica; this 2008 NEP builds on and expands the 1996 SEP.

And as will be seen later in this article, OSHA is particularly concerned with abrasive blasting operations and has set in place specific program elements in the NEP related to abrasive blasting, regardless of the abrasive used.

Highlights of the NEP on Crystalline Silica

The new NEP includes several key areas of interest to the painting and construction industry. Essentially, the NEP directs the OSHA Compliance Safety and Health Officer (CSHO) to evaluate specific items as identified below and provides guidance on issuing citations (under existing General and Construction Industry Standards) when violations are found. Key areas are summarized below.

Monitoring Workers for Respirable Silica: Complex but Not Impossible

The NEP requires the CSHO to conduct exposure monitoring for respirable silica and to collect bulk samples for analysis. Appendix C of the NEP provides a detailed procedure for air sampling and sample analysis. This includes the following specific requirements.

- Sample pump flow rate of 1.7 liters per minute to be evaluated before and after each use
- Use of an air sampling device with a 10 mm Nylon Dorr-Oliver cyclone and pre-weighted 37 millimeter cassette
- Procedures for cleaning and monthly leak testing of the cyclone using a pressure gage (See Appendix D of the NEP)

Appendix C also provides guidance on determining compliance with the PEL for respirable crystalline silica.

Under this methodology, the laboratory and/or industrial hygienist performing the sampling and analysis must provide you with the following information.

- Respirable dust concentration in the air
- Percent respirable crystalline silica
- Total weight of the dust collected in the air samples in milligrams
- Total volume of air sampled for each sample in cubic meters (1000 liters = 1 cubic meter)

ALL Abrasive Blasting Operations

OSHA does not simply single out silica exposure in abrasive blasting and other operations. In fact, of the 10 pages in the NEP on program procedure, nearly two pages, or one fifth of the procedures, are devoted to monitoring abrasive blasting operations whether they include silica sand or not as the media. The NEP directs the OSHA CSHO to perform the following during abrasive blasting operations.

- Conduct monitoring to determine employee exposure to metals such as: lead, arsenic, manganese, chromium, cadmium, copper, and magnesium in paints or abrasives. Most of the metals can be monitored with the same pump and filter media (except silica and hexavalent chromium).
- Where an alternative to sand is used for abrasive blasting, (i.e., glass beads, steel grit and shot, sawdust and shells), ensure that the contractor has appropriately evaluated the hazards associated with the materials.
- Determine whether the ventilation systems for abrasive blasting room and containment structures prevent escape of dust and provide prompt clearance of dust laden air.
- Conduct noise exposure monitoring.
- Evaluate respiratory protection and breathing air quality.
- Verify absorbent beds are in use in the compressor and maintained.
- Review air pressure controls.
- Confirm that the "dead man" is present and operational on blast nozzles.

In fact, don't think that the NEP won't apply to you if you aren't using silica sand or other silica-containing abrasives. Many common coating systems contain quartz and free silica. "A Case Study: Comparison of Occupational Exposures Among Painters Using Three Alternative Blasting Abrasives," published in the *Journal of Occupational and Environmental Hygiene* (September 2006), reported that existing coatings contained high percentages of quartz, ranging from 5.9 to 9.6 percent by weight. Even when these coatings were abrasive blast cleaned with non- or low-silica abrasives, worker exposures ranged from 0.42 mg/m^3 to 90.1 mg/m^3. The authors' review of Material Safety Data Sheets indicated that quartz and other forms of silica may be present in many coating systems.

• Total sampling time for each air sample in minutes

Note that unlike lead and other hazardous metals where the PEL is a fixed number (e.g., 50 micrograms per cubic meter), the PEL for respirable silica must be calculated based upon the percent of respirable silica present in each unique sample.

The current OSHA Construction Industry PEL for silica is expressed in millions of particles per cubic foot (mppcf). However, the sampling methodology in use when this standard was established (i.e. particle counting) is now obsolete. Modern sampling methodology for silica is based on gravimetric analysis (i.e., weighing the filter before and after sampling) as well as x-ray diffraction or fourier transform infrared analysis. The results cannot be expressed in mppcf. Currently, air sample results are expressed in milligrams per cubic meter (mg/m^3).

The NEP provides a procedure in Appendix E for converting mg/m^3 into mppcf so that results can be compared directly with the OSHA Construction Industry PEL.

Given the rigorous requirements for the sampling, calibration, and calculation of the PEL and the actual results, use of an industrial hygiene professional may be necessary to obtain valid and accurate monitoring results.

Engineering and Work Practices Will Be Checked

The NEP directs the OSHA CSHO to evaluate the following.

- Isolation of the dust generating source from others and use of local exhaust ventilation
- Use of HEPA vacuums
- Employers' use of compressed air for cleaning silica contaminated surfaces

The last item is of significant concern because use of compressed air for "blow-down" is a common and necessary practice for removing spent abrasives from a blasted surface. As stated in the NEP, this practice appears to be prohibited when crystalline silica is present.

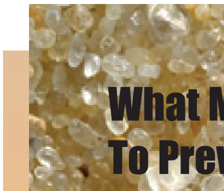
Respiratory Protection and Medical Records

The NEP requires the OSHA CSHO to evaluate respiratory protection per the requirements of the respirator standard. The CSHO is also required to interview employees regarding the understanding of their rights regarding medical records and confidentiality and to review the employer's recordkeeping program. Appendix F of the NEP introduces an "Employee Questionnaire" that may be used be the CSHO for employee interviews.

Hazard Communications Play a Role

The NEP requires labeling on containers and Material Safety Data Sheets (MSDS) for crystalline silica. It also requires carcinogen warnings on containers and MSDS if the material contains more than 0.1 % crystalline silica by weight.

The CSHO is directed to perform bulk sampling of materials



What Measures Can We Take To Prevent Silica Overexposure?

What's does this mean to our industry? Most of the protections commonly used to control exposures to lead and other toxic metals (i.e., containment/ventilation) will also help control silica exposures. However, all employers potentially exposing their workers to silica should consider the following measures.

- Review the MSDS for abrasive materials for the presence of free silica, and consider evaluating existing coating systems for the presence of quartz or other free silica.
- Perform crystalline silica monitoring during operations to verify that exposures are below the PEL for crystalline silica.
- Implement ventilation and verify that control practices are in place. In our industry, we sometimes tend to treat ventilation, clean-up, etc., as something we only need to do when lead or other toxic materials are involved.

(such as abrasives) if the MSDS appears inadequate or incomplete.

Non-Mandatory Medical Monitoring for Exposed Workers

The NEP includes Appendix G, non-mandatory medical monitoring recommendations that go far beyond current regulatory requirements. Appendix G suggests that employees who are potentially exposed to crystalline silica at one-half the permissible exposure limit (PEL) or more be provided with a preplacement baseline medical examination emphasizing the respiratory system, as well as an occupational and medical history and chest roentgenogram (X-ray).

The non-mandatory Appendix G further recommends that the medical exam and chest x-ray be repeated every three years if the employee has less than 15 years of crystalline silica exposure, every two years if the employee has 15 to 20 years of exposure, and annually if the employee has 20 or more years of exposure. An employment termination x-ray is also recommended.

NEP Includes Checklist for Silica-Related Inspections

The NEP includes Appendix H, a non-mandatory CSHO Checklist for Conducting Silica-Related Inspections, which summarizes the items discussed above. While the CSHO does not have to use the checklist, it is fairly comprehensive guidance document for abrasive blasting, including items such as the following under the heading of "Abrasive Blasting."

• Verify that abrasive blast cleaning equipment meets parameters established in the NEP.

Owners may want to:

• Specify non- or low-silica abrasives for use on their projects; require abrasive and coatings testing for the presence of crystalline silica content (typically quartz or crisotobalite).

• Consider controlling potential exposures on other construction operations such as concrete work, deck replacement, graffiti removal, etc., that are typically not as rigorous in their use of containment, ventilation and respiratory protection.

Because abrasive blast cleaning operations, as well as construction of all types, have been "targeted" by OSHA, all of us do well to verify our compliance with the mandatory requirements of this NEP. A copy of the NEP can be accessed at:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=37

- Sample for silica and metals (including bystanders' exposure)
- Sample for noise
- Check ventilation and dust containment
- Check PPE and respirators
- Check carbon monoxide alarm
- Check manual control of blast nozzle operating valve
- Check electrical grounding
- Check pressure range (90—120 psi)
- Monitor heat stress

Follow-up, Monitoring Are Mandatory for Citations

Where citations are issued for overexposure to crystalline silica, follow-up visits are mandatory and must be conducted to determine if exposures have been reduced below the PEL. If the project is completed, the Area Office is to request written updates from the employer documenting their progress on the corrective actions and to track the resolution of the deficiency.

Summary

OSHA's initiation of a NEP regarding exposure to crystalline silica will result in an increased likelihood of inspection of employers within the targeted industries, given that OSHA has required that, at a minimum, two percent (2%) of all inspections will involve a crystalline silica-related inspection. Additionally, this NEP expands the scope of the CSHO inspection activities far beyond those that were required in the 1996 SEP, to include evaluation of ventilation and abrasive blast cleaning operations. ■

A Survey of Practices:

Surface Preparation for Industrial Coating Work

By the JPCL Staff

Abrasive blast cleaning is the most commonly used method of surface preparation for steel and concrete, according to responses to a May 2008 *JPCL* survey on the state of practices in industrial surface preparation. However, rising costs, compliance with environmental and worker health regulations, and advances in surface preparation equipment have led many contractors to change their methods or materials for surface preparation over the past ten years, according to nearly half of the respondents to the *JPCL* survey.

JPCL conducted the survey on line, emailing the questionnaire to most of the 1,500 contractors who had, earlier this year, identified themselves as industrial painting contractors when they completed the form for *JPCL*'s March 2008 Annual Directory of Industrial Painting Contractors. The majority of the contractors contacted are based in the U.S. and Canada.

We selected the 2008 Directory respondents for the survey to minimize sending duplicate forms to the same company. Of the 1,500 contractor firms, approximately 100 either lacked email or had Internet servers that rejected our email. Of the approximately 1,400 firms receiving the form, approximately 193 recipients, or 14%, completed it by the deadline. Not all respondents answered every question.

Unfortunately, we were not able to include every method and material in the survey. A scientifically developed and conducted survey was beyond our scope (and budget). Rather, we developed the survey to get (and provide) an informal look at current practices in surface preparation. In this article, we focus mainly on preparing steel, the more common of the substrates in the survey.

