TECHNICAL ARTICLE LF-8117

Considerations for Relative Humidity and Temperature Control in Atmospheric Corrosion Test Standards

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In LF-8116, *A New Era in Corrosion Testing*, we discussed a short history of modern atmospheric corrosion testing and recent advances in the field. In this article we will cover a topic that generates many questions from laboratory technicians and researchers who operate corrosion test chambers: how relative humidity and temperature are measured and controlled in these devices.

The loose, and sometimes poor, descriptions of relative humidity measurement and control in corrosion test standards have led to significant confusion in the testing community. Device manufacturers have implemented various measurement techniques, each representing a reasonable interpretation of the standards but which may or may not yield similar results to one another. Adding to the confusion is the fact that the very need for control of relative humidity is not as clear as one might expect of a modern test standard. Finally, what is the role of laboratory conditions in meeting the requirements of the standards?

The Difficulty in Defining Temperature and Relative Humidity in Standards

What do the standards say about temperature and relative humidity? ISO 16151 *Corrosion of Metals and Alloys* says the following: “An appropriate system shall be used to maintain the cabinet and its contents at the specified temperature and humidity. The temperature shall be measured at a position at least 100 mm from the walls of the cabinet.” ISO 9227 includes very similar language. Although the ISO requirement addresses a potential concern in chamber designs with poor insulation in the walls or heaters contained within them, discussed further below, it does not address the complexity of temperature and RH measurements. ASTM standards B117 and G85 share language regarding temperature control and measurement: “Each set point and its tolerance represents an operational control point for equilibrium conditions at a single location in the cabinet which may not necessarily represent the uniformity of conditions throughout the cabinet…”

ASTM alludes to the major challenge in defining the conditions of corrosion tests without directly addressing it. That is, variable microclimates around the specimens create temperature and RH measurement issues in all cyclic corrosion tests. For example, during the dry-off period and while the specimens are still wet, it is unavoidable that the RH at the specimen/air interface is effctively 100%. However, a few millimeters from the specimen surface in the small air gap between specimens, the RH is somewhat lower. And near the chamber wall farther away from the wet surface, the RH is lower still. This fact has implications for chamber manufacturers because placement of sensors becomes a complicated issue.

This effect is magnified when a cyclic corrosion test is run manually in a large room rather than a highly engineered test chamber. This was the case with the development of many automotive cyclic corrosion methods, such as GMW 14872. In those cases, the RH sensor might be a meter or more away from the humid microclimate between the specimens, and the room air is not circulated to the same degree as it is in a typical test chamber. These facts contribute to differentials between room measurements and conditions near the specimens.

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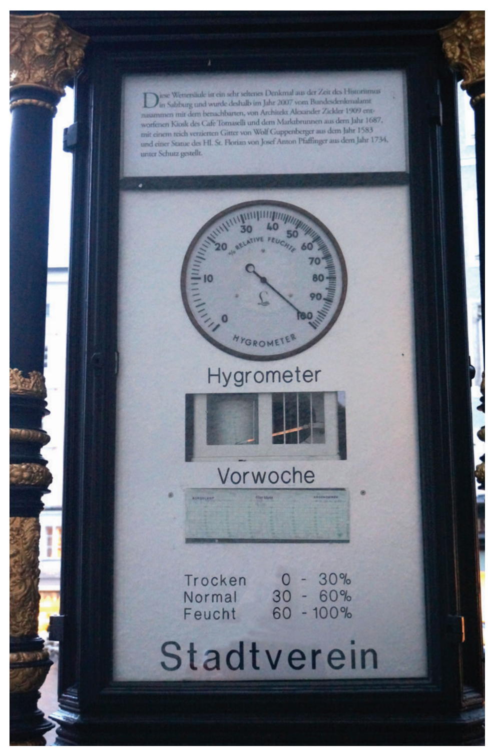
Although GMW 14872 and most international standards avoid discussion about where and how to measure the relative humidity, Volvo provides some guidance in VCS 1027.149, *Accelerated Corrosion Test: Atmospheric Corrosion*. Unlike the ISO standards, Volvo directly addresses the issue of chamber wall insulation rather than specify a minimum distance for placement of sensors. It also says, “The climate chamber should be equipped with means to provide evenly distributed efficient circulation of air to secure small temperature and humidity variations in the chamber.” An experienced reader of standards recognizes use of the words “should” and “small,” meaning that there is no mandatory requirement in the statement but rather a desirable condition to be achieved. In this case, the writers understood that microclimates exist during the test and therefore it is necessary to avoid a specific uniformity requirement that may be physically impossible to achieve. The standard goes on to say, “The humidity and temperature sensors should reflect the climate conditions in the very test area.” Use of the word “reflect” seems to be deliberately imprecise because it recognizes the complexity of measurements in the context of the varied microclimate conditions during the test. It also implies there are many ways one could position a sensor to capture chamber temperature and RH.

This brings us to the topic of types of RH sensors and the specific challenge that comes with measuring the RH in a corrosive environment. Modern RH sensors, technically referred to as hygrometers, use electrical resistance and capacitance techniques to measure moisture in the air. Various technologies exist, with trade-offs between accuracy and resistance to condensation, which ruins the measurement. None of them are particularly tolerant of corrosive conditions, however. This is a critical factor in chamber design because corrosive solutions decrease the accuracy of the measurements and cause premature failure of these sometimes costly sensors. Some manufacturers have designed clever mechanisms that retract sensors during applications of corrosive solution in order to improve the robustness of their RH sensors. The challenge with such systems is their complexity and placement relative to the various microclimates inside the chamber.

