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Combined Corrosion and Weathering: Validating a Concept With Over a Decade of Research

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When coatings degrade from UV exposure, they can become more susceptible to corrosion attack. In the early 1990s, ISO and ASTM standardized a combined corrosion/weathering cycle. Today, this is still considered the most effective test method for determining the usefulness of industrial maintenance coatings.

This paper reviews current corrosion/weathering tests results on different industrial maintenance coating systems, including lower VOC coatings such as water-borne acrylic coatings and silicone-based coatings. Additionally, some of the industry's leading experts provide their insights into corrosion/weathering testing as well as recommendations for modified cycles developed for special applications.

Background

Accelerated corrosion testing is an excellent tool when used as a relative indicator of corrosion resistance. As with any accelerated test, the more realistic the laboratory exposure is, compared with the service environment, the more useful test data becomes.

The traditional and most widely used method for accelerated corrosion testing is salt spray, which uses a continuous exposure to a 5% salt fog at 35°C. This test (ASTM B117) was first used for corrosion testing around 1914. Salt spray testing is required by innumerable material specifications, even though there has long been a general agreement that it is not a good simulation of most service environments.

Beginning in the 1960s, engineers and scientists attempted to develop cyclic corrosion test procedures to predict more accurately the corrosion of materials. Cyclic corrosion testing is intended to be a more realistic way to perform salt spray tests than traditional, steady-state exposures. Because actual atmospheric exposures usually include both wet and dry conditions, it makes sense to pattern accelerated laboratory tests after these natural cyclic conditions. Research has indicated that, with cyclic corrosion tests, the relative corrosion rates, structure and morphology are more similar to those seen outdoors. Consequently, cyclic tests usually give better correlation to outdoors than conventional salt spray tests.[A]

Many different cyclic corrosion tests have been developed. Simple cycles, such as prohesion, which has been found especially useful for certain industrial maintenance coatings, may consist of cycling between salt fog and dry conditions. Methods that are more sophisticated may call for multi-step cycles that incorporate ambient, humidity, condensation or other conditions, in addition to salt spray and dry-off. These tests all use wet/dry cycles in an attempt to produce lab conditions that represent more closely the cyclic conditions found outdoors. One specific type of cyclic test, a combined corrosion/weathering method, was developed in the 1980s by researchers at the Sherwin Williams Company to test industrial maintenance coatings.

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Combined Corrosion/ Weathering Test

When using the prohesion test to investigate three coatings systems, researchers at Sherwin Williams found that prohesion by itself did not discriminate between the differences in performance of a series of coatings (Alkyd (zinc chromate inhibitor) – alkyd topcoat; Acrylic latex (barium metaborate inhibitor) – acrylic latex topcoat; Epoxy-polyamide (zinc phosphate inhibitor) – epoxy polyamide topcoat).[B]

Based on the theory that, as a coating degrades from UV exposure its ability to protect against corrosion is reduced, a new combined corrosion/ weathering test was developed. The new internal procedure was a combination of prohesion (ASTM G85) and QUV® weathering test methods (ASTM G154).

After exposure to the new cyclic combined corrosion/weathering test, the performance rankings of the three coatings systems were the same as seen in actual service (see Table 1). In addition, the gross corrosion rates and the morphology of the products of corrosion were found to be more like outdoor results than when using either prohesion alone or the traditional salt spray.

Exposure Condition	Ranking (Best to Worst)
Exterior – Marine Environment	Latex > Alkyd > Epoxy
Exterior – Industrial Environment	Latex = Alkyd > Epoxy
Conventional Salt Spray	Epoxy > Alkyd > Latex
Prohesion	Latex = Alkyd = Epoxy
Combined Corrosion/ Weathering Cycle	Latex > Alkyd > Epoxy

Table 1 - Sherwin Williams rank correlation of outdoor versus lab exposures.

Sherwin Williams' researcher, Brian Skerry, concluded, "Rankings predicted by the combined corrosion/weathering test were most consistent with rankings in the field." However, as could be expected, the relative advantages of various exposure temperatures, durations and sequences tend to remain application-specific. [C, D]

Corrosion/Weathering Test Cycle

The corrosion/weathering cycle consists of one week of prohesion alternating with one week of QUV exposure under the conditions described in Table 2. Typically, the test is continued for some 2000 hours.

	Corrosion Cycle (1 Week, Q-FOG® CCT Chamber)	QUV Cycle (1 week)
Test Cycle	1 hr salt fog application at 25°C (or ambient temp), 1 hr dry-off at 35°C *	4 hrs UV exposure, UVA-340 lamps, 60°C 4 hrs condensation (pure water), 50°C
Remarks on Conditions	* Dry-off is achieved by purging the chamber with fresh air, so that within three to four hours, all visible droplets are dried off the specimens.	Prohesion electrolyte solution: 0.05% sodium chloride + 0.35% ammonium sulphate Solution acidity: pH 5.0 - 5.4 Typical duration: 2,000 hrs

Table 2 - Test conditions for combined corrosion/ weathering cycle.

Over time, the combined corrosion/weathering cycle proved to do an excellent job of ranking the performance of water-borne coatings. This new test was in the mid-1990s in ISO 11997-1&2 and ASTM D5894. Both color and gloss retention are reported as part of the ASTM D5894 protocol.

Validating Combined Corrosion/ Weathering

The combined corrosion/weathering cycle has been closely studied by The Cleveland Coatings Society (CCS), The Steel Structure Painting Council (SSPC) and several manufacturers. These studies have validated the ways in which this test method provides a more realistic simulation of surface morphology degradation, corrosion product formation and relative coating performance (compared with other accelerated corrosion tests). Test results using the combination test show a higher rank correlation to outdoor results (see Table 3).