Fig. 1: Respondents and Industrial Surface Preparation*

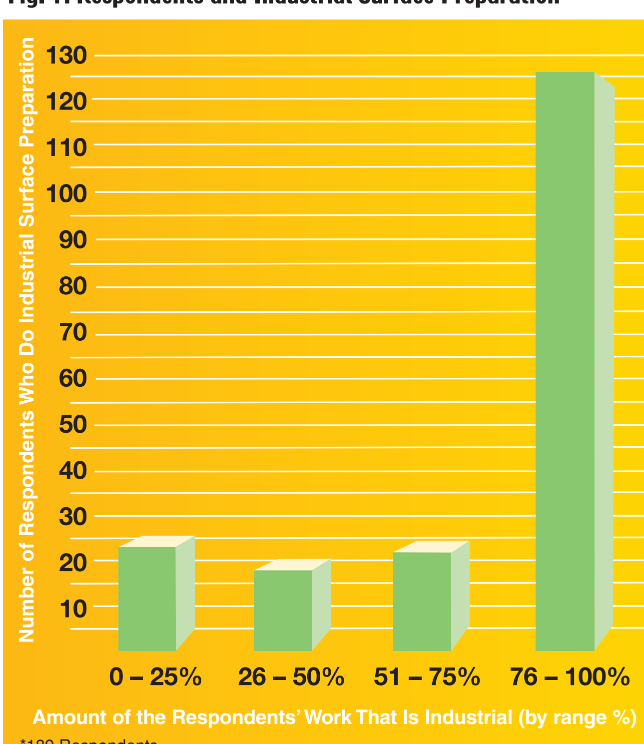


Fig. 2: Respondents and Surface Preparation of Steel*

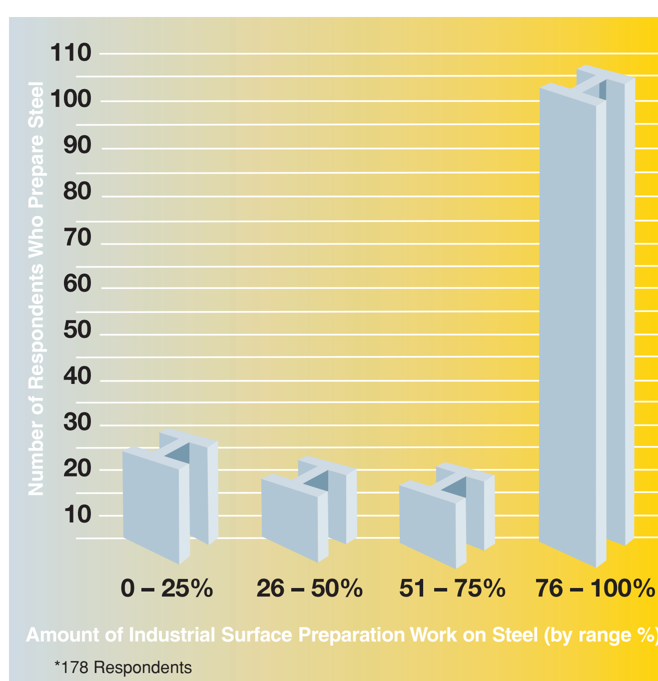
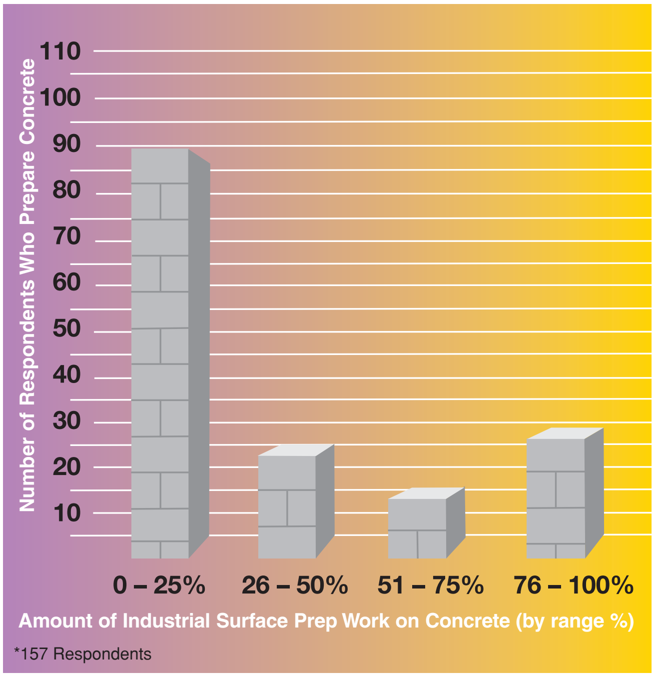


Fig. 3: Respondents and Surface Preparation of Concrete*



A Profile of Our Respondents

As shown in Fig. 1, 126 respondents of 189 total respondents perform more than 75% of their work in the industrial settings. Figure 2 shows that 108 contractors of the 178 who answered the question perform more than 75% of their industrial work on steel, while in Fig. 3, 28 of 157 respondents perform a majority of their industrial work on concrete.

Figure 4 reflects the average percentage of industrial coating contracts for the survey respondents per sector: private, public, and military. More than half of the contracts are from the private sector.

The Survey at a Glance

Tables 1—5 reflect answers about the frequency with which each respondent's firm uses a number of the com-

Table 1: General Overview of Methods Used – Steel

	Never	Occasionally	Often	Almost Always
Dry abrasive blast cleaning	5.8%	8.1%	33.7%	52.3%
Wet/water cleaning	20.0%	35.0%	36.9%	8.1%
Power tool cleaning	5.9%	38.2%	45.9%	10.0%
Other	37.3%	39.0%	15.3%	8.5%

Rows may not add up to 100% because of rounding.

Table 2: Abrasive Blasting Practices – Steel

	Never	Occasionally	Often	Almost Always
Blast cleaning with coal slag	33.9%	26.7%	25.5%	13.9%
Blast cleaning with copper or mineral slags	47.2%	35.4%	11.8%	5.6%
Blast cleaning with recyclable shot or grit	25.6%	22.0%	24.4%	28.0%
Blast cleaning with silica sand	50.3%	25.1%	17.4%	7.2%
Blast cleaning with sponge abrasive	77.4%	17.7%	3.7%	1.2%

Rows may not add up to 100% because of rounding.

Table 3: Water Methods – Steel

	Never	Occasionally	Often	Almost Always
Ultra-high-pressure (UHP water-jetting (>25,000 psi)	61.5%	25.4%	8.9%	4.1%
High-pressure water jetting (10,000-25,000 psi)	58.4%	28.3%	10.8%	2.4%
High-pressure water cleaning (5,000-10,000 psi)	32.9%	35.9%	27.1%	4.1%
Low-pressure water cleaning (<5,000 psi)	19.2%	30.2%	38.4%	12.2%
Wet abrasive cleaning	41.2%	47.6%	11.2%	0.0%

Rows may not add up to 100% because of rounding.

Table 4: Other Methods – Steel

	Never	Occasionally	Often	Almost Always
Power tool cleaning	6.4%	39.9%	42.2%	11.6%
Paint removal with lasers or heat methods	86.0%	11.6%	2.3%	0.0%
Blast cleaning with dry ice	86.3%	13.1%	0.0%	0.6%
Blast cleaning with garnet	53.6%	34.5%	10.7%	1.2%
Paint removal with chemical strippers	37.3%	54.4%	7.7%	0.6%
Other	75.7%	10.8%	10.8%	2.7%

Rows may not add up to 100% because of rounding.

mon methods of preparing steel. The answers are qualitative, only, and therefore somewhat subjective because, for the sake of making the survey useable, "occasionally," "often," and "almost always" were not further defined.

Table 1 gives an overview. Perhaps not surprisingly, just over half of contractors who responded use dry abrasive blasting almost always, while power tool cleaning ranked second in frequency of use at 45.9%. Wet and water methods ranked third at 36.9%, and "Other" methods ranked fourth (39%). "Other" methods contractors reported for preparing steel (that were not part of other questions on the survey) included track blasting, hand tool cleaning, solvent cleaning, steam cleaning, diamond grinding, and wheel blasting.

Of the abrasives we listed in Table 2, recyclable steel shot and grit had the highest percentage of materials "almost always used" (28%).

Wet and water methods of cleaning have not, according to our respondents, caught up with dry methods in frequency of use, but there is strong occasional use of the five types of wet methods we listed (Table 3).

And of alternative methods that we offered as choices in the survey (Table 4), power cleaning had the highest rating. "Other" methods recipients listed (that were not part of the survey elsewhere) included blasting with aluminum oxide, paint stripping with steam, and blasting with crushed glass.

While we must underscore the fact that these results are relative and somewhat subjective, they indicate, as shown in Table 5, that contractors do use a variety of methods to prepare steel; every method identified is used to one degree or another, albeit not by all contractors.

The same can be said of contractors who prepare concrete (Table 6). The response to our question about frequency of use of nine methods indicat-

Fig. 4: Average % of Industrial Coating Contracts by Sector

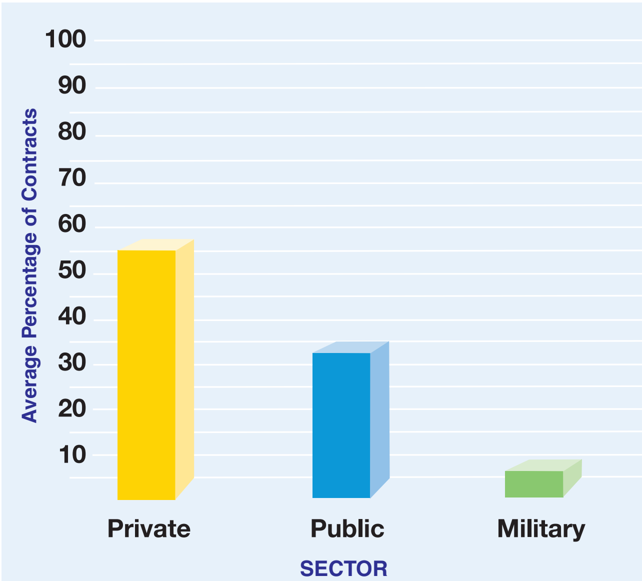


Table 5: Overall Use of Methods – Steel

	1 (most common)	2	3	4	5 (least common)	N/A
Dry abrasive blast cleaning–open blast cleaning with expendable abrasives	48.2%	15.9%	10.6%	7.1%	10.0%	8.2%
Dry abrasive blast cleaning–self contained machine with recyclable abrasive	28.4%	10.5%	11.7%	11.7%	21.6%	16.0%
Wet abrasive blast cleaning	3.7%	7.5%	14.9%	18.0%	28.0%	28.0%
Low-pressure water cleaning (<5,000 psi)	18.9%	16.5%	20.1%	11.0%	18.3%	15.2%
High-pressure water cleaning (5,000 to 10,000 psi)	8.7%	14.9%	13.7%	16.1%	20.5%	26.1%
High-pressure water jetting (10,000 to 25,000 psi)	5.6%	4.4%	12.5%	11.3%	34.4%	31.9%
Ultra-high-pressure water jetting (>25,000 psi)	6.9%	6.3%	5.7%	11.9%	32.1%	37.1%
Powel tool cleaning	22.1%	29.1%	16.3%	17.4%	9.3%	5.8%
Paint removal with chemical strippers	4.8%	7.2%	14.4%	13.8%	36.5%	23.4%

Rows may not add up to 100% because of rounding.

ed that many methods have a place in the contractors' repertoire. No method was rejected by everyone, just as no single method was the only one used.

Trends: From Tougher Regs to Better Technology

We also asked contractors if their surface preparation methods had changed over the past ten years, and if so, how. 165 people responded to the question. Just over half, 53%, said their practices had not changed in 10 years, while just under half, 47%, said their practices had changed. For those who have made changes in the way they conduct surface preparation, here are some of the changes or causes of

Table 6: Overall Use of Methods – Concrete

	1 (most common)	2	3	4	5 (least common)	N/A
Dry abrasive blast cleaning– open blast cleaning with expendable abrasives	32.6%	13.9%	11.1%	6.3%	16.0%	20.1%
Dry abrasive blast cleaning– self contained machine with recyclable abrasive	19.0%	14.3%	14.3%	5.4%	23.1%	25.2%
Wet abrasive blast cleaning	2.1%	10.6%	21.3%	12.8%	26.2%	27.0%
Low-pressure water cleaning (<5,000 psi)	21.3%	18.4%	20.6%	13.5%	8.5%	17.7%
High-pressure water cleaning (5,000 to 10,000 psi)	7.7%	10.6%	16.2%	14.1%	26.1%	25.4%
High-pressure water jetting (10,000 to 25,000 psi)	2.9%	8.6%	7.2%	7.9%	37.4%	36.0%
Ultra-high-pressure water jetting (>25,000 psi)	6.7%	6.7%	4.4%	6.7%	36.3%	39.3%
Powel tool cleaning	14.7%	23.1%	17.5%	11.9%	14.7%	18.2%
Paint removal with chemical strippers	7.0%	13.4%	16.2%	12.0%	26.8%	24.6%

*Rows may not add up to 100% because of rounding.

change that they described.

Five persons specifically said that regulations or other restrictions had led them to change how they worked: containment/disposal requirements were cited. "EPA-OSHA and cost have eliminated media blasting," noted another.

One respondent reported, "We used to use inexpensive silica sand (99% of our work is new steel) and now the insurance companies do not allow the silica providers to sell to blasting contractors. Our raw product costs have increased almost 4 times...."

Other comments on the regulatory climate were more general: "stricter requirements and enforcement of specifications," and rule[s] and law[s] enforced."

Without naming regulations on blasting operations as a reason for changes in their work, many respondents said that in the past ten years, they have shifted to different abrasives for blast cleaning or to other methods altogether, and many of the changes pose fewer risks to workers and the environment.