The Volvo corrosion standards are rare in that they describe types of sensors, instructing users to “use a hygrometer designed for measurements at high humidity levels, e.g. a high-quality psychrometric sensor or a gold mirror dewpoint meter.” The second of these types is impractical for use in a corrosion test chamber, but many chamber manufacturers utilize wet bulb/dry bulb thermometer psychrometers



This late 19th century weather station in Salzburg, Austria was declared an historical landmark in 2007. Pictured is the side displaying the relative humidity. Hygrometers of this era commonly used human hair under tension, since it changes length depending on the moisture content of the air.

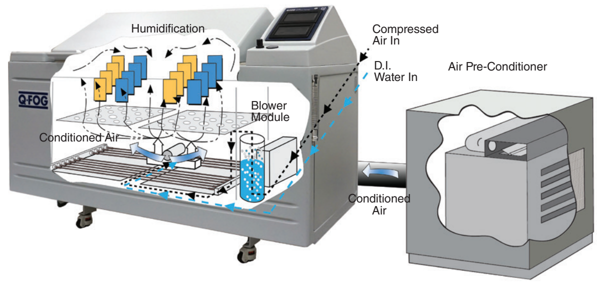
due to their high accuracy and ease of calibration. The technique, developed centuries ago, uses two thermometers: one which remains dry while it measures air temperature and one which includes a moisture-wicking “sock” over it to keep it wet during measurements.

Evaporative cooling “depresses” the temperature reading of the wet bulb thermometer relative to the dry bulb. By comparing the two temperatures and using well-established psychrometric charts, the relative humidity of the air can be determined with high accuracy. These hygrometers require airflow over the wet and dry bulbs to facilitate evaporation. Sling psychrometers achieve this by having the user whip the device around over their head.

Using this system in a corrosion test chamber is complicated by two factors. First, the dry bulb thermometer must be kept dry and the wet bulb sock must be kept wet, clean, and free of salts. Second, this first point must be accomplished while allowing sufficient airflow over the wet bulb to facilitate evaporation. Therefore, chamber manufacturers must choose between systems to wash salt from the wet bulb socks and keep dry bulbs dry while inside the chamber, or systems that keep the wet and dry bulbs out of the corrosive atmosphere inside the chamber. As always, placement of sensors relative to the chamber microclimates is a concern. One solution to this problem is found in the words “represent” from ASTM and “reflect” from Volvo. During cyclic corrosion tests, chamber air is exchanged up to several times every minute, eventually achieving equilibrium conditions inside the chamber. This makes the area where air exits the chamber an ideal location to obtain a representative measurement of chamber conditions.

Relative Humidity Conditions in Corrosion Standards: What is Required?

Now that we’ve discussed the complexity of chamber conditions during cyclic corrosion tests and various techniques used to measure temperature and RH, we can move on to a wider view of the automotive cyclic tests. A common feature of these tests is what GMW 14872 calls an “ambient phase”, which was part of the cycle developed in temperature and RH-controlled rooms. The temperature of this phase is 25 ± 3 °C and the RH is 45 ± 10%. Ford and Volkswagen have ambient phases with a temperature of 23 °C and RH of 50%, with various tolerances. A source of confusion and some controversy is whether a corrosion test chamber designed to run these tests must be able to control the RH.



The Q-FOG CRH cyclic corrosion test chamber that allows control of relative humidity through the use of an air preconditioner.

The answer depends on whether or not the laboratory in which the chamber is installed can reliably meet the specified conditions.

If a laboratory is precisely controlled to the ambient conditions listed in the standard, and specimens are exposed to these conditions either by opening the chamber lid or circulating room air over specimens to achieve equilibrium between the inside and outside of the chamber, then the ability to adjust and control the RH in the chamber is not required. However, control of laboratory conditions to the precision required by these tests is rare, especially in facilities where corrosion tests occur. So as a practical matter, control of the RH inside the chamber is necessary given the variable climatic conditions of laboratories in the global marketplace. Additionally, standards may also require mass loss measurements of corrosion coupons throughout the test, knowing that good control of conditions is necessary to achieve the mass losses required. Given the importance of properly controlling RH in some tests, use of such mass loss coupons is a trend that is likely to continue.

A challenge for chamber manufacturers in designing for these variable laboratory conditions is that the ambient phase temperature and RH can be difficult to achieve in many environments. For example, if a laboratory is temperature-controlled at 25 °C and the RH goes up to 60% (a common situation during summer months when the dew point outside is high), the air entering the corrosion test chamber must be dehumidified to achieve the required condition of 45 ± 10%. If the laboratory temperature reaches 29 °C, the air must be chilled to meet “ambient” conditions. For these reasons, many chamber manufacturers have designed chiller and dehumidification systems to meet the required conditions.

The best laboratory practice for automotive cyclic corrosion tests is to always use chambers with the ability to control the RH and systems to cool and dehumidify the air, whether the standard specifically requires these or not. This ensures the best possible test for repeatability and reproducibility.

Test Standards: The Path Ahead

Control of relative humidity is a relatively new capability in the century-old field of cyclic corrosion testing. As in many fields, there is tension between the requirements of and the capabilities of commercially-available test equipment. Chamber manufacturers and standards writers cannot be out of sync with one another. Over several decades, the two sides have developed methods that accommodated the lack of RH control in the equipment, but this situation is increasingly recognized as untenable by automotive OEMs. As more equipment with RH control enters the market, standards writers must also modernize test methods to take advantage of better testing technology while maintaining hardware-neutral standards that allow open competition in the market.

Conclusion

In this article we discussed some of the difficulties with RH measurement and control in a corrosion test chamber and how test standards have historically addressed these issues. Because various measurement techniques may result in different test conditions within the confines of test standards, the use of measurement controls such as mass loss coupons is likely to increase. In the coming years, test equipment manufacturers and standards creators must continue a dialog, with the goal of clarifying and improving the requirements of tests where control of RH is important.

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