

SSPC: The Society for Protective Coatings

TECHNOLOGY UPDATE NO. 5

Accelerated Testing of Industrial Protective Coatings

1. Scope

1.1 This document describes only laboratory experiments. In an industrial setting protective coatings are used for a variety of reasons. Service environments for protective coatings may range from a mild atmospheric exposure condition to a severe chemical or immersion setting.

2. Introduction

2.1 APPLICATION OF ACCELERATED TESTING:

The application of accelerated testing differs from user to user. Some typical users are described below. The length of exposure of a coating system in any given test depends on the expected durability of the system and on the severity of the testing environment.

2.1.1 Formulators: Formulators use accelerated testing as a method to screen and compare the behavior of test formulations. The general goal is to optimize the formulation through experimental design or the typical ladder series. Formulators often employ ladder series in which one or more components in the coating formulation is changed in a controlled fashion.

2.1.2 Manufacturers: Manufacturers use accelerated testing in the same manner as a formulator. In addition manufacturers use accelerated testing for drawing comparisons between different products, to follow the results of shifts in raw material supply, and to show conformance with the performance requirements of procurement specifications.

2.1.3 End Users: The desire of end-users is to use accelerated testing as a reliable means of predicting long-term performance, but the goal of predicting performance is not achievable at this time, and it may never be achievable. Currently most end-users therefore employ accelerated testing to rank relative performance of competitive products or to screen coating systems for inclusion on qualified products lists.

Coating manufacturers and specifiers frequently use test exposures of coating materials in an attempt to assess the service life of various candidate coating systems before recommending their use. Test exposures are recognized to be a relevant predictor of coating system performance but can take a very long time to complete. Short term accelerated testing is often used to help provide early indications of coating system performance.

Predicting actual performance of a coating system, based solely on short term testing, can be misleading. A typical short term test may not impose on a coating system the unique

combination or frequency of stresses that lead to failure in actual use.

2.2 INTENDED USE: This document is addressed to users and specifiers of protective coatings in an industrial setting. It is intended to provide information on the state-of-the-art in the technology of short term, accelerated testing of coatings. This technology update begins with a discussion of the environment in which coating systems are expected to perform. The specifier may use this update to assist in interpreting the results of certain accelerated tests. A qualitative analysis of the attributes of typical test methods and their relevance to actual exposures is also provided.

3. Referenced Standards

3.1 SSPC AND JOINT STANDARDS:

SP 11	Power Tool Cleaning to Bare Metal
SP 5/NACE No. 1	White Metal Blast Cleaning
SP 6/NACE No. 3	Commercial Blast Cleaning
SP 7/NACE No. 4	Brush-Off Blast Cleaning
SP 10/NACE No. 2	Near-White Blast Cleaning
SP 12/NACE No. 5	Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating

3.2 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS:

B 117	Standard Practice for Operating Salt Spray (Fog) Apparatus
B 287	Standard Method of Acetic Acid-Salt Spray (Fog) Testing (Withdrawn 1997)
C 868	Standard Test Method for Chemical Resistance of Protective Linings
D 609	Standard Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products
D 870	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion
D 1654	Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

- D 2246** Standard Test Method for Finishes on Primed Metallic Substrates for Humidity-Thermal Cycle Cracking (Withdrawn 1992)
- D 2247** Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity
- D 2933** Standard Test Method for Corrosion Resistance of Coated Steel Specimens (Cyclic Method) (Withdrawn 1990)
- D 4585** Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation
- D 4587** Standard Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light- and Water-Exposure Apparatus
- D 5894** Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)
- G 8** Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
- G 23** Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials. (Withdrawn 2000; Replaced with G 152 to G 153)
- G 26** Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials (Withdrawn 2000; Replaced with G 155)
- G 53** Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Non-metallic Materials (Withdrawn 2000; Replaced with G 153)
- G 85** Standard Practice for Modified Salt Spray (Fog) Testing
- G 87** Standard Practice for Conducting Moist SO₂ Tests

3.3 NACE INTERNATIONAL STANDARDS:

- TM0174** Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials in Immersion Service

4. Characteristics of the Service Environment

4.1 TYPICAL SERVICE ENVIRONMENT DESCRIPTIONS: The specifier should always remember that coating systems subjected to short term testing are applied, and are expected to provide protection, in a real environment. A wide range of service conditions or environments can be defined under which industrial maintenance protective coatings are expected to perform. A description of environmental zones is given in Appendix A. This is taken from Table 3 of Chapter 1, "How to Use SSPC Specifications and Guides," in the SSPC Painting Manual, Vol. 2 Systems and Specifications. Many

service environments under which a coating system shall perform are described by the classification system. To be of value, short-term accelerated tests should reproduce and accentuate the stresses imposed on a coating system by the actual service environment. There are some special use categories which are not covered in the environmental zone concept; these include abrasion resistance, marine fouling, graffiti control, mildew resistance, skidding, or high temperature service. Specially designed tests may be needed for such exposures.