Approximately 15 respondents have switched to recyclable abrasives exclusively or are using them more often. Remarks on the switch included "We are shifting towards all recyclable blast materials," "more steel abrasive used on a daily basis," "more recyclable abrasives than expendable," "stopped using silica and went with grit," and "recycling with steel grit is the biggest change."

Other media in the mix now weren't used by some contractors ten years ago. Comments included "sponge, soda, ultra-high water"; "utilizing environmentally improved blast mediums (water and glass)"; "ceramic micro bea[d]s blasting in an enclosed cabinet"; "using a lot of crushed glass"; and "use of grits (coal and copper slag)."

Cost effectiveness figures in changing materials for some contractors. One noted, "We use primarily mineral slag and are switching more towards aluminum oxide and steel grit as costs increase."

Almost as many respondents have switched to water cleaning methods or are using them more often than they did 10 years ago. "We have substantially increased the amount of steel and concrete surface preparation...with UHP waterblasting equipment," wrote one contractor. Another said that in the last 10 years, his company has used "only HP water cleaning at 7200 psi hot/cold."

Some contractors noted benefits of the switch: "Use mostly water now instead of some type of sand or other abrasive...more cost-effective, less hazardous," wrote one person surveyed, while another said simply, "higher pressures, less water."

Taking advantage of advances in equipment also figured in some companies' changes in practice. "We have added a 60-foot steel grit blast & paint booth. It has revolutionized our business," wrote one contractor. Another recipient noted simply the company's "Upgrad[ing] of equipment, use of after coolers, dryers, sizes of blast hoses, different nozzles, etc."

One contractor's response about changes combined cost-effectness, regulatory compliance, and advances in technology: "We do mainly maintenance projects that do not give us a lot of time for prep so cleanup was always an issue. In the past we power tooled most of the jobs because of this reason. Now with better equipment and abrasive technologies, we are able to do a better, safer surface prep and clean up in the same time that power tooling used to take." ■

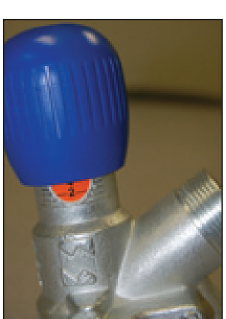
A Snapshot of New Technologies in Surface Preparation

By the* JPCL *staff

Developments in surface preparation technologies continue unabated, or so it seems, as *JPCL* surveys a sample of the latest offerings from manufacturers of industrial surface prep equipment. The following product profiles are not comprehensive in scope, but do represent many of the manufacturers' submissions to the *Journal* in the past year. The profiles below are intended to demonstrate that new technologies, as well as advances in existing technologies, can serve many purposes—to meet new environmental and safety regulations, and to increase equipment functionality, efficiency, and user friendliness.

Blasting Units and Components

Axxiom Manufacturing Inc. (Fresno, TX) has introduced an abrasive control valve, the patent-pending MV2™, which shows the operator the valve settings. The valve is the successor to the Schmidt® Microvalve. (Axxiom has acquired the exclusive rights to manufacture all Schmidt® products.) The new metering valve features a virtual position indicator (VPI) that shows the position of the plunger relative to the abrasive orifice inside the valve. There are also gradation marks that count the number of turns of the adjustment knob. The VPI gives the operator more precision and consistency when adjusting the abrasive flow for different application conditions, nozzle sizes, blast pressures, and abrasive size and types, according to the company.



The valve also utilizes the compressed air before it is mixed with abrasive to loosen or aerate the abrasive particles sitting above the valve, where they tend to pack if stagnant for a while. Loosening the packed media produces a more consistent flow of abrasive. The valve's internal components are made from improved abrasive-resistant materials. Because of its reconfigured body and fewer wearing parts, the valve is easier to disassemble and rebuild than its predecessor. For more information: www.axxiommfg. com.

Blastrac® (Oklahoma City, OK) has introduced the 1-9DEZ, a portable, lightweight shot blasting system used to prepare concrete surfaces before application of paint or coatings. Suitable for smaller jobs or tight areas, the 1-9DEZ runs on 120-volt power to strip, clean, and profile in one step.

According to the company, there is no rinsing or drying time, and the profile provides a better surface for coating adhesion. With a 9-inch blast pattern and a manual travel speed, the blaster can prepare up to 275 sq ft per hour, the company says.

The blaster is designed for applications such as small industrial floor areas, tight areas around equipment and obstructions, and test patches. For more information: 800-256-3440.

The Blastrac Highway and Airport Division has introduced the 2-45DT Mounted Blaster to meet the increased demand for higher production surface preparation equipment. With a 45 in. blast pattern, the 2-45DT shot blaster is designed for large projects.

The highway-ready truck has all the required equipment—dust collection, abrasive storage, hydraulic controls, and spare parts—contained inside the customer truck body, thus eliminating the need for additional support equipment. Once on site, the closed-circuit, dust-free shot blasting process is attached to the front and controlled by a single operator from the cab of the specially modified truck.

The 2-45DT retextures asphalt, concrete roads, highways, and airport runways and taxiways. In addition, it removes rubber. It can also be used for surface preparation of bridge decks prior to the application of waterproofing membranes or polymer concrete toppings. For more information: 800-256-3440.

Kärcher Industrial Products (Camas, WA) has introduced a dry ice blaster that it describes as a highly effective and mess-free tool for in-place cleaning.

The new IB 15/80 Dry Ice Blaster uses compressed air to propel dry ice pellets at supersonic speeds; the pellets flash freeze and then remove paint, rust, and other contaminants from a broad range of surfaces. The pellets quickly dissipate into the air, leaving only the soiled contaminant, which is swept up or vacuumed and disposed of, the company says.

The blaster is safe to use on a wide range of surfaces, including all metals, the company says.

The unit operates on electricity and uses a blasting pressure of 44 to 230 psi. Compressed air requirements range from 150 to 300 cfm. For more information, 800-347-6116, ext. 175.

Marco (Davenport, IA) has introduced three new blast machines: the 6.5 Easy Fill Series, the Big Red Stationary, and the Big Red Yard Towable. All three machines are rated at 150 psi working pressure for use with high-output compressors, which, according to the company, provides high pressure at the blasting nozzle, thus increasing productivity.

The 6.5 cubic ft Easy Fill Series combines a low loading height, designed to make it easy to fill with bagged abrasive, an easy to use with the company's KwikFire 125 remote control system and its Bantam Metering Valve.

Easy Fill Series

The Big Red Stationary Bulk blast machine, with a capacity of 160 cubic feet, features a 1600 CFM moisture separator that protects the tank from excess moisture and contamination. A low pressure drop design increases production by providing consistent delivery pressure during all phases of operation, the company says.

The Big Red Yard Towable blast machine shares all the features of the Big Red Stationary, but is mounted on a four-wheel trailer that features an adjust- able military hitch and removable jack. For more information: 800-252-7848.

The MBX® Bristle Blaster from **Montipower** (Boyce, VA), a hand-held power tool, removes corrosion, mill scale, and defunct protective coatings while simultaneously generating an anchor profile. Developed by **Marquette University** (WI), the tool creates a surface similar in visual cleanliness and texture to a surface prepared by grit blasting, the company says. According to the company, this combination of functions is designed to simplify surface preparation and reduce expense through the elimination of grit blasting equipment and media and the associated environmental and safety measures.

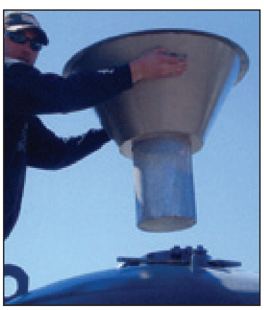
Although the rotary bristle tool is ideally suited for spot-repair applications, it is also recommended for larger surface areas where the use of other metal cleaning processes may be prohibitive.

The company says recent tests done at other organizations indicate that the tool restores corroded and pitted steel surfaces to a Near-White or White Metal appearance, and an anchor profile of 2.6

to 3.3 mils is routinely obtained on standard API 5L steel, which is commonly used for petroleum piping applications. For more information: 540-837-1138.

Olympus Painting and Sandblasting (Reno, NV) has introduced the Screen Saver, a removable stainless steel bulk abrasive blaster filter system designed to remove contaminants and eliminate abrasive waste and the need to monitor abrasive loading into the bulk pot. The Screen Saver is compatible with most bulk pots available on the market, according to its manufacturer.

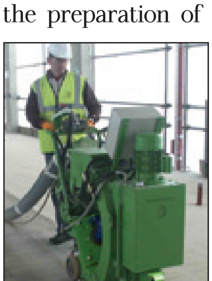
The device is designed to easily fit inside the filler port, with the cone outside to accommodate the flow of the abrasive and prevent abrasive spillage around the filler port. According to the company, for most other abrasive systems, the operator must monitor and regulate the flow of the abrasive into the bulk pot; the Screen Saver, however, frees the operator from performing this function.



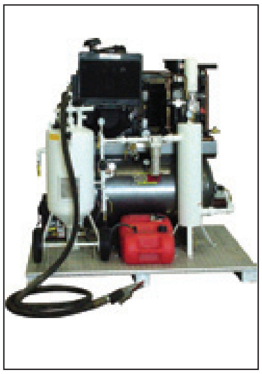
For more information: 775-322-0346.

The Preparation Group (Lincoln, UK) has launched the model PPC 558 shotblaster. According to the company, the compact and maneuverable machine offers production rates of up to 450 sq m per hour. Intended applications include the preparation of industrial and warehouse floors, ship decks, storage tanks, airport runways, highways, and bridges.

Designed for use where high levels of productivity are required, the machine fully contains and recycles abrasive. Wear parts are easily interchangeable, according to the Group. For more information: www.ppcgroup.co.uk.



According to Houston, TX-based **SodaBlast Systems LLC**, its soda blasting systems clean and strip the most vulnerable surfaces with unequaled results. And because baking soda is an all-natural, 100% biodegradable, and water-soluble blasting medium, the clean-up is both easy and gentle to the environment.



The company's soda blasting systems deliver baking soda by compressed air onto fiberglass, metals, wood, masonry, and other surfaces. Some of the uses include paint stripping, de-greasing, graffiti removal, mold remediation, and fire/smoke restoration. For more information: 800-216-7632.

Waterblasting Units and Components

Jet Edge, Inc. (St. Michael, MN) has introduced the iP36-280DS diesel-powered waterjet intensifier pump. The company says that the pump is ideal for use in remote or mobile locations where electricity is scarce. The unit is powered by a 280 hp turbo diesel engine that meets domestic and international Tier 3 emissions standards, the company says. Tier 3-compliance means that the unit meets emissions standards promulgated by the U.S. Environmental Protection Agency to regulate the amount of hydrocarbons and nitrogen oxides generated by off-road engines of all sizes.

It is capable of producing a flow rate of up to 7.2 gallons (27 liters) per minute of 36,000 psi (2,500 bar) ultra-high pressure water for waterjet cutting, surface preparation, and cleaning applications, Jet Edge reports.

The iP36-280DS utilizes a pressure-compensated hydraulic system to drive dual plunger-style intensifiers. The use of hydraulic fluid power provides smooth

flowing UHP water resulting in long system life. Reliable and precise control of the electronically shifted intensifiers ensures superior performance standards with reduced operating costs. The pump is built on a skid-mounted frame with lifting eyes and forklift guides provided for increased mobility. For more information: 800-538-3343.

Jetstream of Houston (Houston, TX) has introduced the X-Series mobile waterblast unit featuring Jetstream's patented UNx™ fluid system designed for fast conversion between 10,000, 20,000, and 40,000 psi operating pressures. The new unit also features the Guardian Filter System™—a water tank system with integrated filters designed to help extend system life—as well as a new trailer design with a lower center of gravity and an optimized wheelbase for improved towing and steering.

Consisting of a rotomolded 100-gallon tank with dual replaceable filters inside, the Guardian Filter System automatically frees all fill water of abrasive, dirt, and other contaminants that can shorten the life of pumps and gun components.

Positioned at the front of the trailer frame to improve tank and pump access while optimizing weight distribution on the dual axle trailer frame, the large capacity water tank reduces chances of cavitation by increasing dwell time, the company says.

The X-Series is available in 110 to 500 hp models, with operating pressures from 6,000 to 40,000 psi. For more information: www.waterblast.com.

