More Realistic Tests for Atmospheric Corrosion

New Standards for Cyclic Corrosion Tests Offer Alternatives to Continuous Salt Spray

by Douglas M. Grossman

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Salt spray cabinets were first used for corrosion testing around 1914. In 1939, the neutral salt spray test was incorporated as ASTM Method B 117. Today B 117 is the Practice for Operating Salt Spray (Fog) Apparatus under the jurisdiction of Committee G-1 on Corrosion of Metals. This traditional salt spray specifies a continuous exposure to a fog of 5% salt solution at 35°C. In some cases B 117 is useful for quality control testing, but in other cases it is not. During the course of 80 years of use, there have been many modifications to B 117. In spite of all these refinements, there has long been general agreement that salt-spray exposure results frequently correlate poorly with the corrosion seen in actual atmospheric exposures.

In the paint industry, every formulator can tell horror stories of paints that performed well for years outdoors but failed quickly in salt spray exposure; or worse yet, paints that lasted thousands of hours in salt spray but failed miserably outdoors. Nevertheless, B 117 has been generally accepted as *the* standard corrosion environment and is still widely specified in testing painted and plated finishes, military components and electrical components. Considering that salt spray exposures are the basis for purchasing hundreds of millions of dollars of coatings which protect billions of dollars of structures, the potential for economic loss is staggering.

One limitation of B 117 is that the 5% salt solution is not necessarily a realistic representation of electrolytes encountered in service. Various different electrolyte mixtures are now being used for different applications.

A more serious limitation of B 117 salt spray is that it provides a continuous environment with no changes in conditions. In contrast, materials exposed to the weather experience cyclical changes in wetness, temperature, sunlight, and corrosive solution concentration. Corrosion in a cycling environment can be very different from corrosion in a continuous environment, in terms of both the chemical reactions and the type of materials that will best resist corrosion. Researchers around the world have experimented with a variety of cyclic corrosion tests (CCTs) that incorporate various combinations of wet/dry cycling, temperature cycling, solution concentration cycling, and in some cases ultraviolet. An impressive body of research has been built up, demonstrating that, for many applications, CCTs are better able to distinguish which materials will be more durable outdoors. A number of these CCTs have recently been adopted by various standards bodies. Specifiers now have a choice of standardized cyclic tests. A description of some of these tests follows.

