Monetizing the Risk of Coating Failure

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Coatings can fail because of soluble salt contamination remaining on the substrate after surface preparation. This article discusses methods of salt removal and the importance of good surface preparation specifications. A case history reveals the possible costs of a coating failure from salt contamination.

Government regulations and scientific advances have led to improved coatings over the years, and there are numerous products to choose from. Buyers and users may be confused by the complexities of choices and the many decisions to be considered when selecting the best coatings system for a project. The goal is long life coating performance at low cost.

In the past, coatings containing lead provided excellent protection, often exceeding 20 years. Lead coatings reacted with soluble salts that were left on the surface. Surface preparation standards of the day were visual because they proved to be sufficient for a long life cycle lead coating, and the technology did not exist to conduct quantitative microanalytical testing of coating failures.

After the lead-based coatings ban in the late 1970s, oil and solvent-based alkyd resin coatings became predominant. In the late 1980s, hydrocarbon-based solvents fell under the volatile organic compound emission standard restrictions. Combined with rising raw material prices, this development led to the need for alternative coating systems and surface preparations. This article describes the importance of soluble salt decontamination during surface preparation to ensure adequate coating life.

Surface Preparation Versus Coatings

The objectives of a coating are to protect productive assets and sometimes to enhance appearance. A buyer can control coatings because the coating manufacturers provide vast resources on conditions, types of services, compatibility, etc. The matrix of data specifies the best product for the service intended. On the other hand, surface preparation has traditionally been given little attention.

Surface preparation can be thought to follow the "80/20 rule," as ~80% of surface conditioning is accomplished without compromises; the remaining 20% is often left out of guide specifications, thus possibly compromising the intended coating life. Missing from many surface preparation specifications, for example, are the testing for and removal of corrosion-inducing soluble salts. Soluble salts on steel substrates in contact with moisture form electrolytic cells that can generate deep and narrow micropits from the cyclic reaction of acid and the iron salt products formed. Chloride ions migrate into the pit, forming concentrated solutions or ferrous salts (usually chlorides, sulfates, or nitrates), which by hydrolysis create acid solutions.[1] The high salt anion concentration and low pH ensure that the pit surface remains active.[2]

Decontamination

Surface preparation should include eliminating or reducing the level of corrosion-inducing soluble salts to recognized threshold levels, which will not impact the performance or significantly affect the life of a coating. Removing the salt anion from the electrolytic cell is key to stopping corrosion and consequential coating failure.

Coating Project Interfaces

A coating project is generally compartmentalized among the asset manager/owner, coating applicator, and coating manufacturer. Asset manager/owner expertise in proper coating application for a specific structure may be limited, and may not be given a high priority. The asset manager/owner has three major choices:

1) Gain the personal expertise necessary to ensure a coating project is undertaken and completed using the best practices and up-to-date technology. This is unlikely because diverse responsibilities do not allow the time to gain the expertise required.

2) Rely on a contractor who is assumed to offer the best and most advanced processes for completing a coatings project. This is valid in theory, but in reality a contractor's incentive is to complete the project in the most cost-conscious fashion and within strict time constraints. Also, projects are frequently awarded to the lowest bidder.

3) Seek the assistance of an outside coatings consultant/inspector to create a specification, serve as a third-party expert to oversee its proper implementation, and institute best practices for quality results. To bring in a consultant for what may be considered commonplace knowledge or a simple task is perceived to be an added cost. Furthermore, unless the consultant/expert is kept on the project from its inception, proper implementation may not be followed unless total control of project monitoring is delegated to the consultant.

Cost of Corrosion

According to a 2002 U.S. Federal Highway Administration-funded study,[3] the identifiable cost of corrosion in the United States is estimated at $276 billion annually, with an actual cost more likely to be more than $500 billion. Life cycle extension through proper surface preparation and coating application can raise the cost effectiveness of the project. The "just paint it" approach to protective coating projects is wasteful and actually poor stewardship of resources.

Primary Asset Preservation Responsibility

The primary responsibility for maximizing coating life and performance falls on the asset manager/owner. This person must ensure that the specification standards and project performance requirements will maximize the return for a given expenditure.

The correlation between corrosion-inducing soluble salts and coating failure is well known and documented.[4-5] A good first step is to test for these nonvisible soluble salt contaminants. It is worth considering the minimal cost of field testing for these contaminating species, and removal if necessary, during surface preparation to minimize premature coating failure. Commercially available, field-ready, nondestructive inspection/examination test kits can be used for this purpose. Checking the bare substrate immediately after abrasive removal of mill scale and surface rust exposes the pits in which the salt anions may be concentrated.

If contaminating soluble salts are identified, conventional removal methods may be ineffective or more costly than alternatives.[6-7]

An alternative for surface salt removal is an acidic chemical wash. It is worth validating the efficacy of an acidic salt remover to ensure it has proven performance and no environmental restrictions and waste disposal costs.

Cost and Performance

The incremental cost of testing and chemical remediation to achieve specified limits on surface soluble salts is calculated at ~3% of the total project cost. This is not significant for a controllable variable, which can cause coatings to fail prematurely.

One method of dealing with salt-contaminated surfaces has been to perform several cycles of abrasive blasting and water washing. The total cost of several of these cycles is ~$2/ft^2 per cycle. Waterjetting for surface preparation has become popular; the cost of equipment is lower, but the calculated full cost is in the range of $4.60 to $6/ft^2.