The *Steel Structure Painting Council* (SSPC) tested 15 different systems, including alkyds, acrylics, epoxies and urethanes. The SSPC research compared outdoor results (31 months) with results from the combined corrosion/weathering cycle, conventional salt spray, a cyclic salt spray employing a 5% sodium chloride solution, prohesion and two types of cyclic immersion tests.

Laboratory Test Method	Correlation Coefficient Against Severe Marine Environment
Conventional Salt Spray	–0.11
Prohesion	0.07
Cyclic Immersion Procedures	0.48
Cyclic Immersion With UV Procedure	0.61
Combined Corrosion/ Weathering Cycle	0.71

Table 3 - Correlations between different test cycles and actual marine environment.

The SSPC research confirmed that the combined corrosion/weathering cycle provided the best agreement with severe outdoor marine exposure. [E, F]

The *Cleveland Society for Coatings Technology* (CSCT) researched the correlation of a number of accelerated laboratory corrosion tests compared with several outdoor service environments. The accelerated tests investigated include salt spray (ASTM B117), wet-dry cyclic 5% salt spray, prohesion and combined weathering/corrosion. The outdoor test sites were in New Jersey, North Carolina coastal, Florida, California inland, California coastal, Ohio, Missouri and Oregon. The test specimens consisted of nine coatings on cold rolled steel substrates.

The method of evaluation included commonly used ASTM evaluation methods for creepage, rusting, blistering, filiform corrosion and specular gloss. Spearman rank correlation was used to compare the outdoor results to the laboratory results.

When comparing the degree of blistering and surface rusting, the CSCT found that ASTM B117 salt spray did not correlate well with outdoor environments. The wet-dry testing using 5% sodium chloride solution provided slightly better correlation than B117 salt spray. Combined corrosion/weathering provided better rank order correlation with most of the outdoor exposure sites. [G]

The *American Association of State Highway and Transportation Officials* (AASHTO) uses 15 cycles of combined corrosion/weathering for evaluating coating systems with zinc-rich primers that are specifically designed for iron and steel surfaces (such as bridges). According to Corbett, "ASTM B117, more commonly known as 'salt fog or 'salt spray', is a recognized industry standard for corrosion testing, though some deem this standard to be archaic and prefer the ASTM D5894 test instead. ASTM D5894 is a cyclic corrosion test incorporating both corrosion testing and UV exposure, methods which more closely resemble 'real world' field conditions." [H]

Modifications to Combined Corrosion/ Weathering

It is generally recognized that ASTM D5894 is a substantial improvement to the traditional salt spray test (B117) in terms of reproducing atmospheric corrosion in an accelerated fashion. However, rarely can a single test adequately characterise a coating's ability to perform in a complicated environment such as an inland oil refinery. "The first step in putting together a meaningful testing protocol is to define the environment in which the coating is expected to function." [I]

Over the years, many researchers have modified the corrosion/weathering cycle to suit their particular materials or applications. The following are several examples.

A desert industrial environment is a highly specialised situation. Experience has shown that under conditions such as those in Kuwait's industrial areas, coating degradation has tended to be faster than in Western countries, where most coatings are developed. A study of 11 industrial coating systems compared data of two and a half years from five sites in the industrial belt of Kuwait and related coating performance to prevailing industrial atmospheric conditions.

The laboratory tests included modifications to earlier corrosion/weathering test programs. Different cycles and solutions were used to better simulate the Kuwait industrial environment. The laboratory tests combine 100-hour salt spray employing 5% sodium chloride and 3000ppm sulphate solution, followed by 16 hours of ambient drying and then exposure in a QUV, using 12 hours UV at 60°C and 12 hours condensation at 40°C. The investigators found that this test cycle provided good correlation with the Kuwait industrial environment. [J]

The *Institute of International Container Lessors* (IICL) has adopted a modified version of the combined corrosion/weathering cycle for testing container coatings. Due to the ocean-going nature of containers, the corrosion wet time was increased (the test specifies four hours spray at 30°C and two hours dry at 40°C). [K]

The *US Federal Highway Administration* finds ASTM D5894 'the logical test method' for warm climates, but has developed a modified exposure procedure that incorporates a freeze/thaw cycle for cold climate testing. This variation tests the mechanical stresses of bridge coatings and takes into account thermal cycling. The low temperature phase is followed by a cycle of UV light and continuous condensation, which is then followed by salt fog and drying cycles. The cycle is documented in French Standard NF T 34–600–1997, Annex B. [L]

Rohm & Haas slightly modified ASTM D5894, using lower condensation and UV exposure temperatures. For their coatings, Rohm & Hass "have found this cyclic test to give results more consistent with those found on outdoor exposure." [M,N]

Conclusion

Almost two decades after its development, industry experts still agree that a combined corrosion/weathering exposure is the best approach for testing the corrosion resistance of coatings that are susceptible to degradation from sunlight. The approach has been validated by a series of studies correlating accelerated and field results. [O]

Researchers have demonstrated successful results by modifying the original ASTM and ISO methods to create conditions more appropriate to their product's end-use environment by introducing acid solutions, freeze/thaw cycles and other adjustments.

Skerry of Sherwin Williams probably sums it up best. "Although (combined corrosion/weathering) is highly recommended, it is not yet the panacea of test methods. Much work remains to be done to correlate performance quantifiably and to optimize the test cycle conditions and test period time factors. Nevertheless, it is still probably the best test available at this time. It offers many possibilities to customise the method to suit specific user needs." [P]

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