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, are used to describe the same test procedure, and are used interchangeably when describing and discussing this test.

Accelerated Corrosion Testing

The purpose of an accelerated corrosion test, such as the salt spray test, is to duplicate, in the laboratory, the corrosion performance of a product in the field. This allows scientists and engineers the opportunity to advance the development of new products in a quick manner. The salt spray test has been used extensively for this purpose. With respect to coated steel sheet products, it has been used for many years by researchers involved with the development of new metallic coatings, new paint coatings, as well as miscellaneous types of chemical treatments and paint pretreatments applied to metallic-coated steel sheet products.

One requirement for an accelerated corrosion test to be useful is that the results correlate with the performance in the real world. Unfortunately for the salt spray test, no one has ever been able to demonstrate that it correlates with any type of atmospheric exposure. This leads many researchers to conclude that the salt spray test has no relevance, and should be discontinued. However, there continues to be extensive use of this test in product literature, in customer specifications, in product data sheets, as well as in the technical literature. The results quoted in this literature give 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 seems impossible. Clearly, any push to eliminate it would require that alternate accelerated-corrosion tests be proposed and accepted by architects, specification writers, etc. Simply put, the performance of different products with respect to corrosion behaviour have been compared in this test for so long that it would be difficult for today’s researchers to not have salt spray test data when they are presenting performance data on a new product to a potential end user. That’s how commonly accepted the test, and the data generated by it, are accepted by the end-user community. Also, salt spray testing is a good screening test because results can be generated in a timely manner.

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. Typically, the solution is a 5% salt (sodium chloride) solution. The samples being tested are inserted into the chamber and then the salt-containing solution is sprayed as a very fine fog mist over the samples. The temperature within the chamber is maintained constant. Since the spray is continual, the samples are constantly wet, and thus, 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 described in ASTM B 117 Standard Practice for Operating Salt Spray (Fog) Apparatus.

Within the chamber, the samples are rotated frequently so that all samples are exposed as uniformly as possible to the salt spray mist. Test duration can be from 24 to 480 hours, or longer in some cases.
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 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

<table>
<thead>
<tr>
<th>Product</th>
<th>Approximate Time to 5% Red Rust (per micron [µm] of coating thickness)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galvanize (zinc-coated)</td>
<td>10 hours(^1)</td>
</tr>
<tr>
<td>Galfan(^\circledast) (zinc-5% aluminum alloy-coated)</td>
<td>25 hours(^2)</td>
</tr>
<tr>
<td>Galvalume(^\circledast) (55% aluminum-zinc alloy-coated)</td>
<td>50 hours(^3)</td>
</tr>
</tbody>
</table>

\(\circledast\)Galfan is a trademark of the Galfan Technology Centre, Inc.  \(\circledast\)Galvalume is a registered trademark of BIEC International, Inc.

\(^1\)Galvanize Z275 – typical coating thickness/side is 20.5 µm, so approximate time to 5% red rust is 205 hours in salt spray.

\(^2\)Galfan ZGF275 – typical coating thickness/side is 21.5 µm, so approximate time to 5% red rust is 540 hours in salt spray.

\(^3\)Galvalume AZ50 – 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 been experienced 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.

A second ASTM standard has been developed for modified salt spray testing. It is covered in G 85 Standard Practice for Modified Salt Spray (Fog) Testing, and has several modifications involving cyclic acid and SO\(_2\) additions. This standard is not as widely used as B 117.
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. How meaningful, therefore, can the data be? For example, galvanized steel sheet is very susceptible to a higher rate of corrosion in sulphide containing atmospheres than in non-sulphide containing atmospheres. One would not expect the corrosion reactions to be the same in a chloride containing atmosphere as in a sulphide containing atmosphere. Thus, one would not expect the results in the salt spray test to correlate with the performance outdoors in sulphide containing environments. Also, the use of coated-steel sheets for applications that involve continual exposure to moisture (as occurs in the salt spray test) is never recommended by the manufacturers of these products. In fact, the good performance of zinc based coatings on steel requires that the application involve drying between periods of rainfall, and the need for these wet/dry cycles is generally well known. It is the development of a passive and relatively stable oxide 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 layer to develop.

When considering the use of the salt spray test to evaluate painted material, 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 quite a high amount of variance.

One can list many reasons to claim that the salt spray test does not correlate with most real world exposure conditions. For instance, statistical studies have shown no correlation between the results in the salt spray test and real-world performance.

Does the Test Have Any Value?

Clearly, 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 can have 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 this test. In comparing a thin electroplated zinc coating, to a thicker G90 hot-dip galvanized coating, it can be seen after salt spray testing that the thin zinc coated sample would exhibit considerably more paint undercutting corrosion along a sheared edge of the panel than a comparably painted G90 panel. This result suggests that a thicker zinc coating is preferable beneath the paint coating for applications where generally high rates of corrosion are expected (outdoor roofing, for example). Indeed, the value of using a thicker zinc coating has been clearly demonstrated for applications where the general corrosivity of an application tends to be 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 end 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. Unfortunately, one needs to be aware that these are qualitative differences. 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 routine testing of production lot samples is one 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 quite different than expected, one can have some degree of assurance that the outdoor performance will be diminished. In this instance, the lack of good quality control might be highlighted.

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.

- Corrosion-test requirements in the salt spray test are 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 replacement accelerated-corrosion test to replace the salt spray test. If the steel industry, the paint industry or the treatment suppliers really desire to replace the salt spray test, they need an easy to use replacement test. Today, no replacement test exists except for several cyclic tests that have been developed specifically for the automotive and prepainted building panel industries. It may be too simplistic to expect that any one specific accelerated corrosion test will correlate with all types of applications.

Perhaps the best one can ask is that the user community be knowledgeable about what the salt spray test really means, and understand its limitations. This is an ongoing effort that has met with only limited success.

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