GalvInfoNote

3.4

The Salt Spray Test

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Introduction

This GalvInfoNote concerns the performance of coated-steel sheet products in accelerated corrosion testing. Specifically, the discussion will concentrate on the *salt spray* or *salt fog* test. Both terms, *spray* and *fog*, refer to the same test procedure, and are used interchangeably when describing and discussing this test.

Accelerated Corrosion Testing

The purpose of an accelerated corrosion test is to duplicate in the laboratory the field corrosion performance of a product. This provides scientists and engineers with a means of quickly developing new products. For many years the salt spray test has been used extensively for this purpose by researchers in the evaluation of new metallic coatings, new paint coatings, as well as testing miscellaneous types of chemical treatments and paint pretreatments for use with metallic-coated steel sheet products.

For an accelerated corrosion test to be truly useful, a prime requirement is that the results correlate with performance in the real world, something that has never been demonstrated with the salt spray test. This has lead many researchers to conclude that the test has no relevance, and should be discontinued. However, the results of salt spray testing are extensively used in product literature, customer specifications, product data sheets, as well as the technical literature. Typical data gives the "life" of a given type of coating, the benefits of new paint systems, the salt spray requirements for the acceptance by an end customer of an alternative product, etc., so it seems virtually impossible to stop using the salt spray test at this time. In fact, there are so many specifications in use today that require a product to exhibit a *specified number of "hours to failure" in the salt spray test,* that any change to the test or its elimination is improbable. Clearly, any push to eliminate it would require that architects, specification writers, etc. accept some alternate accelerated corrosion test(s). Simply put, the corrosion performance of different products has been compared using this test for so long that it would be difficult for today's researchers to not have salt spray test results when they are presenting performance data on a new product to a potential end user. That's how commonly accepted the test and its data is by the end-user community. Also, salt spray testing, while severe, is a good screening test because results can be generated in a timely manner and "poor contenders" can perhaps be eliminated early on in the evaluation process.

The Salt Spray Test Procedure

Basically, the salt spray test procedure involves the spraying of a salt solution onto the samples being tested. This is done inside a temperature-controlled chamber. The solution is a 5% salt (sodium chloride – NaCl) solution. The samples under test are inserted into the chamber, following which the salt-containing solution is sprayed as a very fine fog mist over the samples. The temperature within the chamber is maintained at a constant level. Since the spray is continuous, the samples are constantly wet, and therefore, constantly subject to corrosion. Through the years, there have been some new twists added to better simulate special environmental conditions, but the most common procedure by far in North America is the test as described in ASTM B117 *Standard Practice for Operating Salt Spray (Fog) Apparatus.*

In summary, the procedure is:

- Wooden racks are contained in the salt fog chamber (3' high, 3' deep, 5' wide)
- Place samples on a wooden rack at a small tilt angle
- 5% NaCl in tap water pumped from a reservoir to spray nozzles
- Solution mixed with humidified compressed air at nozzles

- Compressed air atomizes NaCl solution into a fog at the nozzles
- Heaters maintain a 95°F cabinet temperature
- Test duration can be from 24 hours to 1000 hours and more for some materials

Within the chamber, the samples are rotated frequently so that all samples are exposed as uniformly as possible to the salt spray mist.

When the salt spray test is used for testing metallic-coated steel sheet, the corrosion performance is rated in the following ways:

- Number of hours until rusting of the steel is first evident
- Number of hours until 5% of the surface area is rusted
- Number of hours until 10% of the surface area is rusted, etc.

The onset of red rust on a sample of galvanized sheet, for example, means that the coating has been consumed by the corrosion reaction, and the corrosion of the base steel is beginning. There is no one best performance criterion. It simply depends on what the user defines as failure. The following table is one guideline that can be used as a measure of expected performance of three zinc-containing hot-dip coatings.

Guideline to Salt Spray Resistance of Zinc-Containing Hot-Dip Coatings

Product	Approximate Time to 5% Red Rust (per micron [µm] of coating thickness)
Galvanize (zinc-coated)	10 hours[A]
Galfan® (zinc-5% aluminum alloy-coated)	25 hours[B]
Galvalume® (55% aluminum-zinc alloy-coated)	50 hours[C]

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[A] Galvanize Z275 – typical coating thickness/side is 20.5 µm, so approximate time to 5% red rust is 205 hours in salt spray.

[B] Galfan ZGF275 – typical coating thickness/side is 21.5 µm, so approximate time to 5% red rust is 540 hours in salt spray.

[C] Galvalume AZM150 – typical coating thickness/side is 21.5 µm, so approximate time to 5% red rust is 1075 hours in salt spray.

When the salt spray test is used to rate the performance of paint pretreatments, paint primers and/or topcoats, the normal rating schemes involve:

- Measuring the width of paint undercutting either along a scribed line through the paint or at a sheared edge after 250, 500, 750 etc hours of exposure in the test chamber,
- Measuring the amount of paint blistering that has occurred on the surfaces of the painted steel panel in 250, 500, 750 etc. hours.

There are other ways to define failure, but the above two are very common.

Since the salt spray test does not involve any exposure to ultraviolet light, paint fading and chalking are not measured in this test.

An ASTM standard has been developed for modified salt spray testing. It is *G85 Standard Practice for Modified Salt Spray (Fog) Testing*, and has several modifications involving cyclic additions of acid and SO_2. This standard is not as widely used as B117. Method A5 of G85 has been found by some producers to be able to rank materials and coatings similar to that witnessed in actual service[i].