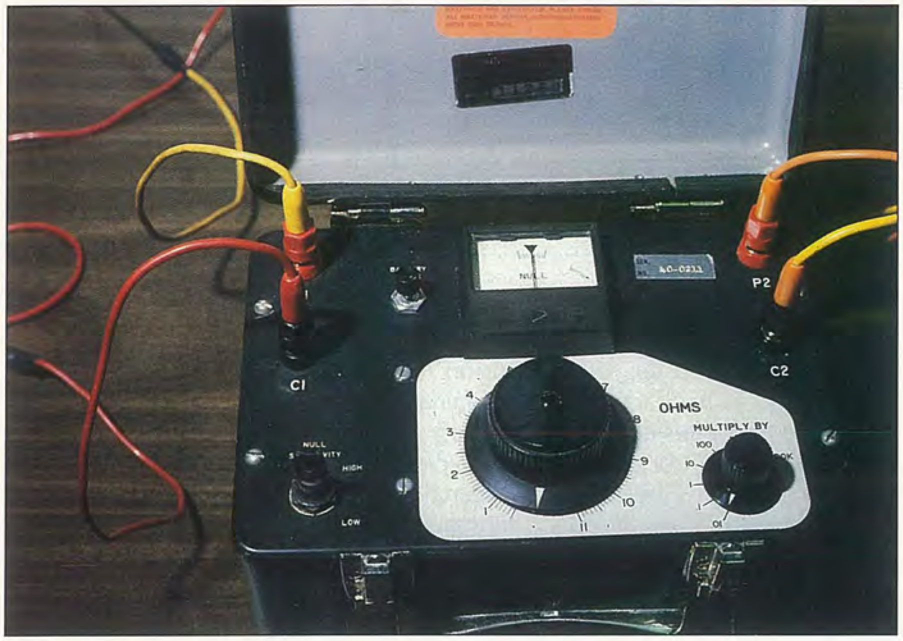
ASTM G 85 Annex A5

This new annex to ASTM Standard G 85, Practice for Modified Salt Spray Testing, under the jurisdiction of Committee G-1, describes the so called "prohesion" cycle. This widely used cyclic exposure was developed in England for industrial maintenance coatings. Prohesion also has a reputation as a good cycle for filiform corrosion. This cycle alternates one hour of fog with one hour of dry-off. The electrolyte solution is much more dilute than traditional salt fog, but with the addition of sulfate to somewhat represent industrial atmospheres. As the solution dries off, it becomes more and more concentrated, thus cycling the specimens through a complete range of solution concentrations. Exposure conditions include:

Electrolyte Solution	**0.05% sodium chloride and 0.35% ammonium sulfate**
Solution pH	**5.0 to 5.4.**

The prohesion exposure cycle is:

1 hour	**salt fog application at 24°C (or room temperature)**
1 hour	**dry off at 35°C**



One of the soil resistivity instruments available on the market. It functions on the basis of 97 Hz square-wave frequency.

Conclusion

Currently there are ASTM standards for measuring pH in soil (G 51, Test Method for pH of Soil for Use in Corrosion Testing) and for measuring soil resistivity (G 57, Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Mode). These standards are the most accurate and should be followed by everyone interested in electrical or corrosion properties of the soil.

Subcommittee G01.10 is in the process of replacing G 57 with two standards to further clarify the techniques and to eliminate any sources of confusion. One standard will deal with the Wenner four-point method; the second will deal with the use of the soil box. All interested individuals are welcome to attend the next meeting, which will be held May 23-24 in Orlando, Fla. For more information contact the author or Bob Held, ASTM (610/832-9719). **SN**

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Cyclic corrosion test cabinets are used for new standards that require cyclic exposure to salt, fog, dry-off and humidity.

The dry-off is achieved by purging the chamber with fresh air, so that within 45 minutes all visible droplets are dried off of the specimens.

ASTM D 5894 Cyclic Salt Fog/UV

ASTM Standard D 5894, Practice for Cyclic Salt Fog/UV Exposure of Painted Metal (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet), just passed ASTM Society Review in January. The D 5894 cycle consists of one week in a cyclic salt fog chamber (prohesion) alternating with one week in a fluorescent UV/condensation chamber per ASTM G 53, Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials. The total duration is usually six to 12 weeks depending on the durability of the material. Extensive research has shown that for industrial maintenance paints, this cycle is a much better reproduction of atmospheric corrosion than continuous salt fog, or even prohesion alone.[1,2,3,4,5] This is because UV damage to this type of coating can make it more vulnerable to corrosion. The test cycle is performed as described in the chart below:

- **Start with one week in fluorescent UV/condensation tester per ASTM G 53 at the following cycle:**
  4 hours — UV exposure at 60°C using UVA-340 lamps
  4 hours — condensation (pure water) at 50°C

- **After one week, manually move the samples to a cyclic salt fog chamber and expose for another week per ASTM G 85 Annex A5:**
  1 hour — salt fog at 24°C 0.05% sodium chloride and 0.35% ammonium sulfate
  1 hour — dry-off at 35°C

- **After one week, manually move the samples back to the fluorescent UV chamber and repeat the whole procedure for a total of six or 12 weeks.**

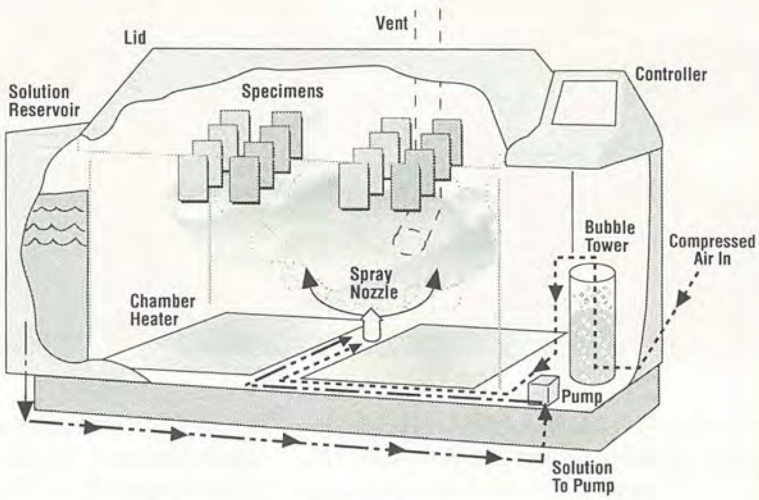
Cyclic Corrosion Testers: *How They Work—*