In immersion service, the use of clean, uncontaminated abrasive to remove rust and to develop the desired surface profile, followed by the application of a properly balanced chemical formulation, typically will cost-effectively remove the contaminating salts with one wash. The chemical is applied with a pressure washer immediately following abrasive blasting. Costs for this surface preparation sequence range from $2.15 to $2.75/ft^2 (regional cost factors and NACE No. 2/SSPC SP-10[8] near white metal or NACE No. 1/SSPC SP-5[9] white metal surface create the range).

Verification of removal of the salts to specified limits is important because the tolerance levels under coatings are extremely low. Three µg/cm^2, a common chloride limit for immersion service,[10] is the equivalent of 0.17 oz/1,000 ft^2.[11] Thus, accurate microanalytic field testing techniques should be used to ensure ion-specific species are accurately quantified.

Case Study: Cost of a Coating Failure

In a tank-lining project, a turnkey bid was issued to reline the floor and up 2 ft (0.6 m) on the wall of a light fuels storage tank. The total area to be abrasive-blasted to white metal (NACE No. 1/SSPC SP-5) and relined was slightly more than 18,500 ft^2 (1,718 m^2). The tank was emptied and made available to the contractor at a stage where sludge was to be removed and properly disposed of. The tank was then hydroblasted and solvent cleaned to prepare for surface preparation and recoating. The contract was awarded to the low bidder at $111,030 ($6/ft^2), a typical cost experienced by the owner on similar projects.

The specification outlining the required work was provided by the owner. It did not indicate testing for surface salts or salt decontamination. The presence of corrosion-inducing residual salts is more pronounced in severe services, such as tank linings, than elsewhere.[12] In this case, the testing for and use of a chemical soluble salt remover for the area involved was estimated at slightly more than $4,100 (Table 1).

The risk for not testing and remediating salts on the substrate surface can be calculated from Equation (1):

$$\text{Risk} = \text{Probability of the Event} \times \text{Cost of the Event} \qquad (1)$$

TABLE 1

TESTING AND DECONTAMINATION COSTS

Cost Breakdown	Testing(A)	Decontamination(B)	Total
Labor	$152	$650	$802
Materials	906	2,405	3,311
Total	$1,058	$3,055	$4,113

(A)Eight tests/h at $45/h: five tests for the first 1,000 ft^2, two tests on each 1,000 ft^2 of the next 4,000 ft^2, and one test for 1,000 ft^2 thereafter.
(B)15 h at $28/h.

TABLE 2

COST OF REWORK FOR A TANK LINING FAILURE(A)

Tank empty and clean:	$33,000	Sludge remove, disposal, venting, dehumidification, hydroblasting, solvent clean
Failure analysis:	45,000	Failure inspection, testing, legal fees
Tank use loss:	8,500	60 days of 20-year life tank with original investment of $1 million
Overhead expense:	5,551	5% of project expense. Include safety, training, disruptions, security, etc.
Abrasive blasting:	55,515	NACE No. 1/SSPC SP-5 white metal blast
Testing and salt removal:	4,100	
Coating:	22,402	Coating plus $15,000 labor
Total	$174,068	

(A)Does not take into account any environmental impact costs.

TABLE 3

RISK UNDER THREE ASSUMED SCENARIOS

	Coating Failures Caused by Residual Salts (%)		
	15	50	80
Monetary risk of the coating failure	$26,112	$87,039	$139,263

The probability of the event is the percentage of failures found during forensic analysis that have been caused by leaving residual salts on the surface prior to coating. To be as objective as possible, and because this has not been scientifically or statistically validated, values of 15 to 20% of failures to upwards of 80% of failures have been attributed by field inspectors during failure analysis. Three scenarios—15, 50, and 80%—are used in this discussion as the probability ranges for determining the numeric risk for not testing and removing surface salts.

Table 2 describes the cost of the event. The events of the initial project are repeated, but costs from an unplanned failure must be added.

Table 3 shows the risk under the three assumed scenarios, using the estimated cost of rework and associated costs from Table 2.

In some cases, expenses may be amortized over the expected life of the project. In the case of hydrocarbon storage tanks and API standards, and more specifically API 652,[13] the industry is working to increase the time between inspections from 10 to 20 years, so a 20-year coating life would be the minimum required. The discount value of the expense for a failure occurring during a distant future year is immaterial, because residual salts may cause coating failure in the first few months to three years.

The numeric risk of 15% of all coating failures being caused by remaining corrosion-inducing salts is more than $26,000. If the risk is at 80%, the number is much greater. The incorporation of testing and chemical removal of contaminating salts adds an incremental cost of ~$4,100 (Table 1). This initial expense is significantly less than the risk of even a 15% coating failure rate. The coating failure rate caused by salts could be lowered to <3% and still justify the inclusion of both testing and remediation in the work project.

Conclusions

Generational changes in coatings, updated surface testing techniques and equipment, and time-efficient steps incorporated into surface preparation specifications offer fundamental, simple, and proven methods for asset owners/managers to achieve objectives of optimizing the coating life cycle, reducing long-term costs, and eliminating unnecessary asset downtime.

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