

Development and Demonstration of RH-Controlled Accelerated Atmospheric Corrosion Test Environments

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ABSTRACT

In this work, we discuss the development of accelerated atmospheric corrosion test cycles designed to produce similar types of corrosion damage observed during field exposures while also highly accelerating the formation of that damage. These four cycles vary the times spent in three different ranges of RH (high, intermediate, and low) while maintaining a constant temperature. The ratios of testing time spent in each of these three RH ranges were inspired by the RH profiles obtained during field exposures in a variety of locations throughout the continental U.S. To ensure similar performance between the two testing labs involved in performing testing, extensive qualification of the test environment was performed prior to and during testing, including analysis of the salt depositions as well as examination of the RH profile of the test chamber. After the test chambers were found to be performing similarly, lapped 7075 aluminum coupons with galvanic recessed fasteners were coated with a variety of military-grade coating systems, and subjected to 500 or 1000 hours in the test environment. Analysis of the resulting corrosion is presented and compared between the different cycles.

Key words: Atmospheric Corrosion, Corrosion Tests, Test Methods

INTRODUCTION

Accelerated atmospheric corrosion tests that accurately produce similar damage to that seen in field exposures but in a more rapid way are highly sought after. Representative tests would improve life assessments, improve maintenance practices, and inform material substitutions. However, a test that both accelerates damage while replicating damage modes seen in field exposures has remained elusive. To improve correlation with observed data, cyclic tests are often used, and newer cyclic tests, including some currently being developed, require the test chamber to have control over the relative humidity of the environment. Many existing cyclic tests specify the environmental cycle which may include fogs or sprays of electrolyte for salt deposition, wet-bottom periods for humid conditions, and higher temperature holds or dry air purges to encourage drying¹. Due to technological limitations of test chambers, these tests typically refer to qualitative measures of drying or wetting, such as in GMW 14872² the requirement that “visible water droplets” be observed during the wet-bottom portion of the test to ensure that humidity is high. Specific ramp rates for RH are not specified since most chambers cannot control the ramp rate, so a wide range of RH ramp rates can be observed in chambers testing in accordance with specification. These differences in the amounts of time the test chamber spends at different relative humidities can have significant effects on both the type and amount of corrosion observed. Newer technologies that allow for RH control integrated with more traditional fogging or shower capabilities are now available, and the focus of this work is on quantifying the environment within this chamber, and understanding the variability inherent in this type of testing.

EXPERIMENTAL PROCEDURE

The primary aim of this work is to quantify and compare the environments inside accelerated atmospheric corrosion test chambers (often referred to as salt fog chambers). One test cycle was used in two chambers at two different laboratories, one at Southwest Research Institute, the other at Naval Air Systems Command (NAVAIR) at Patuxent River, MD. The chambers used by these two labs were the same model of Q-Fog’s CRH chamber, and they were purchased at the same time. Each laboratory ran trial periods of the cycle, and these trials are reported here along with the various techniques used to quantify and compare the environments and characteristics produced by each chamber.

Environmental Cycling Profiles

In this work, a four-hour test cycle profile was developed with periods of fogging, RH ramps, and RH holds. Throughout the test, the chamber temperature was kept constant at 40°C. 48 hours of the test cycle, or two full cycles, is shown in Figure 1. In this cycle, a one-hour fog is followed by a 3 hr 50 minute ramp to 30% RH, then a 1 hr 10 minute hold at 30% RH. In the next three four-hour cycles, the RH is rapidly increased to 90% for one hour, the RH is ramped down to 30% for 3 hours and 50 minutes, and then the RH is held at 30% for an hour and 10 minutes. At this point, the testing cycle begins again with a fog. The complete cycle period is 24 hours, with four sub-cycles, one of a fog and one substituting the fog portion of the test with a high-humidity hold.

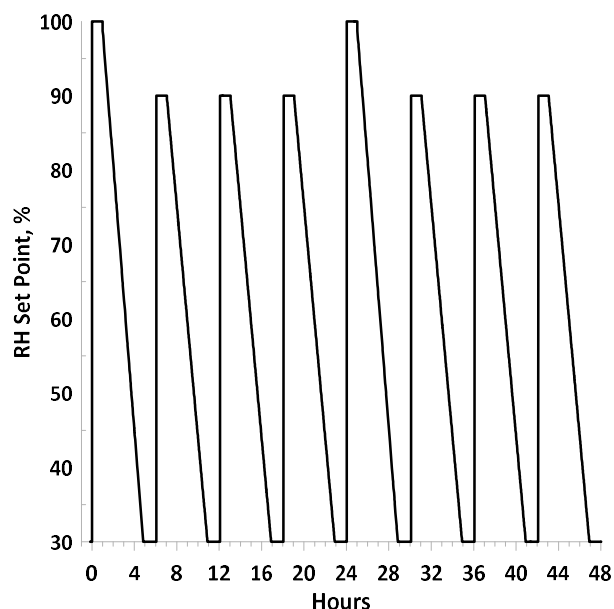


Figure 1. The environmental test cycle used for this testing. Temperature was held at 40°C throughout testing.

Due to the lower frequency of fogging compared to many existing accelerated tests, 4.0 mL/80cm²/hr was targeted as the fog deposition rate as measured by funnels and graduated cylinders. The electrolyte composition of the fogged solution is shown in Table 1. The pH of the solution was adjusted to 3 by the addition of HCl.

Table 1. Salt Solution Compositions

<i>Test Solution #1 – Modified Sea Salt Solution with Nitrate Ions</i>	
NaCl	11.13 g/L
MgCl ₂ • 6H ₂ O	5.55 g/L
Na ₂ SO ₄	2.00 g/L
NaNO ₃	1.64 g/L
HCl (1N)	(1 mL) to pH 3

Salt Deposition Classification

One of the challenges in fogged tests is the uniformity of the fog density and resulting solution deposition around the chamber. We attempted to investigate this uniformity in two ways, one using funnels and graduated cylinders to capture and measure the deposited fog volume, and the other using inert panels and Bresle patches to measure the salt loading density.

The most common method for determining fog deposition amounts is to place funnels of a known area atop graduated cylinders to measure the volume collected per unit area of the funnel. Dividing by time gives the deposition rate for that volume area. This technique is challenging for the one-hour fog durations used in these tests since significant volumes do not accumulate in the cylinders in that short a period, despite the higher fog deposition rate. Thus, for initial chamber performance validation, fogging periods were lengthened to six hours. This time was chosen because it was short enough to allow two measurements to be made in a single 24 hour period during regular working hours, and because it resulted in measurable accumulations of fogged liquid. Also, longer fogging periods would likely report