

Is It Worth Its Salt?

by:

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A look at the controversial salt spray test—its history, how it works, and its pros and cons. Is it really worth its salt?

In the early days of my career, when I was occasionally working on new part approvals, and then later when I was overseeing such activity, a common and frustrating event was to discover that parts submitted to the customer for approval did not pass their salt spray test. This was particularly confounding because those same parts would have passed our internal testing and often that of our plating vendor. I would quickly come to learn that this is a common industry problem and one likely experienced by every fastener manufacturer or distributor at one time or another.

To compound this frustration, I learned that although the experts have long debated the plusses and minuses of this test, regardless of which side they fall, they universally agree that this test may not provide similar results between test cabinets (even though all process parameters have been followed) and that the mechanism of failure is so radically different from real-world application, that there is no known or accepted correlation between salt spray hours passed and actual performance in real-world service.

One might logically ask then, what the value of this test is, what is really happening amid that salt fog and why other test methods haven't replaced it. The following is an attempt to understand more about the process and tackle these and other questions regarding this universal and deep-rooted test method in qualifying fastener quality and ability to withstand service corrosion conditions.

History & ASTM B117

Perhaps one of the primary reasons that this test is so deeply rooted in quality and validation activities and universally accepted across all industries, is that this test is about 100 years old. The first testing method was developed about 1910, although it was not standardized until about thirty years later with the first release of *ASTM B117* in 1939. Like so many other things that have stood the test of time, this original version is now only a distant cousin to today's *ASTM B117-2011* version. However, the **ASTM** standard remains the basis from which all other standards, either from other consensus standard organizations or OEMs, are derived.

The earliest standard and tests varied significantly in the percent composition (by weight) of the salt, with levels as high as 20%. These high concentrations of salt created multiple problems, perhaps most prevalent among them the buildup of salt on the fogging nozzles so that performance was erratic and not particularly uniform. It was soon discovered that reducing the concentrations to 5% (still significantly higher than natural marine environments of 1.8% to 3%) actually accelerated the results without the negative process drawbacks. Therefore, in 1954 the **ASTM** standard was revised to a controlled mass percentage of sodium chloride (NaCl) of 5%.

The *ASTM B117* standard is a detailed practice of how to control the process parameters within the test chamber. In a nutshell, it prescribes a continuous salt fog test where the salt concentration is 5%, the pH is between 6.5 and 7.2 (considered neutral, which is why this is often referred to as the Neutral Salt Spray Test) and the temperature is $35^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Naturally, there are many other factors and requirements defined in the standard such as position of exposure, purity of the salt, air supply and type of water to name just a few. The standard does *not*, and this is critical to understand, dictate how the progress of corrosion activity is to be interpreted. These guidelines are left exclusively between the supplier and customer or in the details of product and plating/coating specifications.

How Does Corrosion Occur?

It is probably impossible to appreciate the merits or drawbacks of this test without some rudimentary understanding of how the corrosion process works. At one level, we all have a general understanding that if we leave a piece of bare iron out in the rain, it will rust. Those of us living on the USA's coasts or in the midwest also understand that exposure to the ocean air or road salt spread in the winter typically accelerates the corrosion of unprotected metal surfaces. Therefore, we all have some basic feel for what is happening inside the salt spray cabinet's test chamber, namely that the salt water fog accelerates the corrosion process on any samples contained within.

However, let us look at this process in just a little more detail. The actual corrosion mechanism is an electrochemical reaction. This means that at the microscopic level a chemical process is going on, causing tiny self-generated electrical current flow. For such a process to work, the reaction requires an "electrode" (the metallic part), which is immersed in an "electrolyte" (electrically conducting liquid) and a "potential" difference (driver to start the reaction), produced for example by atmospheric oxygen or a dissimilar metal that is also in contact with the electrolyte. One of the best everyday examples of this process is the standard dry-cell flashlight battery. When turned on, a chemical reaction occurs inside the battery creating the electrical current between its positive and negative electrodes, which powers the flashlight or other small appliance. In this case, the zinc electrode is eroded, which eventually results in our having to replace batteries.