Cyclic corrosion tests expose specimens to a series of different environments in a repetitive cycle. Simple tests may consist of cycling between two conditions: fog and dry. More sophisticated procedures, such as automotive, call for multi-step cycles incorporating humidity or condensation, along with salt fog and dry-off.

Fog Function

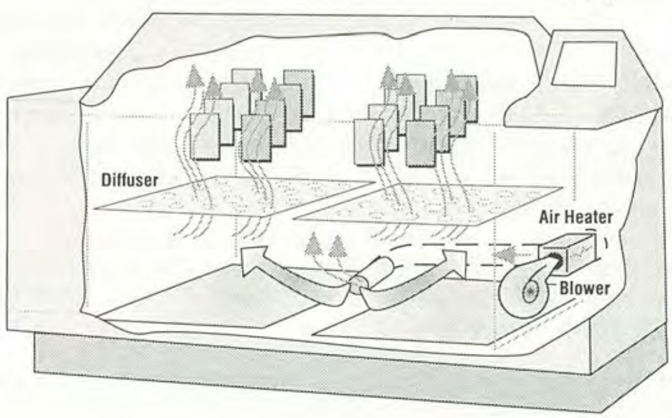
During the Fog Function, the corrosion tester typically operates as a conventional salt spray.

- Corrosive solution from the internal reservoir is pumped to the nozzle where it mixes with compressed air.
- Compressed air is humidified by passing through the bubble tower on its way to the nozzle (except for Prohesion tests).
- Nozzle atomizes solution and air into a corrosive fog.
- Chamber heaters maintain the programmed chamber temperature.



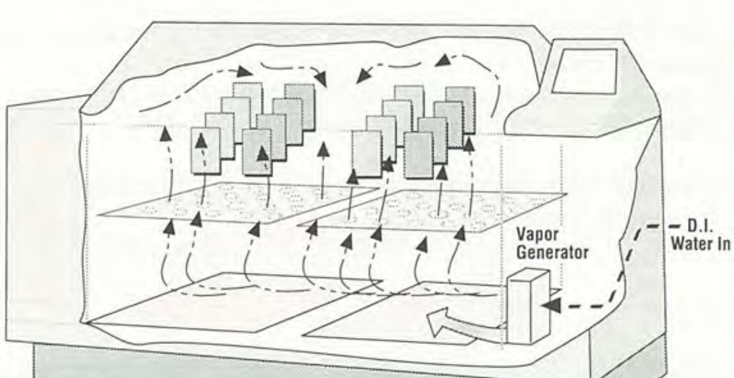
Dry-off Function

During the Dry-off Function, a purge blower forces room air over an air heater and into the chamber. This creates a low humidity condition inside the chamber. The chamber temperature is controlled by the chamber heaters and the air heater.



Humidity Function

During the Humidity Function, the chamber is maintained at 100% relative humidity by forcing hot water vapor into the chamber. The vapor generator heater maintains the programmed chamber temperature. The Humidity Function is available on model CCT only.



ASTM D 5894 calls for UV exposure cabinets in combination with cyclic salt fog cabinets.