NLB Corp. (Wixom, MI) has introduced the NLB 325 Series of convertible water jet units, which operate up to 400 hp at any of six pressures up to 24,000 psi. The new convertible quintuplex pumps have many features and parts in common with models in the company's 225 Series. The common features simplify operation, maintenance, and inventory for waterjetters who use the units from both series.

Two diesel-powered models are available, each with a low-wear quintuplex pump and a convenient swing-out manifold that makes conversion easy, the company says. Model 405 (400 hp) can be converted to run at six pressures between 8,000 and 24,000 psi. Flows range from 25 gpm to 74 gpm. Model 365 (365 hp) can also run at six pressures between 8,000 and 24,000 psi. Flows range from 22 gpm to 64 gpm.

NLB 325 Series convertible water jet unit

NLB also has introduced the MGV15-3000, a multi-gun valve for high-pressure water jetting that operates at high flow and that can be repaired in the field in less than five minutes. A multi-gun valve allows the use of two or more water jet lances from a single high-pressure pump unit.

The MGV15-3000 is designed for operating pressures from 4,000 psi to 15,000 psi (276 to 1,050 bar) and flows up to 30 gpm (113 lpm) per side. It features a disposable, screw-in cartridge seal.

According to the company, the valve can be used with any dump-style water jet lance. Each operator independently controls the loading and dumping of his own lance, and the nozzles in the lances can be different sizes. For more information: 248-624-5555.

Surface Grinders and Cutters

New from **CDCLarue Industries** (Tulsa, OK), the Hum-B™ edge grinder is ergonomically designed to allow the user to grind in an upright position, helping to eliminate fatigue, backaches, and jobsite injuries. The product is designed for grinding or polishing concrete, terrazzo, stone, and masonry, or removing paint, adhesives, mastic, and epoxy floor coatings.

The Hum-B™ is equipped with the Dust Grabber™ dustless shroud, which allows the Hum-B to float across the surface with out creating suction lock to slow down the grinding process. According to the company, the shroud eliminates 100% of suction lock, captures 99% of airborne dust, and cuts shroud replacement cost by 75%. The replaceable polymer seals are designed to be quick and easy to replace and do not require the diamond wheel or shroud to be removed.

The 110-volt grinder is available as a single speed (6,000 rpm) grinder or as a variable speed (3,000 rpm) grinder for polishing. It is equipped with gas-filled shocks for level grinding and a twelve-segment diamond grinding wheel. For more information: 918-216-6100.

According to **Sawtec**, its new handheld DEKRASAW® is ideal for the decorative concrete industry and can be used by one person to cut and score decorative lines into concrete.

The 110V saw is composed of an aluminum base, making for a durable and lightweight machine. An optional pivot base, when combined with the unit, can be used for radial cuts to create geometric shapes, arcs and circles, the company says. Front and rear roller guides allow users to easily follow a chalk line for accurate straight line cutting. For safety and convenience, a spring-loaded head pushes the blade down to cut and then automatically retracts the blade when not in use. The cutting depth is adjusted with a thumb screw, requiring no tools. For more information: 800-256-3440.

Paint Strippers

Green Products LLC's (Romeoville, IL) aMAIZEing™ Biobased Solvent & Stripper is derived completely from a proprietary blend of U.S. grown corn and soybean esters. According to the company, the stripper is designed to lift, strip, and remove mastics, adhesives, lead paint, and other substances from concrete, masonry, wood, metal, and other surfaces. It can be applied by brush or sprayer.

The company says that the product is 100% biobased per ASTM D 6866-04 (Test Methods for Determining the Biobased Content of Natural Range Materials Using Radiocarbon and Isotope). It also complies with the Federal government's Biobased Product Procurement Preference Program, and it is suitable for use in restoration and maintenance programs under the U.S.G.B.C. LEED Green Building Rating System®, the company reports.

The stripper contains no environmentally hazardous ingredients or ozone depleting chemicals (ODCs). For more information: 877-474-7481.

New from **NexTec, Inc.** (Dubuque, IA), the PreTox 8000 paint stripper is designed specifically for removing lead-based industrial paint systems. PreTox 8000 will chemically stabilize the leachability of lead in the resulting paint waste to avoid U.S. EPA RCRA-TCLP Hazardous Waste characterization, the company says. The new product can be spray applied.

According to the company, the fast-acting stripper contains no methylene chloride, MEK, or caustics; is not highly flammable; and meets current VOC requirements.

PreTox 8000 may be used in typical paint stripping processes, and also offers significant improvement to blast removal rates using conventional grits and other blast media such as UHP, CO_2, or ice, the company reports. The product has been developed for use in large industrial paint removal projects done previously with grit blasting alone and to address the growing need for localized paint removal on bridge structures undergoing inspection, the company says. For more information: 800-338-8296.

■

What in the World of Standards is New for Surface Preparation?

By Brian Goldie, *JPCL*

Standards play an important part in all industries, and the field of surface coatings is no exception. Standards allow comparisons of products, techniques, and practices to be carried out globally so that meaningful specifications can be drawn up and decisions made on best practice.

Within the surface coatings field, good surface preparation is essential for long-term performance. A brief description of several major standards-writing bodies follows, along with a list of new, updated, and withdrawn surface preparation standards as well as those under review from the main organizations from around the world that issue the standards: the International Organization for Standardization (ISO), the European Standards Committee (CEN), SSPC: The Society for Protective Coatings, NACE International, and ASTM International. The list covers major activities over the past six months, but it is not intended to be comprehensive.

A Glance at How Standards Come into Being

Within ISO and CEN, standards are drafted by technical committees made up of national delegations of experts chosen by the national standards bodies that make up ISO. ISO and CEN cooperate and coordinate to make the best use of resources and avoid redundant efforts. One or the other of the two will take the lead in developing a standard that is of interest to both bodies. The draft is then voted on by the two organizations so that on approval, it can be adopted as both an International (ISO) and European Standard (EN).

ISO standards, which have a separate identity from national standards, can stand alone. EN standards, however, must be adopted by the individual member nations of CEN, and conflicting national standards must be withdrawn. Hence, one standard can have the same number, but prefixed by ISO, EN, and the national designation (e.g., BS for British Standards), and the text must be identical from nation to nation.

SSPC and NACE also have an agreement to issue joint standards, usually for surface preparation, to avoid unnecessary duplication of work between the two organizations and confusion among users in the field. Working groups drawn from both associations draft the standards, and they are revised and approved through a standards review process.

New CEN, ISO Standards

- EN ISO 129445–5, Paints and varnishes. Corrosion protection of steel structures by protective paint systems. This standard supersedes the 1998 edition.

CEN, ISO Standards under Review

- EN ISO 8501–2, Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness. Preparation grades of previously coated steel substrates after localized removal of previous coatings.
- EN ISO 8502, Preparation of steel substrates before application of paints and related products. Tests for assessment of surface cleanliness

Part 2, Laboratory determination of chloride on cleaned surfaces

Part 3, Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)

Part 4, Guidance on the estimation of the probability of condensation prior to paint application

Part 5, Measurement of chloride on steel surfaces prepared for painting (ion detection tube method)

Parts 6–8 are not under review

Part 9, Field method for the conductimetric determination of water soluble salts

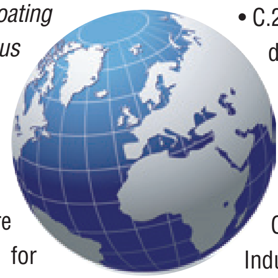
- EN ISO 8503, Preparation of steel substrates before application of paints and related products. Surface roughness characteristics of blast-cleaned steel substrates

Part 1, Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces

Part 2, Method for the grading of surface profile of abrasive blast-cleaned steel

Part 3, Method for the calibration of ISO surface coating comparators and the determination of surface profile. Focussing microscope procedure

Part 4, Method for the calibration of ISO surface coating comparators and the determination of surface profile. Stylus instrument procedure



• EN ISO 8504-3 Preparation of steel substrates before application of paints and related products. Surface preparation methods. Hand and power tool cleaning

• EN ISO 11124 Preparation of steel substrates before application of paints and related products. Specifications for metallic blast-cleaning abrasives

Part 1, General introduction and classification

Part 2, Chilled iron grit

Part 3, High carbon cast-steel shot and grit

Part 4, Low carbon cast-steel shot

• EN ISO 11125, Preparation of steel substrates before application of paints and related products. Test methods for metallic blast-cleaning abrasives

Part 1, Sampling

Part 2, Determination of particle size distribution

Part 3, Determination of hardness

Part 4 Determination of apparent viscosity

Part 5, Determination of percentage defective particles and of microstructure

Part 6, Determination of foreign matter

Part 7, Determination of moisture

• EN ISO 11126, Preparation of steel substrates before application of paints and related products. Specifications for non-metallic blast cleaning abrasives

Part 1, General introduction and classification

Part 3, Copper refinery slag

Part 4, Coal furnace slag

Part 5, Nickel refinery slag

Part 6, Iron furnace slag

Part 7, Specification for fused aluminium oxide

Part 8, Olivine sand

• EN ISO 11127, Preparation of steel substrates before application of paints and related products. Test methods for non-metallic blast cleaning abrasives

Part 1, Sampling

Part 2, Determination of particle size distribution

Part 3, Determination of apparent density

Part 4, Assessment of hardness by glass slide test

Part 5, Determination of moisture

Part 6, Determination of water-soluble contaminants by conductivity measurements

Part 7, Determination of water-soluble chlorides

• EN ISO 12944, Paints and varnishes. Corrosion protection of steel structures by protective paint systems.

Part 4, Types of surface and surface preparation

SSPC, SSPC/NACE Standards under Development

The documents below are identified first by committee number (C.x.x) or task group number (TG XXX)

• C.2.1, Standard for sponge-encapsulated abrasives. Ballot of draft #1 for committee comment

• C.2.8, Standard for brush-off blast cleaning of non-ferrous substrates. For ballot by unit committee

• SSPC TG A/NACE TG 006, Revision/re-affirmation of SSPC-SP 5, White Metal; SP 6, Brush-Off Blasting; SP 7, Commercial Blasting; SP 10, Near-White; and SP 14, Industrial Blast Cleaning. For review by Steering Committee prior to formal ballot.

• SSPC TG D/NACE 275-278, Proposal to split existing SSPC SP-12/ NACE No. 5,White Metal, into 4 separate standards. Preparing revised draft for re-ballot

• SSPC/NACE TG 350, Surface preparation by wet abrasive blast cleaning. Second draft for ballot by respective committees

• SSPC/NACE TG 142, Revision of technical report on surface preparation of contaminated surfaces. Awaiting final draft for review by committee

SSPC Proposes Revised Standards for Comment

• SSPC-Guide 6, Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations

• SSPC-AB 1, Mineral and Slag Abrasives

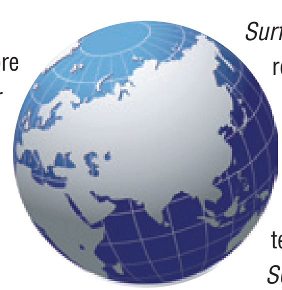
• SSPC-AB 2, Cleanliness of Recycled Ferrous Metallic Abrasives

SSPC Standards Planned for Reaffirmation in 2008

• SSPC-VIS 1, Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning. Due for 5-year reaffirmation/revision

• SSPC-VIS 2, Guide and Reference Photographs for Evaluating Degree of Rusting on Painted Steel Surfaces. Due for reaffirmation/review

Other Standards Activity



Surface Coatings International (*SCI*, Vol. 91, 2, March 2008) reported that two standards have been proposed for withdrawal: the European and International standards, ENV ISO 8502-1 and ISO/TR 8502-1, Preparation of steel substrates before application of paints and related products. Test for assessment of surface cleanliness. Field test for soluble iron corrosion products.

SCI also reported that the transitional national standard (TR), designated as a development draft (DD), has been proposed for confirmation: DD/ISO/TR 15235, Preparation of steel substrates before application of paints and related products. Collected information on the effects of levels of water soluble salt contamination.