4.2 VARIABILITY OF THE SERVICE ENVIRONMENT:

With the sole exception of Zone 0 - Dry Interior (Appendix A), none of the environmental zones present a uniform, invariable service environment. All the service environments in Appendix A for which painting is recommended show variations in one or more of the following stresses:

- Temperature - e.g., daily changes, or freezing and thawing
- Humidity - e.g., morning formation of dew
- Time-of-wetness - e.g., periodic immersion, or rainfall
- Ultraviolet light intensity and exposure time
- Atmospheric pollutants - e.g., SO₂/NO₂, smog, salt or particulate deposition
- Chemical attack - e.g., exposure to deicing salts, splash and spillage of acids or alkaline agents
- Mechanical Stresses - e.g., chipping by stones, freeze/thaw cycling.

Natural service environments are as changeable as the weather. To help better replicate the type and frequency of coating failure found in actual use, many accelerated test methods incorporate controlled variations in test conditions.

4.3 DESIRED OUTCOME OF EXPERIMENT: The purpose of the program dictates the scale and nature of tests used to establish the performance of coatings. For example, a coating to be used in submersion would not be tested in the desert sun. Defining the intended service is important in determining the type of test to use in coating evaluation. This entire process is known as experimental design.

5. Experimental Design Parameters

5.1 Although the experimental design follows from the desired outcome, there are a wide variety of options available for consideration. The primary intent of experimental design is to reduce the number of independent variables which might affect and skew the results of the test program.

5.2 VARIABLES CONTROLLED BY EXPERIMENTAL DESIGN

5.2.1 Choice of Substrate: This should be identical with the substrate upon which the coating shall be applied; i.e., if the structure is ASTM A 36 steel, use A 36 steel for testing.

testing. On certain occasions, special panels may be required that mimic common structural shapes or commonly encountered design or fabrication flaws.

5.2.2 Choice of Surface Preparation: Unless surface preparation is a variable under study in the experiment, the type of preparation should be identical with the type of preparation required for real application. Typical specifications for surface preparation for industrial maintenance coatings are given by SSPC-SP 5/NACE No. 1, SSPC-SP 6/NACE No. 2, SSPC-SP 7/NACE No. 4, SSPC-SP 10/NACE No. 3, SSPC-SP 11, and SSPC-SP 12/NACE No. 5. Typical preparation requirements for sheet metal products are given in ASTM D 609.

5.2.3 Profile: This should be the profile recommended for use with the coating system unless it is a parameter to be examined in the test program.

5.2.4 Choice of Coating Systems: A valid control coating system or set of controls should be employed. Controls are those systems for which well-defined performance expectations are known, both in actual use and preferably within the tests used in the program. Control coating systems spanning a range of performance from poor-moderate through excellent should be used. This will help in subsequent ranking of candidate coating performance.

5.2.5 Application: This should be the type of application to be employed in actual use and that recommended by the paint manufacturer. Results obtained from use of ideal application methods, producing a defect-free film, will be of less use in assessing how a coating will perform in actual service.

5.2.6 Types of Experimental Design: If each factor in the design is given equal weight, then the design is called full factorial. Full factorial designs can dramatically increase the number of replicate specimens prepared. One can reduce the scope of the experimental design by careful selection of the points within a design at which maximum replication will occur. Such an approach is called a composite or mixture design. When screening coating formulations, a third approach is often taken which provides replication on only one point.

5.2.7 Number of Test Replicates: Replicate specimens are essential. The number of test replicates is governed in part by the type of experimental design. There are a number of operator dependent variations in applied system characteristics. To accommodate these uncontrollable variations, multiple specimens are needed for each factor in the experimental design. With very large replicate sets, 20 or more, it can be demonstrated that failures do not all occur at the same time. Dubbed lifetime analysis, this also reflects actual paint performance where failures on a large coated surface occur in a sporadic manner. For many comparative studies, a minimum of five to six replicates is appropriate to improve the validity of the data. (Almost all existing performance based specifications

call for no more than two replicates.)

6. Characteristics of Controlled Accelerated Tests

6.1 CLASSIFICATION OF ACCELERATED TEST METHODS: Accelerated test methods can be classified in accordance with the following criteria:

1. Constant stress or cyclic/variable test
2. Industry standard test or non-standardized test
3. Multi-component stresses or single component stress

Appendix B summarizes the characteristics of many accelerated test methods typically used in evaluating industrial maintenance coatings.

6.2 COMMON ACCELERATED TEST METHODS: An ideal accelerated test would expose new coatings to the stresses expected in real exposure, would induce exactly the type of failures observed in real use, and would do so quickly. In reality, this ideal is difficult to achieve.