So in the salt spray cabinet, when a droplet of salt water forms on a test sample, there are differences in the electrical state produced at the interface of the electrode (the metallic sample) and the electrolyte (which in this case is the salt water). This difference creates chemical reactions, which either begin to dissociate atoms from the metal electrode or create corrosion by-products such as rust at the site of the

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corrosion attack. Over time, many of these reactions will result in the base metal becoming noticeably deteriorated or accumulating corrosion by-products. Naturally, components with platings, finishes and barrier coatings are intended to resist this attack for as long as possible, but eventually the process will find and exploit a weakness in the surface (scratch, crevice, pore, thin spot, etc.) or “wear” these protective finishes down to create a corrosion site. The salt spray test results are measured by the number of hours that a part is able to withstand such an attack.

The actual mechanisms by which corrosion occurs in the chamber are varied and quite complex. They generally vary from material to material. The corrosion mechanisms for a zinc die casting are not the same as for a steel fastener. Additionally, the conditions such as humidity, constant surface wetness, chemical presence and temperature inside the salt spray chamber may look very different from real-world conditions. Applying this understanding, one would not expect for example, that a fastener used on a car in Phoenix, AZ, USA, and subjected to completely different conditions, would behave in a similar fashion as a fastener exposed to the conditions in a test chamber.

Salt Spray Cabinet

Salt spray test apparatus (cabinets) are available from multiple different manufacturers and in many different sizes. It was determined that very small-volume chambers did not produce reliable results, so chambers smaller than 9 ft³ are generally not available. However, chambers large enough to accommodate an entire automobile are not unheard of. For fastener manufacturers, the average cabinet is about the size of a medium chest-style deep freezer.

Although this is an over simplification, the test cabinet is comprised of a deep chest-like box (the test chamber) that is entirely lined in noncorrodible plastic materials. Around the periphery of the test chamber box will be several columns and devices that serve to deionize the water, act as storage for the salt solution, act as a mixing chamber for the water and salt solution, create the salt fog and heat the chamber. The salt fog is then continuously introduced into the chamber through several baffled tubes so that it is both uniformly distributed and does not directly impinge on any of the samples within.

Significant Surfaces

Although following the process parameters of the test as defined by *ASTM B117* is critical to providing test consistency, it is equally important to understand and be able to interpret the results of the test. On fasteners, that means understanding “significant surfaces”. A March 2001 IFI Technical Bulletin titled, “ASTM Publishes Electroplating Standards Specifically for Threaded Fasteners”, describes how *ASTM F1941* identifies measurement points on significant surfaces. The ASTM standard goes on to define a significant surface as, “Significant surfaces are areas where the minimum thickness to be met shall be designated on the applicable drawing or by the provision of a suitably marked

sample. However, if not designated, significant surfaces shall be defined as those normally visible, directly or by reflection, which are essential to the appearance or serviceability of the fastener when assembled in normal position, or which can be the source of corrosion products that deface visible surfaces on the assembled fastener.”¹

It is common for product specifications such as the ones written for various platings or coatings to define the significant surfaces. This is important to understand, as normally sharp edges such as one would find on fastener threads and recesses commonly found on fastener heads are excluded as significant surfaces. With such possible exclusions, there may be justification that a part passed the test even if it has some corrosion material in these excluded or “nonsignificant areas”. In any event, understanding the acceptance criteria is important so that any incidence of corrosion products can be properly assessed and classified as subject to failure or not.

Advantages

There are some that might argue that there are no advantages to this test, that its limitations are too great and that it should simply be put out to pasture. However, adopting such an approach fails to recognize that with proper usage, understanding and process control, there are some compelling positive aspects of this test.

1. This test is truly an accelerated test. Although testing duration has significantly increased in the last 15 to 20 years (to mirror raised expectations of customers), they are still a small fraction of the time it may take to get meaningful results from field exposure tests. In fact, what may take months or years in the field takes only a matter of hours or days in a salt spray chamber.

2. Although the test cannot predict what actual performance or life expectancy will be, it can be used pretty effectively as a process control tool. In other words, it is an effective tool in identifying parts or lots which perform in a subpar manner to previous or other lots. As an example, it might be a useful process control tool to a plating company to evaluate the uniformity of coating or plating thickness, or the degree of porosity over time on a particular part or within a particular group of the same parts.

3. The test is easy to perform, and with the proper equipment, maintain the requirements established in *ASTM B117*.

4. It is the most widely accepted method of evaluating corrosion protection. Therefore, there is a wide body of knowledge available, accessibility of test equipment and availability of resources to conduct and interpret tests.