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New Book Analyzes Blast Cleaning Technology

By the JPCL *Staff*

In *Blast Cleaning Technology*, Andreas Momber devotes 540 pages, which include 385 figures and 169 tables, to the science of the abrasive blast cleaning process for surface preparation before painting. According to its publisher, Springer-Verlag, the book is a systematic and critical review of the theory behind the technology, the current state of blast cleaning, surface quality aspects, and the effects of blast cleaning on the performance of applied coatings.

In the Introduction, the author gives a brief history of blast cleaning and its early use for industrial applications.

In chapter two, Abrasive Materials, Dr. Momber focuses on the physical characteristics of abrasive materials, such as their structure and hardness, shape, diameter, density, kinetic energy, and fracture mechanisms.

In chapter three, Basic Aspects of Air and Abrasive Acceleration, the author discusses the properties of compressed air, abrasive particle acceleration in nozzles, and the structure of high-speed air jets. He also talks about the effects of air pressure on particle velocity and how the physical characteristics of abrasive materials affect velocity.

The next chapter looks at the general structure of abrasive blast cleaning equipment. More detailed discussions focus on nozzles.

In chapter five, Substrate and Coating Erosion, he talks about the erosion of oxides and organic coatings. Detailed discussion is given to coating removal models.

The surface preparation process is discussed in chapter six. The author examines the effects of pneumatic parameters, performance and abrasive parameters, efficiency of blast cleaning, weld seam cutting, cost aspects, and underwater applications. Chapter seven, looks at health, safety, and the environment and delves into the safety features of blast cleaning. Airborne emissions of dust, metals, minerals, and organic compounds are closely examined. Soil contamination, personal protective equipment, confined spaces, waste disposal, and recycling abrasive materials also are discussed. Chapter eight is devoted to surface quality. Visual cleanliness, visual standards, substrate roughness and profile, surface integrity, surface energy and adhesion, and wettability of metal substrates are examined.

The ninth and final chapter, Coating Performance, looks at the corrosion protection and performance of coatings and the effect of blast cleaning (i.e., blasting angle, stand-off distance, abrasive type and size, air pressure) on adhesion.

For more information, visit the Springer-Verlag website: www.springer.com.

Dr. Andreas Momber has degrees in Process Engineering and Civil Engineering and is currently head of research & development at Mühlhan Surface Protection International GmbH and a lecturer at Aachen University, Germany, in the Development of Mining, Metallurgy and Earth Sciences. He has worked for an equipment supplier and in academia, both in Europe and the U.S.

Cyclic Laboratory Tests for Evaluating Coatings: A Brief Review of Literature

By Tom Bos, Ph. D.

In 2006, the annual cost of corrosion in the Netherlands was estimated at a staggering 17.5 billion Euro. Had the proper coatings technology been employed, the costs could have been reduced by approximately 30%.[1]

Organic coatings of many different types and formulations protect metal structures from corrosion. Many environments still require the development, selection, and qualification of new coatings. This process requires a thorough characterization of the most important coating properties for a specific application. To this end, the ability of accelerated laboratory tests to accurately characterize coating properties and predict the service life of organic coatings is extremely important to coating manufacturers, suppliers, and end users.[2,3] This article will review and critique the most widely used accelerated tests for protective coatings.

Figure 1: Outdoor exposure of coated panels can take years to assess coating performance. For this reason, the development of accelerated tests to accurately assess coating performance and predict service life has been critical.

Exterior Exposure Testing

The most reliable way of determining the suitability of a coating system for a specific use is to expose it, generally on coated test panels (Fig. 1), in its intended environment.[2,4,5]

Because years of such exposure are required to characterize coating performance, the industry has continued to search for accelerated laboratory tests that reliably predict field performance of experimental systems.

Accelerated Tests

Many researchers have attempted to speed the natural coating degradation process by increasing the physical and chemical stresses imposed during accelerated testing.

Ideally, the accelerated stresses only cause the system to fail at a faster rate, while the mechanism of failure remains the same as in field exposure.[5,7,8,9,10] The ideal accelerated test would reduce the time-to-market for new products by substituting short-term laboratory tests for long-term field exposures.

Editor's note: This article was condensed from an earlier version.

Salt Spray (Fog) Test

Historically, the most widely used accelerated test for evaluating corrosion resistance of coatings is ASTM B117 Salt Spray (Fog) test, despite its many published deficiencies.[9,11,12,13,14]

Many references suggest that little, if any, correlation exists between salt spray test data and in-service performance. Some coatings have performed well in salt spray tests but poorly in the field, whereas others have performed poorly in the salt spray test but exhibited good field performance.[17]

The following test variables are frequently mentioned as the principal causes of poor correlation with field performance.

- Constant stress[9,11]
- High concentration of spray electrolyte
- Chemical composition of spray solution
- High test temperature

Researchers usually attribute poor correlation to the constant temperature (95 F) and salt spray concentration (5 weight percent sodium chloride), maintained throughout the salt spray testing. The conditions depart dramatically from the cyclic characteristics of nearly all exterior field exposures environments.

For barrier coatings, osmotic forces imposed during the salt spray test are much lower than in the field and even may be completely reversed from those of exterior exposures.[18] Except for the harshest of marine exposure sites, the 5 weight percent sodium chloride produces unrealistic results. The exclusion of chemical species, present under normal conditions, results in unnatural chemistries of the corrosion products.[14,19] The high temperature in the test cabinet takes

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many coatings above their glass transition temperatures, rendering them non-protective with poor film properties.[9,18,20,21,22]

In addition, in salt spray testing of zinc-rich coatings or coated galvanized substrates, zinc is not likely to form a passive film that it forms in the field.[18]

Cyclic Testing

To overcome the deficiencies of continuous salt spray tests in predicting coating performance, cyclic tests have been developed and evaluated. In the 1960s, J.B. Harrison and his co-workers used a mixture of 0.25 weight percent sodium chloride and 3.25 weight percent ammonium sulphate as the electrolyte solution in the salt spray test. This change improved correlation with coatings exposed for 14 years in an industrial environment. Next, Timmins employed a diluted salt mix and introduced wet and dry cycling. This procedure was named the [Mebon] Prohesion test, an acronym for "Protection is Adhesion."[11,23,24] [Editor's Note: Prohesion is a trademark of BP Chemicals.]

Skerry and his co-workers added ultraviolet (UV)-moisture condensation exposure cycles to the above wet-dry cycling, to further reflect the stresses and degradation that coatings are subjected to upon exterior application. Cycling between salt fog, dry-out, UV exposure, and water condensation improved the rank order of performance of test coatings and more closely duplicated failure modes in exterior exposure.[5,9,11,13]

The principles of this cyclic test were submitted to ASTM for consideration as a standard, and after review, revision, and final adoption, ASTM published ASTM D5894 in 1996. ASTM has since revised and reissued the standard.

The standardized procedure exposes panels to alternating UV/condensation cycles and wet/dry salt-spray cycles:
- 4 hours UV (UVA-340) at 140 F (60 C) and
- 4 hours condensation at 122 F (50 C)

After 1 week (168 hours) in the UV-condensation test chamber, panels are transferred to the test chamber that will subject them to salt fog-dry cycling conditions.
- 1 hour salt fog at 77 F (25 C) and
- 1 hour dry at 95 F (35 C)

The test protocol is usually repeated three to six times, for a total test time of six to twelve weeks.[11]

Incorporating cycling steps seems intuitively justified, considering that coatings exposed to outdoor environments undergo similar effects. Indeed, many researchers have claimed the superiority of cyclic tests over conventional salt spray tests, because cyclic tests produce failures more representative of field results, with better correlation to actual environments.[2]

In fact, one of the most important distinctions among exposure tests is whether they create constant or cyclic stress, for the following reasons.

Table 1: Overview of Spearman rank correlation coefficients of various tests with 12 months of outdoor exposure, modified from Carlozzo et al.[15]

Test	Delamination, corrosion ASTM D1654	Rusting ASTM D610[a]	Blistering ASTM D714[b]
Salt fog	-0.173	0.045	0.058
Cyclic Salt Fog	-0.050	0.315	0.769
Prohesion	-0.122	0.541	0.688
Prohesion/UV	0.519	0.481	0.782
Outdoor exposure (intercorrelation exposure sites)	0.693	-	-

a Correlation based on 5 exposure sites; remaining sites not differentiated enough to report
b Correlation based on 4 exposure sites; remaining sites not differentiated enough to report

- Cyclic variation of temperature allows for some thermally induced expansion and contraction of the materials, causing stresses between the coating and the substrate.[11,25]
- Absorption of water into a coating and subsequent drying cause volume expansion and contraction, resulting in stresses, fatigue, and coating degradation.[6]
- Corrosion and wet-dry cycling cause the successive formation and drying of corrosion products, which can affect (wet) adhesion of a coating.[14,19]
- Corrosion on coated steel substrates at areas of film defects (e.g., near scribes) is faster during wet-dry transitions. These effects may be even more pronounced on zinc substrates.

Although ASTM D5894 is highly recommended,[11,17] it is not yet the panacea of accelerated test methods. For example, excessive corrosion of zinc-rich systems has been cited in literature. The standard spray solution is thought to be inappropriate, and the pH is too low for such systems.[11,18]

While ASTM D5894 has been found useful for industrial applications, NORSOK M-501 is a standardized Norwegian test designed for the harsh offshore conditions of the North Sea. M-501 is now probably the most recognized, global standard for offshore coatings.[5,12,26]

Common to ASTM D5894 and NORSOK M-501 is the cyclic exposure to salt spray, drying, and UV/condensation. The tests differ in the spray electrolyte, number of hours exposed in each chamber, and total number of cycles/weeks. In the fifth revision of NORSOK M-501, published in June 2004, performance testing of coating systems was brought in accordance with ISO 20340. [27] (The current standard is ISO 20340: 2003, “Paints and varnishes—Performance requirements for protective paint systems for offshore and related structures.”) The ISO standard combines two well-developed cyclic tests: the NORSOK M-501 and the French Standard, NFT 34-600.[28] A useful feature of the French standard is the freeze cycle at −20 C.[29] Because the freeze cycle is not obligatory, ISO 20340 allows for cyclic testing under differing conditions. For both options (freeze cycle or not), one test cycle takes 1 week (168 hours). The ISO 20340 test also runs for 25 cycles over 25 weeks.[30]

The different dry-out temperatures of -20 C and +23 C can significantly affect the test results.[29,30] Mitchell, for example, compared the effect of the freeze cycle on barrier coating systems and zinc-rich primed systems. The freeze cycle doubled the underfilm creep of the high solids hydrocarbon-modified epoxy, whereas the freeze cycle had virtually no effect on the performance of zinc rich-primed systems. In both cases, the incorporation of a freeze cycle gives results much more similar to those seen in practice.[29]

However, a procedural difference between ISO 20340 and the NORSOK in the test panel scribing can result in cathodic disbondment of immersion panels when following the ISO procedure (i.e., two versus one scribe). The latest NORSOK standard allows for the omission of the 0.05 mm scribe specified in ISO 20340.

Published Correlation Studies

Many published studies intend to establish correlation between accelerated tests and outdoor exposure. SSPC/ASTM and CSCT (Cleveland Society for Coatings Technology) have undertaken considerable work in this area.[15,16]

The later CSCT study compared the results of common accelerated tests to 9

Continued

diverse exposure sites throughout the U.S. Table 1 shows the averaged correlation of the tests with those of the outdoor exposure, using different standardized evaluation methods.

The highest correlation for rust creepage (ASTM D1654) was found for the intercorrelation of the 9 exposure sites (rs = 0.69). Of the accelerated tests, Prohesion/UV showed the highest correlation (rs = 0.52) for rust creepage.

Although substantial correlations for visually assessed surface rusting (ASTM D610) and blistering (ASTM D714) appear to be present for some sites, some results are actually an indication of the unnatural failure modes found with high salt concentration electrolytes.

Knudsen et al. performed tests to identify which accelerated test provides superior correlation to coatings in a marine atmosphere.[33] Scribed test panels were exposed at an offshore field test site for about 5 years. Analogous test specimens were subjected to 4 different accelerated tests.