6.2.1 Salt Spray Testing (ASTM B 117, ASTM B 287): Salt spray testing in accordance with ASTM B 117 and ASTM B 287 exposes panels to constant stresses of temperature (95°F), humidity (100%) and a corrosive salt solution (for ASTM B 117 testing, 5% NaCl is used). Panels are commonly scribed and evaluated for rust, blister, and scribe undercut failure. Typical test durations can run anywhere from 500 hours to 5,000 hours or more. Originally developed for use in testing metallic coatings, ASTM B 117 testing became the method of choice for evaluation of coatings on metal products because of the lack of other suitable test methods.

Salt fog testing in accordance with ASTM B 117 is the most widely used method for screening coating performance. Many specifications include the use of this test. Modes of failure observed are blistering, rusting on the panel face, and scribe undercutting. The rust product created by this test is unlike that found in most atmospheric exposures. Blistering failure is far higher than found in most atmospheric exposures.

Studies have shown that the rankings of coatings in salt fog testing often bear little correlation to rankings from exposure in any real atmospheric service. In part this is because the failures are different. The type of reactions occurring on the sample panel are unique to the test chamber; this also causes the discrepancy in results between salt fog testing and real exposure. Table 1 depicts the correlation between salt fog exposures and some typical exposure sites. The data is taken from two studies, SSPC's Performance of Alternate Coatings in the Environment (PACE), and a study of the relative merits of constant or cyclic salt spray exposures by the Paint Research Association (PRA).^{1,2} The PACE results, Table 1A, show that, with one exception, for subclasses of the full set of coatings tested, poor or low correlation is observed between

time to failures by rusting at the marine site, and preliminary screening in ASTM B 117 salt spray. The study at the PRA, Table 1B, used a lower number of coating samples, and also indicates poor correlation between exterior exposure and salt spray exposure. The poor correlation observed is quite typical; note that even the marine site results do not correlate well with ASTM B 117 exposures, especially when waterborne or lead-free coatings were examined.

In some coatings, the high concentration of salt present can induce saponification reactions that contribute to the observed undercutting and blistering failures. Coatings are being tested for their resistance to this unique test environment. Coatings may perform poorly in this test and yet provide good service in outdoor exposures. Despite this anomaly, ASTM B 117 testing continues to be specified and used.

6.2.2 Cyclic Salt Spray Testing (ASTM G 85 Appendix

A5): Cyclic salt spray testing involves periodic drying of the panel surfaces following exposure to a salt fog. Unlike ASTM B 117, the salt used is a weak mixture of ammonium sulphate 0.325% and sodium chloride 0.05% and the salt fog exposure takes place under ambient conditions.⁴ The rapid drying of panels is accomplished by panel heaters and forced air coming into the cabinet. Panel heaters are present in the walls of the cabinet. During the dry cycle the panel heaters are turned on and the

temperature in the cabinet rises to 35°C. Ratings and panel preparation are similar to that for ASTM B 117 testing.

This test is claimed to better reproduce macroscopic visual degradation typical of field failures such as rusting and scribe undercutting. It reduces the incidence of underfilm blistering noted in many other test methods. As blistering is little seen in most real exposures, the test is claimed to be more representative of actual coating performance.

The chemical make up of the rust product is believed to be closer to that found in real exposures. The rust is less crystalline in nature, i.e., more amorphous. The change in character of rust from the ASTM B 117 test is attributed to the constituents and concentrations of the electrolyte and the use of a cyclic exposure. Table 2A depicts the relative performance of a set of ten coatings in cyclic salt spray, salt spray testing in accordance with ASTM B 117, and normal industrial exposure. Accelerated tests were conducted for 1,500 hours and exterior exposures were conducted for 40 months.

The performance of the coating systems was assessed on the basis of undercutting at a deliberately placed scribe defect (see Figure 1 and Table 2B). Scribe undercutting was measured in units of 1 mm in accordance with ASTM D 1654. There are a number of clear discrepancies in the scribe undercutting recorded in the ASTM B 117 exposure when compared with real performance from the field exposure site. The incidence of

**TABLE 1A - CORRELATIONS OF TIME TO RUST FAILURES
ASTM B 117 SALT FOG VS. KURE BEACH**

Paint Systems	Number of Specimens Tested	Correlation Coefficient	Degree of Significance
All Systems	56	0.53	>99%
Lead and Chromate in Oil	15	0.63	<95%
Lead and Chromate, Oil-Free	25	0.57	<95%
TT-P-86G, Type II	8	0.95	>99%
Proprietary Pigment #10 in Oil	6	0.334	low
Acrylic	6	0.308	low

Data taken from references 1 and 8 (SSPC).

**TABLE 1B - PRA TEST
SPEARMAN RANK CORRELATIONS¹**

Comparison Mode	Correlation Coefficient
Exterior vs. Salt Spray	0.18
Exterior vs. Cyclic Salt Spray	0.68
Salt Spray vs. Cyclic Salt Spray	0.65

¹ Minimum correlation or 95% confidence requires a correlation coefficient of at least 0.87.

Data taken from reference 2 (PRA).