Drawbacks

As compelling as some of the advantages may be, an equal or more compelling argument can be assembled regarding the test’s disadvantages. At a minimum, it is clear that the drawbacks to this test are very limiting and any individual or organization relying on this test should clearly understand them and proceed cautiously in applying the information received from the test.

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1. Because the corrosion mechanisms are so different in this test from actual practice, there is no known correlation between exposure time in the salt spray chamber and real-world life expectancy. In other words, salt spray testing cannot be relied on by the designer to predict the actual behavior in the field or by the manufacturer/coating supplier to warrant that the part will perform as intended. In fact, the *ASTM B117* document warns users about this, clearly stating the following: “3.2 Prediction of performance in natural environments has seldom been correlated with salt spray results when used as stand-alone data, and, 3.2.1 Correlation and extrapolation of corrosion performance based on exposure to the test environment provided by this practice are not always predictable, and, 3.2.2 Correlation and extrapolation should be considered only in cases where appropriate corroborating long-term atmospheric exposures have been conducted.”²²

2. Although a salt spray cabinet may provide consistent results on one part tested over time in that cabinet, there is no such guarantee that it will produce equally consistent results with another cabinet. For the fastener Quality Engineer, this presents a real dilemma as there is always a built-in risk that your cabinet may not produce the same results as your customer’s cabinet. In those cases, whose cabinet becomes the referee? Again, *ASTM B117* acknowledges this limitation and states in Section 3.3, “The reproducibility of results in the salt spray exposure is highly dependent on the type of specimens tested and the evaluation criteria selected as well as the control of the operating variables. In any testing program, sufficient replicates should be included to establish the variability of the results. Variability has been observed when similar specimens are tested in different fog chambers even though the testing conditions are nominally similar and within the ranges specified in practice.”²²

3. The salt spray test is not a good qualitative test or one intended to rank performance of one part or finish over another. In fact, certain materials may perform poorly in salt spray testing, but quite well in real-world application. Too much dependence on salt spray results might cause an individual or organization to discount a perfectly good product, either delaying or completely eliminating its introduction to the market. A prominent and real example of this is with the hot dip galvanized and galvanized sheet metal used on today’s automobiles. These materials perform much better than their predecessors, but were delayed from introduction because they perform poorly in salt spray testing.

Other Test Methods

With the significance of these limitations, new and conceivably better technology is always being sought. Today there are a variety of cyclic tests employed, mostly by the automotive companies that are believed to be better indicators of real-world performance.

Additionally, there are certain materials that are not good candidates in neutral salt spray. The following is a list of some of the more common, salt spray related, ac-

celerated test methods employed today and the best uses of these tests.

Standard	Description	Best Used on These Test Subjects
ASTM B117	5% Neutral Salt Spray	Coatings and platings on most metallic substrates
ASTM G85	Acetic Acid Salt Spray Test	Decorative Chromium plate Cadmium plating on steel Zinc die castings
ASTM B368	Copper-Accelerated Acetic Acid Salt Spray Test (CASS)	Decorative copper-nickel-chrome or nickel-chrome on steel Zinc die castings Anodized aluminum
GM9540P	Cyclic Testing (humidity/salt spray/heat)	Coatings and platings on most metallic substrates

Conclusion

Undoubtedly, the salt spray test has its limitations. However, it is widely used across all industries and pretty universally accepted. It is likely to be around in some form or another for a long time.

Regardless of the experience individuals or organizations have previously encountered with this test, perhaps the most important and useful take-away is to become educated in its strengths and limitations, and more importantly, be able to educate your customer in the event of a disagreement over test results.

Prepare yourself with any and all standards or technical bulletins that address the limitations, and be prepared to access and share these. In this way, the next time you have discordant results with your customer, you may be able to resolve the matter quickly and in a manner that gains you the customer’s respect as opposed to the customer’s ire.

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Citations:

¹ *Industrial Fastener Institute, ASTM Publishes Electroplating Standards Specifically for Threaded Fasteners, (Independence, OH: IFI, March 2001) p.1.*

² *ASTM International, Standard B117: Standard Practice for Operating Salt Spray (Fog) Apparatus, (West Conshohocken, PA, 2011: ASTM International, 2011) p. 1.*

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- *ASM Handbook, (USA: ASM International, 1998) Vol. 13 Corrosion*
- *ASTM International, Standard B117: Standard Practice for Operating Salt Spray (Fog) Apparatus, (West Conshohocken, PA, 2011: ASTM International, 2011).*
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