The significance of an accelerated test is measured against how well it correlates with field performance.[11] Correlation coefficients can be considered indicators of the uniformity of acceleration within a batch of samples.[18]

The performance was assessed by measuring the maximum and average scribe creep. Using correlation coefficients calculated with equations in references 31 and 35, the overall correlation factor (r) for average scribe creep was 0.34 for the standard salt spray test and the cyclic salt spray test. The correlation of the Volvo test (Volvo Corporate Standard 1027, 1375 procedure 2A) was 0.76. The correlation of the NORSOK test, determined for two test series, was, 0.62 and 0.76, respectively.

In 1999, ECCA (European Coil Coating Association) and TNO (Netherlands Organisation for Applied Scientific Research) executed an extensive research program to assess the reliability of different artificial corrosion tests and their correlation with 10 years of outdoor exposure. The complete program included 49 different systems, 6 European exposure sites, and 9 laboratory tests.[34] Researchers concluded that none of the accelerated tests assessed in the study could reliably predict the medium and long-term durability of coil-coated materials. Unfortunately, there is no data on the correlation with field-applied protective coatings, but the conclusions are worth mentioning because outdoor exposure in a similar environment is the most reliable way of testing coating durability (next to evaluation of actual field applied coatings).

Besides the correlation between natural and accelerated weathering, standardized tests leave some degree of freedom for the operating conditions of the test, which can cause a large scatter in test results. Hubrecht et al. details a similar test executed by four different laboratories using similar specimens. The amount of scribe creep was often substantially different and even affected the performance ranking of the systems.[32]

Conclusions

Based upon this literature review, the following conclusions can be drawn.

- The standard salt spray test is not reliable for predicting coating service life or rank order performance.
- Cyclic accelerated testing imparts more realistic stresses on the coating system than does salt spray.
- A wide variety of cyclic tests is now available, allowing the formulating chemist to select the test conditions that best reflect the environment in which the coating will be applied.
- Some studies report that the combined cyclic salt fog/UV tests show an improved reproduction of coating performance ranking and failure modes observed in practice.
- All accelerated tests are relative tests, and they do not give absolute predictions of the actual service life of a material.
- Different outdoor service conditions will lead to different coating performance.
- Standardized visual evaluation techniques of coating failure modes are subjective.

Tom Bos was born in 1974 in Den Helder, The Netherlands. After obtaining his BS in environmental technology in 1998, Tom joined the Netherlands Organisation for Applied Scientific Research TNO. As a project leader, he completed several corrosion related projects. In 2003, Tom started his PhD research on protective coatings. In March 2008, he successfully defended his thesis at the Delft University of Technology.

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Study Evaluates Coatings on Galvanized Steel

L.A. Hernandez-Alverado, L.S. Henandez, O. Dominguez, and G. Garcia discuss a study that compared five coating systems for new and weathered galvanized steel in "Assessment of Paint Coatings on Galvanized Steel," available in its entirety on www.paintsquare.com. The study evaluated the performance of the coatings over galvanized steel that had been prepared with six different surface treatments. The coated samples were subjected to laboratory testing and outdoor exposure. The study found that the surface treatments had less effect than the coating systems on the results of adhesion testing, salt fog cabinet exposure, immersion in salt solutions, and outdoor exposure.

"The authors note that adhesive and cohesive failures were mixed in three of the tested systems, making it difficult to differentiate between the two types."

The authors note that galvanized steel is coated for both protective and aesthetic reasons. Unfortunately, coatings often fail due to adhesion problems with galvanized steel, which can be linked to the reactivity of the zinc coating. Careful selection of the coating system and the pretreatment technique is therefore necessary to ensure a successful result, they state.

The five coating systems evaluated during the study included a two-coat chlorinated rubber system pigmented with micaceous iron oxide; a synthetic resin blend/acrylic system; a two-component polyamide-cured epoxy and two-component polyurethane enamel system; a one-coat, two-component, high-solids epoxy; and a two-component polyamide-cured epoxy and two-component polyurethane enamel system. In addition, the study included an alkyd/iron oxide and alkyd enamel system, which is not recommended for use over galvanized steel, as a control. Of these systems, the chlorinated rubber system and the two epoxy-polyurethane systems gave the best performance in all the tests, the authors report.

Before the testing, galvanized low carbon steel panels were grouped into six batches, which were then subjected to the following pretreatments and cleaning processes: cleaning with an ammonia solution; sweep shot blasting followed by washing with trichloroethylene; chromate pretreatment; phosphate pretreatment; salt fog chamber exposure and wire brushing; and moist sulfur dioxide exposure and wire brushing. The coating systems were applied by air spray and kept for one month in the laboratory to assure complete cure, the authors say.

Carried out in triplicate, laboratory tests included wet and dry adhesion measurement using the pull-off method, salt spray exposure of scribed panels, and immersion in sodium chloride and ferrous sulfate solutions for 260 days. The study also exposed panels outdoors for 16 years.

The pull-off adhesion testing indicated that one of the epoxy-polyurethane systems and the one-coat epoxy exhibited the highest tensile values in the dry condition when averaged over all six pretreatment categories. The authors note that adhesive and cohesive failures were mixed in three of the tested systems, making it difficult to differentiate between the two types. Of the pretreatments, chromating gave the highest average adhesion values.

The authors note that the dry adhesion values for most of the tested coatings decreased after their immersion over 14 days in distilled water or an aqueous sodium chloride solution. Chromating showed the highest adhesion values for panels immersed in the sodium chloride solution and the lowest adhesion values for panels immersed in distilled water. The majority of adhesion values of coated panels immersed in the sodium chloride solution were higher than those of panels immersed in the distilled water, the authors report.

Approximately half of the coated panels exposed to salt fog testing showed slight blistering but no burst blisters or oxidation. The best results were exhibited by the chlorinated rubber system, one of the epoxy-polyurethanes, and the alkyd system. Chromating pretreatment gave the best performance in four of the coating systems, while panels cleaned with an ammonia solution (excluding the chlorinated rubber system) gave poor results. The phosphate-pretreated panels also performed well, the authors note.

Visual inspection of the immersed panels showed that the one-coat epoxy, one of the epoxy-polyurethane systems, and the alkyd system displayed the lowest degrees of blistering. With the exception of the chlorinated rubber and one of the epoxy-polyurethane systems, chromate-pretreated panels gave good performance. The phosphate-treated one-coat epoxy and alkyd systems also performed well, the authors state. Coated panels that had undergone sweep blasting and sulfur dioxide weathering surface treatments were found to have performed the worst.

EIS Can Help Quantify Corrosion Resistance of Coatings

Coating selection based on performance rather than on composition is the key to choosing a product that will provide long-term protection, say J. Sonke and W.M. Bos in their paper, "Scientific methods for quantification and selection of protective coatings." In addition to the battery of tests typically used to quantify the physical and chemical properties of coatings, electrochemical impedance spectroscopy (EIS) is a tool that can provide quantifiable data on the long-term loss of corrosion protective properties of candidate coatings during a short testing period, the authors say. Conventional tests, which include tensile strength, elongation, hardness, impact resistance, abrasion, temperature resistance, and chemical resistance, are helpful in selecting protective coatings for specific environments.

> "(EIS) is a tool that can provide quantifiable data on the long-term loss of corrosion protective properties of candidate coatings during a short testing period, the authors say."

Although the optimal means of assessing the long-term performance of protective coatings is field testing, this method is eschewed in favor of less lengthy laboratory tests. However, the now common practice of using accelerated testing to predict coating performance yields results that are not representative of actual in-field exposure. In fact, coated samples tested with these methods have been found to degrade from different failure mechanisms than those found in field testing, the authors note. Being operator-dependent, accelerated testing also risks inaccuracy.

Sonke and Bos describe their method for coating selection, which is based on a general model for coating degradation of an organic coating. This path to coating degradation consists of the following steps.

- Formation of conductive pathways through the organic coating
- Migration of ions to the substrate
- Development of anodes on the surface of the metal
- Development of cathodes under the coating
- Migration of sodium ions to cathodic sites
- Disbondment of the coating from a combination of increased pH and osmotic force at the cathodic sites

The authors describe the EIS test method, noting that all coatings tested were applied to a thickness of 200 microns to test panels. Attached to the coated surface of the panels and filled with concentrated artificial rainwater, the electrochemical cell included a reference electrode and a platinum counter electrode. The authors describe impedance measurement of the organic coatings and the use of equivalent circuit modeling to analyze the EIS data.

The authors discuss the coating properties that should be measured to quantify coating degradation. Coating resistance can be measured with EIS to determine whether conductive pathways have been formed through the coating, with higher resistance indicating the establishment of a greater number of pathways. Coating properties that hinder the formation of conductive pathways include uniform composition, hydrophilic constituents, crosslinking, chemical resistance, differential tensile strength, elongation, and impact resistance. Dispersive Scanning Calometry (DSC) can provide information on temperature resistance and temperature change for coatings. Thermal EIS testing can also indicate the influence of thermal cycles on performance.

Measurements of a coating's corrosion resistance, coating capacitance, and its deviation from ideal coating behavior at an early stage in its lifetime can indicate the coating's long-term behavior, the authors say. EIS can also indicate the development of an electrochemical double layer and charge transfer resistance of coated steel, the result of the formation of corrosion cells and the process of delamination, respectively. Once corrosion products are generated and stresses develop in the coating, microcracking can occur. A coating's resistance to microcracking can be quantified by evaluating its tensile strength and elongation, the authors add.

Cathodic delamination is a common cause of damage to coatings on steel, the authors state. EIS measurements of metal double layer capacitance, as well as pull-off adhesion testing to assess the dry adhesion of the coating, can provide information on the extent of cathodic delamination.

In addition to quantifying the corrosion protection afforded by candidate coatings, EIS can be used to quantify the condition of weathered coatings for the purposes of coating inspection, the authors add.

Sonke and Bos' paper can be viewed in its entirety at www.paintsquare.com.

SSPC Training Picks Up Steam in China, U.S.

During the week of April 14–18, the SSPC China Chapter hosted its first SSPC Training Course. SSPC instructor Earl Bowry taught 25 students who attended C-2, Managing Coatings Projects, held in Qingdao, China, SSPC reports.

Instructor Earl Bowry and SSPC C-2 course attendees in China

Based in Shanghai, the SSPC China Chapter was officially chartered in the Fall of 2006. According to SSPC, “This [course] represents an important first step in SSPC’s efforts to establish training and certification standards in the Chinese protective coatings industry and offer SSPC’s training and certification courses throughout China.”


Water jetting during C-13 in Seattle


NBPI attendees get down to the business of inspection in Seattle

In the U.S., Manta Industrial, Inc. (Hammond, IN) hosted the Applicator Train-the-Trainer course February 18–19. Bill Corbett and Earl Bowry taught nine students in attendance.

According to SSPC, the training program reviews the applicator curriculum through lectures, team exercises, and a hands-on component that covers hand and power tool cleaning, blasting, and spray application. The course is intended to meet the body of knowledge of the proposed SSPC/NACE joint standard, Recommended Practice TG 320, Industrial Coating and Lining Application Specialist Qualification and Certification. The course also will provide owners and their craft workers with a standardized curriculum for applicator training that can be presented at the owner’s shop or job site.

Thirteen students attended the Fundamentals of Protective Coatings course (C-1) hosted by The Williamson Free School of Mechanical Trades (Media, PA). The five-day course, held March 3–7, provides a practical and comprehensive overview for individuals who are new to the protective coatings industry. Luke Clark was the instructor.

According to Mr. Clark, the students who participated are enrolled in the Structural Coatings Technology Associate’s Degree program. All 13 students successfully passed the C-1 course.


Thirteen students took the C-1 course at The Williamson School

Seattle, WA-based Todd Pacific Shipyards held three training programs: the NAVSEA Basic Paint Inspector (NBPI) on April 7–11; C-7, Abrasive Blasting, on April 14–15; and C-13, Water Jetting, April 16–17.

According to SSPC, the five-day NBPI course was developed by Naval Sea Systems Command (NAVSEA) to train coatings inspectors to inspect critical coated areas as defined by U.S. Navy policy documents. The C-7 program is designed to certify operators of dry abrasive or portable centrifugal blast cleaning equipment. It covers principles of surface preparation, cleanliness, and profile; dust and debris control; and abrasives. The C-13 program assesses the skills of water jetters who have a minimum of 120 hours of on-the-job water jetting experience and prior documented employer-provided training on the equipment the water jetters use, SSPC reports. Pete Judt instructed all three classes.