Historic Problems

Through the years, various challenges to the applicability of salt spray test data have been made. Clearly, many field applications do not involve exposure to salt chemicals, and rarely at a concentration level of 5%. How meaningful, therefore, can salt fog data be? For example, galvanized steel experiences a higher rate of corrosion in sulphide atmospheres compared to sulphide-free atmospheres, and corrosion reactions will not be the same in a chloride atmosphere as in a sulphide atmosphere, so salt spray test results would not be expected to correlate with outdoor performance in sulphide environments. Also, manufacturers do not recommend the use of coated steel sheets for applications that involve continuous exposure to moisture (as occurs in the salt spray test). In fact, the good performance of zinc-based coatings on steel requires drying between periods of wetness, and the need for these wet/dry cycles is generally well known. It is the development of a passive and relatively stable oxide and/or carbonate film during the drying cycle that contributes to the good performance of galvanized coatings. The continual wetness during the salt spray test does not allow this passive oxide/carbonate layer to develop.

When painted material is evaluated using the salt spray test, there is no exposure to ultraviolet light, a common cause of deterioration for paints and primers. This is a serious omission, since the failure mechanisms that eventually cause painted steel sheet to deteriorate are typically not included as conditions in the salt spray test.

There are other vagaries that often show up in the salt spray test. For example, sample-to-sample variability for supposedly identical samples has been large. Also, test data gathered in two different cabinets, even though they are identical in design and operated as recommended, have shown a high amount of variance.

There are many reasons for the salt spray test not correlating with most real world exposure conditions. Three of the most significant are:

- The surface of the test coupons is constantly wet, with no cyclic drying, which does not happen in the field.
- The test chamber temperature is at a constant elevated 95°F, which increases water, oxygen and ion transport compared to the field.
- The chloride content is very high at 5%, preventing zinc from forming a passive film as it does in the field.

These are unusual and severe conditions that rarely, if ever, occur during natural weathering.

Does the Test Have Any Value?

There are those in the scientific community that claim the test has limited or no value. One can make a solid argument for this conclusion. Certainly, the practice of using the salt spray test to rank the relative performance of different coatings and/or paints is meaningless with respect to service performance. However, partly because there are so many historical data in the literature, there are some general ways in which the test has value.

For example, consider the performance of galvanized coatings on steel. The salt spray test shows a linear relation between the thickness of the coating and its life (such as time to first rust). This is similar to the performance correlation in real world exposures. In most types of environmental exposure, the coating life is linear, i.e., twice the zinc coating thickness provides twice the product life. Although the salt spray test does not correlate with outdoor exposure sufficiently to claim that a specific number of hours in the salt spray test will provide “x” number of years life in a real world application, it can be used to confirm that a specific lot of material has approximately the coating thickness claimed by the seller. For example, if the life to 10% rust is only 40 hours, it is essentially certain that the coating does not meet the thickness requirements of the most commonly used G60 and G90 coatings.

To show the test’s value in another way, consider the performance of painted galvanized panels. The benefit of having a thick galvanized coating beneath the paint coating can be shown in the salt fog test. In comparing a thin electroplated zinc coating to a thicker G90 hot-dip galvanized coating, after salt spray testing the thin zinc coated sample will exhibit considerably more paint undercutting corrosion along a sheared edge of the panel compared to a painted G90 panel. This result means that a thicker zinc coating is preferable beneath a paint coating for applications where high rates of corrosion are expected (outdoor roofing, for example). Indeed, the value of a thicker zinc coating has been clearly demonstrated for applications where the corrosivity of an application is severe. Through the years, there have been a number of misapplications of painted galvanized steel sheet where the zinc-coating thickness was not sufficient to provide the service life expected by the user.

The salt spray test can be used to demonstrate the benefit of using a thicker galvanized coating to improve the product life in the field. Be aware, however, that these are qualitative evaluations. The limitation is this: *Using a thicker zinc coating to reduce the rate of paint undercutting corrosion along a sheared edge by one-half in the salt spray test in no way means that the same reduction in undercutting corrosion will be observed in real-world applications.*

Another example where the salt spray test has been demonstrated to have some value is as a quality control test for painted steels. If a well-applied paint system (pretreatment, primer and topcoat) has been shown to perform well in service, the periodic sampling of production materials has merit. For example, if the normal performance in the salt spray test is 500 hours before the onset of a specific amount of undercutting corrosion, the periodic testing of production lot samples is a quick way to determine if there are any major production problems affecting the product quality. The salt spray test may not show conclusively that the product quality is acceptable, but if the performance in this test is substandard, the outdoor performance may also be diminished. In this instance, a lack of proper quality control might be indicated.

There may be some natural environments where the salt spray test may more closely correlate qualitatively with field results. One such environment is the splash zone of a seacoast.

As mentioned earlier, another value of the test is that it is severe – candidate materials may be able to be eliminated earlier in the selection process and perhaps save the expense of field testing.

The Future

Today, the salt spray test is so deeply embedded in the mindset of many users of coated steel sheet products that its elimination as a test procedure seems impossible. There are two primary reasons for this:

- Compliance with the salt spray test is contained in many industry and customer specifications in almost all consuming industries. In addition, many of the companies who use these specifications make claims in their own product literature about the salt spray test “corrosion life” of the coated steels that they use.
- There is no one universal accelerated corrosion test to replace the salt spray test. If the steel industry, the paint industry and the treatment suppliers really desire to replace it, they need an easy to use alternative. As of today, no such alternative test exists. Several cyclic tests have been developed specifically for the automotive and prepainted building panel industries, but they have not been widely accepted as a replacement for salt fog testing. It may be too simplistic to expect that any one accelerated corrosion test will correlate with all types of applications.

If the user community is knowledgeable about what the salt spray test really means, they can then understand its limitations and use the results in a judicious manner.

[i] K.M. DeSouza, ASTM Prohesion Test Predicts Service Performance of Prepainted Steel Sheet, Galvatech ’04 Conference, Chicago, IL, April 4-8, 2004