General Motors GM9540P Method B

According to the research done by the Society of Automotive Engineers (SAE) Automotive Corrosion and Protection (ACAP) Committee, GM9540P Method B is currently considered one of the preferred CCT methods for automotive cosmetic corrosion (painted or precoated metals).[6,7,8] This cycle includes short salt mist periods, room temperature dry-off, hot humid periods, and hot dry-off. The electrolyte includes components of typical road salt. No UV is included in this cycle, because UV does not damage automotive topcoats enough to affect their corrosion resistance. This test is frequently performed manually, using a spray bottle for salt wetting, followed by separate periods in a humidity chamber and an oven. If performed manually, the test requires a 16-hour work day. There are also a number of automated testers available that will perform this exposure in a single chamber. The GM9540P/B exposure conditions include:

Electrolyte Solution	**0.9% NaCl + 0.1% $CaCl_2$+ 0.25 $NaHCO_3$**
Solution pH	**6.0 to 8.0**
Typical Durations	**40 cycles or 80 cycles (960 hours or 1,920 hours)**

The GM9540P/B exposure cycle is as follows:

10 minutes	**Salt mist application**
80 minutes	**Ambient conditions (25°C, 30 - 50% RH)**
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80 minutes	**Ambient conditions (25°C, 30 - 50% RH)**
10 minutes	**Salt mist application**
170 minutes	**Ambient conditions (25°C, 30 - 50% RH)**
8 hours	**Humidity (95 - 100% RH) at 49°C**
8 hours	**Dry Off (<30% RH) at 60°C**
Repeat	

ISO Draft Industrial Standard—Acid Rain CCT

This procedure, intended to simulate an acid rain exposure, is a modification of the Japanese Automobile Standards Organization test method M609 for automotive corrosion. The electrolyte contains some of the major components of acid rain. It has not yet received final ISO approval through ISO Technical Committee 156. Acid rain CCT exposure conditions include:

Electrolyte Solution	**5% (wt) NaCl, 0.12% (vol) HNO_3, 0.173% (vol) H_2SO_4, 0.228% (wt) NaOH**
Solution pH	**3.5**

The acid rain CCT exposure cycle is:

2 hours	**Fog at 35°C**
4 hours	**Dry-off at 60°C, less than 30% RH**
2 hours	**Wet/humid at 50°C, over 95% RH**

The acid rain CCT specifies transition times between environments as follows:

Fog to Dry	**within 30 minutes**
Dry to Wet	**within 15 minutes**
Wet to Fog	**within 30 minutes**

ISO Draft Industrial Standard 11474—Salt Accelerated Outdoor Exposure

This test, often known as the "scab corrosion" test, has not yet received final ISO approval. The test involves outdoor exposure of the specimens on a conventional rack facing 45° south. The samples are manually sprayed with a 3% salt solution twice a week. This simple procedure gives accelerated corrosion along with wet/dry cycling, solution concentration cycling, humidity cycling, temperature cycling and UV exposure. ASTM Subcommittee D01.27 on Accelerated Tests for Paint, part of Committee D-1 on Paint and Related Coatings, Materials and Applications, is also balloting a similar standard with a 5% salt solution.

Future Directions

None of these new cyclic methods is the "be-all and end-all" of corrosion testing. No single test can simulate all end-use environments. Nor can any single test be appropriate for all kinds of materials. In the future, specifiers will have to choose the test method that is most appropriate for the particular material and end use environment. Furthermore, the above methods are all considered to be not fully completed. Work is in progress to improve lab-to-lab reproducibility (always a problem), and to develop more realistic cycles and electrolytes. And we have every hope that other, previously untried methods will be found that are even better for certain applications.

In addition, it is important to remember that all durability tests, including natural outdoor exposures, are relative tests. They do not give absolute predictions of how many years a material will last in actual service. They merely provide an indication of how two or more materials compare with each other in terms of durability. To know where you stand, it is essential to expose control specimens of known durability with every corrosion test, whether it's in a cabinet or outdoors. And of course, resist the temptation to come up with a magic conversion factor where *x* hours of laboratory exposure is equivalent to *y* years of outdoor service.

That being said, these new cyclic tests do promise to give more realistic rankings of the corrosion resistance of various materials. If properly applied, they have the potential to save billions of dollars in unnecessary corrosion damage. Furthermore, the very fact that so many new standards are being developed is evidence of a new era in atmospheric corrosion testing, with a new freedom to develop more meaningful standard tests. **SN**

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