For more information about hosting SSPC training courses, contact Jennifer Miller: 877-281-7772, ext. 2221; miller@sspc.org.

SSPC Issues New Containment Guide, Coating Standard

SSPC has recently issued a new technology guide to help specifiers in lead-based paint removal projects and a standard on moisture-cured polyurethane paint.

According to the Society, SSPC-Guide 18, Specifier's Guide for Determining Containment Class and Environmental Monitoring Strategies for Lead-Paint Removal Projects, describes a six-step process in determining the type of containment system and level of environmental monitoring that should be specified for the removal of paint and coatings that contain lead and other hazardous metals. The selection of the containment and monitoring strategies are based on an assessment of the type of paint removal method that will be used and the potential impact of the operations on the public, other workers in the area, and the environment.

The Guide is intended to assist those who specify, design, construct, or monitor the effectiveness of containments and environmental monitoring procedures on projects where lead-containing coatings are being disturbed. These steps include

- Identifying the emissions potential of the selected paint removal method(s),
- collecting site-specific project data and potential risk indicators,
- determining degree of emissions control required,
- matching the containment requirements with the paint removal method(s) and degree of emissions control required,
- selecting monitoring strategies for assessing emissions, and
- selecting monitoring locations.

SSPC-Paint 41, Moisture-Cured Polyurethane Primer or Intermediate Coat, Micaceous Iron Oxide Reinforced, Performance-Based, contains performance-based requirements for a single-pack, moisture-cured aromatic polyurethane coating with a thermoset binder and micaceous iron oxide pigment reinforcement.

The primary requirements of SSPC-Paint 41 are based on performance. Criteria for the preparation of steel test panels, liquid coating requirements, and standards for laboratory physical tests and accelerated laboratory weathering are stated. Additional notes address application, pigment, volatile organic compound (VOC) content, modifying resins, sieve sizes, and quality assurance tests, SSPC says.

The documents detailed above are available through the SSPC MarketPlace, where current members have free unlimited access to the complete collection of SSPC standards, guides, and specifications. They also are provided as a supplement to the latest edition of *Systems and Specifications, SSPC Painting Manual, Volume 2*.

For more information, contact the SSPC Publication Sales Office at 877-281-7772 (toll-free within the U.S.), or 412-281-2331 (outside the U.S.); fax: 412-281-9992; email: books@sspc.org.

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SSPC Individual Member Update

Below is the list of 52 new individual members who joined SSPC in March 2008. If you have questions about joining, contact Terri McNeill at 877-281-7772 (U.S. and Canada) or 412-281-2331, ext. 2233.

- Ismael Barrera, El Dorado, Panama
- Paul Bosserman, Waynesboro, VA
- Robin Bradley, Edmonton, AB, Canada
- Thomas Braun, Slaughter, LA
- Rayshone Broadnax, Spring Valley, CA
- Frank Cifani, Bradshaw, NE
- Larry Colclasure, Kankakee, IL
- Brian Collins, Greenville, SC
- Rene A. Corella, Calexico, CA
- John Dabinett, Clayton, NC
- Thomas Davis, Portsmouth, VA
- John Davis, Decatur, TX
- Philippe Dedonder, West Deptford, NJ
- Henry Denson, Clayton, NC
- Stelio Flamos, Canton, OH
- Reed W. Goodwin, Marietta, GA
- Rich Hays, West Bethesda, MD
- Yadi Hermayadi, Bogor, Indonesia
- Ray Hinesly, Phoenix, AZ
- J. Darby Howard, Walnut Creek, CA
- Edward Johnson, Raynham, MA
- Charles Wayne Jones, Warrenton, VA
- Harry Kalin, Aurora, OR
- Michael Klinar, Weisskirchen, Austria
- Mark Kucirka, King of Prussia, PA
- Peter Kuzyk, Norwich, CT
- Louis Leclerc, St. Nazaire, QC, Canada
- Mark Leonard, Denver, CO
- Colin Mayer, Bambous, Mauritius
- Patrick McKeeth, Galesville, WI
- Bobby Meador, Lorena, TX
- Heikki Molkka, Mäntsälä, Finland
- Dean Norville, Colorado Springs, CO
- Clayton Page, Madison, WI
- Dale Parson, Port-of-Spain, Trinidad and Tobago
- Vladimir Pushkin, Moscow, Russian Federation
- Randy S. Reichle, Beaumont, TX
- Anthony Rende, Research Triangle Park, NC
- Daniel Ross, New Martinsville, WV
- Butch Schutt, Marathon, FL
- Arjan Sen, Dammam, Saudi Arabia
- James M. Spaulding, Whittier, CA
- Charles Turnbull, LaPlace, LA
- Randy Ussery, Red Oak, TX
- Joseph Vincent, Lees Summit, MO
- Paul Vinik, Gainesville, FL
- Dean Wall, Prospect Vale, TAS, Australia
- Matthew Wash, Edgefield, SC
- James Wigle, La Jolla, CA
- Jae-hong Won, Geoje Gyeongsangnam-Do, ROK
- David D. Young, Norfolk, VA
- Mark Youngberg, West Chicago, IL

Three Rivers Chapter Holds 2nd Successful Golf Outing

The Three Rivers Chapter of SSPC held its 2nd Annual Golf Outing at the Quicksilver Golf Club in Midway, PA, on May 12, 2008. According to Heather Ramsey, chapter secretary, the event turned out to be quite successful, despite the inclement weather. Forty-three golfers from the tri-state area and from as far away as Canada participated in the event, according to Ms. Ramsey.

The winning team consisted of Sauereisen's Dan Schmidt, Adam Ramsey, Ms. Ramsey, and Robert Waters. Skill prizes were won by Bayer's Dee Durkin, Bunny Faterski, and Ed Squiller, and Sauereisen's Robert Waters, Ms. Ramsey, and Adam Ramsey. According to Ms. Ramsey, no one claimed the prize for the hole-in-one contest, worth $25,000 in cash and sponsored by The Sherwin-Williams Co.

Sauereisen's winning team (l-r): Robert Waters, Heather and Adam Ramsey, and Dan Schmidt

At the dinner reception, chapter President Michael Eckart spoke about upcoming chapter activities, including an event to take place during The 25th International Bridge Conference®, which will be held at the David L. Lawrence Convention Center June 2–4 in Pittsburgh. Also discussed was the schedule of monthly meetings. They will take place on the second Thursday of every month, beginning in September. Monthly meetings will wrap up with the chapter's holiday party in December, Ms. Ramsey reported.

The Three Rivers Chapter would like to thank SSPC's Lorena Walker and Shawn Nedley, chapter officers, and the following companies for their sponsorship: Hole sponsors ABTREX Industries, Bayer MaterialScience LLC, *JPCL*/PaintSquare/*JAC*, KTA-Tator, Opta Minerals, PPG Industries, The Sherwin-Williams Co., Steel City Painting, and SSPC. The sports bottles were provided by Bayer MaterialScience LLC, the beverage cart was provided by Opta Minerals, and SSPC donated the door prizes, Ms. Ramsey said.

The Lovelace Group To Host SSPC, OSHA Training

Duluth, Georgia-based The Lovelace Group (TLG) will be hosting two SSPC training courses in the Atlanta, GA, area in July, October, and December of this year.

SSPC C-3, Lead Paint Removal Training, will be held July 14–17, October 6–9, and December 8–11. SSPC C-5, Lead Paint Removal Refresher Training, will be held July 18, October 10, and December 12. TLG also has announced that it will host OSHA 10-hour and 30-hour construction training courses as well as other customized safety and health programs, on a client-specific basis. All courses are taught by SSPC- and OSHA-approved instructors, the company says.

For additional information, contact Suzanne Lovelace: suzanne@thelovelacegroup.com; website: www.thelovelacegroup.com.

Associations

Dr. Claude Bédard of Euclid Chemical Receives ACI Acclaim

The Euclid Chemical Company has announced the naming of Dr. Claude Bédard, P.E., as a 2008 Fellow to the American Concrete Institute (ACI). This award is given to an individual who has made outstanding contributions to the production or use of concrete materials, products, and structures in a variety of areas. Bédard is one of 17 peers recently honored at the ACI Spring 2008 Convention held at the Hyatt Regency Century Plaza in Los Angeles, CA. In addition to being named a Fellow, Bédard was introduced as a newly elected member of the board of directors of ACI.

Bédard is the president of Euclid Admixture Canada, Inc. and vice president and general manager of Admixture SBU North America. He has been the key player in the start-up of Euclid business in Canada and has driven substantial growth, the company says. Before joining Euclid, Bédard was an R&D engineer for Lafarge Canada, Inc. He earned his PhD in civil engineering from the University of Sherbrooke.

Dr. Claude Bédard

Bédard is a member of many professional and industry associations, including the Quebec Order of Engineers, The Canadian Standards Association, the Canadian Precast/Prestressed Concrete Institute, and the American Concrete Institute; he assists in the development of Canadian and American industry standards. Bédard was Chairman of the Canadian Standards Association Technical Committee A23.1/23.2 on Concrete Materials and Methods of Concrete Construction, and twice served as President of the American Concrete Institute Quebec chapter.

The American Concrete Institute (Farmington Hills, MI) is an international organization dedicated to advancing concrete technology and knowledge through seminars, certification programs, and technical documents.

The Euclid Chemical Company (Cleveland, OH) supplies the concrete and masonry industry with concrete admixtures, curing and sealing compounds, epoxy adhesives, floor and wall coatings, and equipment and machinery.

Aerospace Coatings Symposium on Thermal Spray Planned

Highlighting new thermal spray technology for the aerospace industry, the ASM Thermal Spray Society (TSS) will hold an Aerospace Coatings Symposium on Oct. 15–16 at the Sheraton Hotel at Bradley International Airport, near Hartford, CT.

This two-day symposium features two tracks, which are scheduled to address the following specific interests.

- A scientific/engineering track will cover new technology trends, existing and future coating application requirements, and a technical discussion on case barriers, and general wear.
- A track geared to applicators, technicians, EH&S personnel, and process engineers will cover environmental health and safety issues, testing and characterization, quality and process improvements, pre- and post-processing, and metallography.

On October 13–14, TSS will sponsor a two-day educational short course on Materials and Processes for High Temperature Gas Turbine Components.

For more information about the symposium, contact TSS customer service—email: customerservice@asm-international.org; website: www.asm-international.org/tssaerospace08/.

FSCT Issues Call for Papers

The Federation of Societies for Coatings Technology (FSCT) has issued a call for papers for its 2009 Advancement in Coatings Series on "Coating the World of Concrete."

The program will be held Feb. 1–2 in Las Vegas, in conjunction with the World of Concrete show. The two-day conference will offer a two-track forum for professionals who specify and use coatings on concrete, as well as for coating manufacturers and raw material suppliers. Intended participants include architects, specifiers, building and painting contractors, coatings formulators involved with development, laboratory and field testers, applicators, and raw material suppliers.

Organizers are seeking a range of 60-75 papers describing new findings, from theoretical and exploratory, commercial, and research institutions.

Papers should be of a high scientific and technical standard. The use of trade names is not permitted. Those interested should provide a maximum 200-word abstract, along with contact information: title of paper, author(s), company, speaker's name, job title and biographical information, email, telephone, and fax.

For more information, visit the website www.coatingstech.org.

INDOCOATING & Corrosion Summit Slated

INDOCOATING & Corrosion Summit 2008 will be held August 12–14 at the Jakarta Convention Center in Jakarta, Indonesia. Hosted by Ascoatindo (Asosiasi Coating Indonesia/Indonesian Coating Association), SSPC's Indonesia Chapter, and NACE's Indonesia Jakarta Section, the event consists of a technical conference and an exhibition of products and services. The theme of the event is "The Integration of Diversified Knowledges, Professionals, and Industries toward Excellent Quality."

The conference will include technical presentations, panel discussions, and workshops on the following subjects: coatings and linings; safety, health, and environment; pipeline integrity; microbiologically induced corrosion; and risk-based inspection.

Industries addressed will include the following: oil and gas; shipbuilding and repair; petrochemicals and chemical; transportation; military; and infrastructure/public utilities.

To register, or for more information, visit the website: www.iee-c.com/indocoating2008, or contact the Conference Secretariat at PT Indomedia Gemilang Komunikasi, Jl. Kebon Baru III No. 4 Jakarta 12830—email: indocoating.committee@iee-c.com.

Companies

Dow Corning Names Technical Services Manager

Dow Corning Corp. named Doug Kempf manager, Construction Application Engineering & Technical Services (AETS). Kempf will lead the group responsible for managing the day-to-day technical operations that support the company's activities in various construction markets in North and South America.

Doug Kempf

Kempf joined Dow Corning as a co-op student in the 1980s while attending high school in Midland, MI, and continued to work for the company while attending Michigan State University. After graduation, he worked as an engineer at Dow Corning's Elizabethtown, KY, facility. In 1996, he was named southwest regional AETS resource for Dow Corning Construction Industry in Southern California. He returned to company headquarters in

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Midland in 2000, where he has held a variety of marketing positions.

Dow Corning, jointly owned by the Dow Chemical Company and Corning Inc., is a manufacturer of silicon-based technologies for glazing, sealing, and weatherproofing materials used in the construction market.

Enviroline Announces New Appointments

Enviroline Group and Enviroline Monitoring Systems LLC have announced two appointments: Elfriede Lynch-Willson is serving as marketing manager for both Enviroline Group and Enviroline Monitoring Systems, and Allan Bouwers is serving as Enviroline Monitoring Systems' sales manager for Western Canada.

As marketing manager for Enviroline Group, Lynch-Willson is responsible for growing the sales of the company's high-performance coatings and linings; as marketing manager for Enviroline Monitoring Systems, she is charged with developing and executing plans to promote the growth of the company's hydrogen corrosion monitor. Lynch-Willson has 15 years of marketing experience, of which the last 10 have been in the corrosion protection industry. She previously owned Willson Marketing, a marketing consulting and service company. She holds a BA in business administration from the University of Miami in Coral Gables, FL.

Elfriede Lynch-Willson

Allan Bouwers

As sales representative for Enviroline Monitoring Systems, Allan Bouwers is responsible for the sales and support of the Enviroline Corrosion Monitoring System in Western Canada. He has more than 25 years of experience in business development, management, and sales in the oil & gas and telecommunications industries.

Based in Pompano Beach, FL, Enviroline Group manufactures the Enviroline® Series of coatings and linings. Industrial Environmental Coatings Corporation is now doing business as Enviroline Group.

Also based in Pompano Beach, FL, Enviroline Monitoring Systems LLC manufactures the Enviroline Hydrogen Corrosion Monitor, a continuous system that can be used for both corrosion and process monitoring.

Products

Low VOC Anti-Graffiti Coating

SEI Chemical introduced a reformulated version of GPA-200 Graffiti Proofer® Anti-Stick coating as a single-component product with less than 20 grams per liter of VOC, for compliance with air-quality regulations in all 50 states. The applied coating's dry film is characterized by a high degree of durability and chemical resistance, and a high slip coefficient, The company says the coating can be sprayed, brushed, or rolled on, and it dries rapidly. Graffiti can be removed with a dry towel, pressure washer, or household cleaners. The product is based on fluoro-resin technology.

For more information, contact SEI—tel: 800-804-3978; email: info@seichemical.com; website: www.seichemical.com.

Fast-Cure, DTM Polyurethane for Buried Tanks, Pipes

Chemline Incorporated (St. Louis, MO) has introduced Chemthane 2240, a 100% solids, fast-cure, plural-component polyurethane coating specifically engineered for direct-to-metal (primerless) application on buried steel tanks and pipes. The product's cure-to-the-touch time is 6—8 minutes, the company says.

The coating is designed to be spray-applied at a 1:1 plural-component spray mix ratio, and, according to the company, allows applicators to achieve film build of 15—70 mils in a single-coat, multi-pass application.

The product contains no solvents or coal tar extenders. It has a range of certifications, including UL 1746 Parts I, II, and IV for steel tanks.

For more information—tel: 314-664-2230; website: www.chemline.net.

New Digitally Controlled Weathering Chambers

Atlas Material Testing Solutions (Chicago, IL) has developed two new Ci5000 Xenon-arc Weather-Ometers®. The company says that the units have enhanced digital control to give operators more flexibility and control of accelerated weathering testing. Now available in a low voltage or standard voltage option, the instruments are designed specifically for large capacity, accelerated laboratory weathering.

Some of the most notable changes for both units include an embedded control system that replaces the PLC controller of the previous generation. Analog control circuits have been replaced with a digital network for more reliable and accurate control and monitoring of the data.

Other features include sub-cycle repeat programming for copying standards and saving them as templates; a full-color trend plot screen; and streaming data output formatted for compatibility with modern laboratory information management systems (LIMS).

For more information, contact the company—tel: 773-327-4520; website: www.atlas-mts.com.

Purcell To Work on Johns River Bridge

By Kristen Reiner, PaintSquare

The Washington State Department of Transportation awarded a contract of $432,404 to Purcell Painting and Coatings (Tukwila, WA) to paint the Johns River Bridge in Grays Harbor County. The project involves cleaning and coating all existing steel surfaces on a 583-foot-long steel girder bridge over the Johns River, which was built in 1952. The steel will be pressure washed and spot abrasive blast cleaned prior to coating application. The contractor will be required to design a containment system and a barn owl nesting management plan.

Photo courtesy of Washington State DOT

Huntsville Utilities Lets Reservoir Painting Contract

Southeastern Industrial Painting and Supply (Cary, NC) won a contract of $177,307 from Huntsville Utilities to clean and coat the interior and exterior of an existing 104-foot-diameter x 32-foot-tall, 2 MG ground-level water storage reservoir. The interior will be abrasive blast cleaned to a Near-White finish (SSPC-SP 10) and lined with an epoxy system. The exterior, which is currently coated with lead-based paint, will be pressure washed and overcoated with an epoxy-urethane system.

Indiana DOT Awards Venus Bridge Job

The Indiana Department of Transportation let a contract of $457,585 to Venus Painting Company (Lake Station, IN) to clean and recoat structural steel surfaces on three existing bridges over a roadway (230-foot, 236-foot, and 246-foot). Approximately 779 tons of existing structural steel will be coated with an inorganic zinc-rich primer, an epoxy intermediate, and a polyurethane finish. Containment according to SSPC-Guide 6 is necessary, because two of the bridges are coated with lead-based paint.

All-Kote Lining Gets Tank Resurfacing Project

The City of Phoenix, AZ, has awarded a contract of $109,428 to All-Kote Lining Company (Tempe, AZ) to clean and resurface the interior surfaces of two existing underground sump tanks (5 feet x 5 feet x 3.5 feet) at a water treatment plant. The project includes removing the existing fiberglass coating and abrasive blast cleaning the surface to facilitate bonding. The tanks will be relined with a fiberglass-reinforced bisphenol epoxy vinyl ester resin.

Bridge Painting Job Goes to Atlas

Atlas Painting and Sheeting (Amherst, NY) was awarded a contract of $1,100,000 by the Maine Turnpike

Maxcor To Rehab Elevated Water Tank

Maxcor, Inc. (Lockport, IL) was awarded a contract of $519,300 by the City of Naperville, IL, to rehabilitate an existing 500,000 gal. spheroid elevated water storage tank. The contract includes cleaning and coating interior and exterior surfaces, as well as pit piping and concrete foundation surfaces. The tank interior and pit piping will be abrasive blast cleaned and coated with an epoxy system. Heating and solid desiccant dehumidification (2,250 cfm minimum) are required to maintain ambient coating conditions. The tank exterior will be abrasive blast cleaned and coated with a 4-coat epoxy-urethane system. The existing interior dry coatings contain lead and the existing exterior coatings contain chromium. Surface preparation of the exterior, interior dry surfaces, and pit piping surface preparation includes the use of a lead-stabilizing abrasive additive. The contract requires Class 1A shroud-style containment according to SSPC-Guide 6 and waste disposal according to SSPC-Guide 7.

Authority to clean and paint a total of approximately 37,220 square feet of structural steel surfaces on six existing overpass bridges. The project includes coating structural steel, bridge railing, bearing assemblies, sign supports, and miscellaneous metal work using a three-coat paint system. The contract also involves spot painting 400 square feet of end span fascia beam surfaces on one of the bridges. The contract requires the containment and disposal of hazardous waste.

American Hi-Tech Flooring Wins Deck Coating Project

Photo courtesy of U.S. Coast Guard Visual Information Server

The U.S. Coast Guard, Integrated Support Command, Portsmouth has awarded a $24,950 contract to American Hi-Tech Flooring (Norfolk, VA) for a deck coating project. The project, which was set aside for Small Business sources, involves cleaning and recoating deck surfaces in eleven areas on an existing 210-foot-long vessel. A total of approximately 2,185 square feet of decking will be coated with a Type III cosmetic polymeric epoxy resin system (one-step epoxy system).

Luckinbill To Clean, Coat Oklahoma Water Tanks

Luckinbill, Inc. (Enid, OK) was awarded a contract of $635,300 by the City of Stillwater, OK, to clean and coat the interior and exterior of an existing 4 MG raw water storage tank and an existing 750,000-gallon elevated water storage tank. The interior surfaces will be abrasive blast cleaned to a Near-White finish (SSPC-SP 10) and lined with an epoxy system. The exterior surfaces will be abrasive blast cleaned to a Commercial finish (SSPC-SP 6) and coated with an epoxy-polyurethane system. The existing tanks, which were constructed in 1983 and 1987 respectively, might have been coated with lead-bearing coatings.

Classic Protective Coatings Wins Tank Rehabilitation

By Jack Kollmer, KLM Engineering

Classic Protective Coatings, Inc. (Menomonie, WI) was awarded a contract of $407,906 by the City of Grand Rapids, MN, to rehabilitate an existing 500,000-gallon elevated water tank. The project includes recoating the interior and exterior surfaces of the tank, as well as performing miscellaneous repairs. The interior surfaces will be abrasive blast-cleaned to a Near White finish (SSPC-SP 10) and lined with an epoxy system. The exterior surfaces will be abrasive blast cleaned to a Near-White finish and coated with an epoxy-urethane system. The contract requires full containment.

Louisiana DOT Lets Tank Painting Project

Pittsburg Tank and Tower (Henderson, KY) was awarded a contract of $137,000 by the Louisiana Division of Administration to repair, clean, and recoat the interior and exterior surfaces of an existing 118-foot-tall, 50,000-gallon elevated water storage tank. The interior will be spot abrasive blast cleaned to a Near-White finish (SSPC-SP 10), brush-off blast cleaned, and lined with an epoxy system. The exterior will be pressure washed, hand tool cleaned, spot primed, and coated with an alkyd enamel system.

Leadcon Gets Tank Rehab Bid

The City of St. Paul/Ramsey County awarded a contract of $700,000 to Leadcon, Inc. (Hudson, WI) to repair, clean, and paint an existing 2.3 MG standpipe. The interior surfaces will be abrasive blast cleaned to a Near-White finish (SSPC-SP 10) and lined with a zinc-rich urethane primer and two coats of epoxy finish. The exterior surfaces will be abrasive blast cleaned to a Commercial finish (SSPC-SP 6) and coated with a zinc-rich urethane primer, an epoxy intermediate, and two coats of polyurethane finish. The existing exterior coatings contain lead. The contract requires containment to ensure control of hazardous materials.

Todd Pacific Shipyards To Work on Ferry

Washington State Ferries has awarded a contract of $1,454,273 to Todd Pacific Shipyards (Seattle, WA) to drydock and repair an existing 382-foot-long x 73-foot-beam ferry vessel. The project includes cleaning and coating above and below waterline hull surfaces and vessel guard surfaces using various epoxy, antifouling, and acrylic epoxy systems.

Tropex Wins Fuel Tank Painting Bid

The City of Coral Springs awarded a contract of $1,918 to Tropex Construction Service, Inc. (Miami, FL) to clean and coat the exterior surfaces of seven existing propane and fuel tanks at four locations (three 1,000-gallon tanks at separate sites and two 500-gallon, one 150-gallon, and one 4,000-gallon at a fourth site). The tanks will be pressure washed and coated with an owner-furnished waterborne epoxy primer and aliphatic polyurethane finish.