

Examination of Corrosion Sensor Data from Long-Term Field Exposures

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ABSTRACT

This work examines data from a multi-year, large deployment of corrosion sensors in a variety of locations representing a range of corrosivity severities. The corrosion sensors used in this work measure atmospheric parameters such as relative humidity and temperature in addition to electrochemical parameters such as the conductivity of the electrolyte formed by salt deposition and possible deliquescence, and the polarization resistance measured on a variety of structural materials including 7075 aluminum, 2024 aluminum, and 4310 steel. Comparisons between sheltered and unsheltered sensor exposures show the difference precipitation and other rinsing events have on sensor measurements. In particular, the interplay of relative humidity and electrolyte conductivity is discussed in the context of using conductance sensors as a proxy for salt loading. The tendency for protective corrosion product films to form on the sensing materials, resulting in high initial corrosion rates and subsequent lower corrosion rates is demonstrated and the implications for accurately measuring corrosion rates is discussed. A comparison between representative conductance values from the field to values from lab testing is presented to provide context for salt loadings in accelerated laboratory corrosion testing. These discussions can be used to guide the development of models used to predict atmospheric corrosion rates from sensor data.

Key words: Sensors Atmospheric Corrosion, Electrolyte

INTRODUCTION

The current approach to corrosion severity prediction is to use long-term averages of environmental parameters (such as relative humidity, temperature, and pollutants), geographic features (such as coastal proximity), and witness coupon corrosion rates of indicator materials to classify an environment into one of a small number of severity categories. However, recent work has revealed that brief changes in environmental conditions—even those lasting only a few hours—can significantly affect total corrosion damage, and long-term averages of environmental conditions are not sufficient to accurately predict cumulative corrosion damage. To more accurately measure the corrosion damage from these short-term events, corrosion sensors are becoming increasingly popular. The frequent acquisition of data and increased measurement sensitivity are attractive features, however the data from these corrosion sensors is still difficult to interpret in many cases.

The widespread use of corrosion sensors is limited by the current inability to interpret sensor data in the context of maintenance operations. The discussions and examples presented here provide information that will be helpful to inform future sensor deployments, to guide the development of models used to predict atmospheric corrosion rates from sensor data, and to assist the development of more detailed corrosion severity classifications systems.

EXPERIMENTAL PROCEDURE

Over 250 corrosion sensors were exposed at locations in a variety of environments including inland and coastal locations. Data from those a subset of these sensors was analyzed and is presented here, in addition to sensor data from laboratory exposures.

Corrosion Sensors

The corrosion sensors used for this exposure were LS2A sensors manufactured by Luna Innovations¹. These sensors include on-board temperature and humidity measurement devices as well as two interdigitated electrodes (IDEs). One of the IDEs is a free corrosion sensor manufactured of an alloy of interest. This IDE measures the polarization resistance (R_p) which is inversely proportional to the corrosion rate ¹. For these exposures, corrosion rate IDE sensors constructed of UNS A97075, UNS A92024, UNS A96061, and UNS G41300 were deployed. The other IDE material is gold, and this IDE is used to measure solution resistance. The inverse of solution resistance (R_s) is solution conductivity.

Field Exposures

Sensor data from two exposure locations, Andersen AFB in Guam and Dyess AFB in Texas is examined here. Some sensors are exposed on exposure racks with no additional shelter. Some sensors were exposed in simulated aircraft structures (SAS), pictured in Figure 1. These SAS are primed inside and out, and the outsides are topcoated using military aerospace coatings, but no sealant is used, so the SAS are not airtight. The sensors are placed inside the SAS along with some witness coupons, and then the SAS is exposed on racks adjacent to the bare sensor racks.



Figure 1: Photographs of the simulated aircraft structures (SAS) used for sensor exposures

¹ Trade Name

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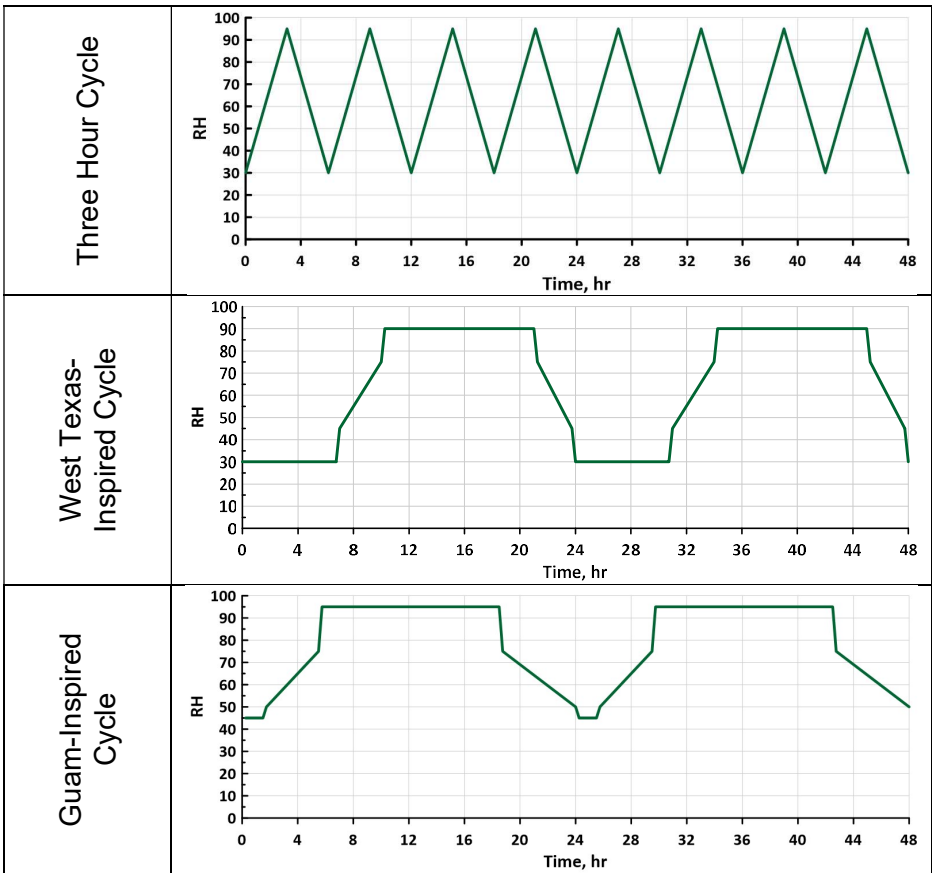
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Laboratory Testing

In order to attempt to estimate the salt loading densities for field exposures, corrosion sensors were exposed in a Thermotron² RH chamber programed to provide cyclic humidity conditions with the salt loading of the samples being increased periodically. A variety of cycles were used for this exposure, including generic ramps as well as those designed to approximate the different field conditions observed in the sensor exposure. These exposure conditions are shown in Table 1. All testing was performed at a constant 30 °C.

The initial cycle was simply a linear three-hour ramp from 30% RH to 95%. Subsequent cycles were modeled on the RH profiles of the exposure locations. To define these cycles, the median time in different RH ranges was determined and then adjusted to sum to 24 hours. These cycles were used to help determine the salt loading levels at the different locations.

Table 1
Cycle Diagrams



Salt was deposited on the sensors during the dry periods of the cycle. For the initial testing, a solution of 0.012 M sodium chloride with a pH adjusted to 3.0 by the addition of acetic acid was sprayed on to the surfaces. Each sample would receive a single spray to the surface, leaving isolated wet droplets rather than a continuous electrolyte film or a large pool of solution. For the spray depositions, the amount of salt deposited was not calibrated beyond the number of sprays the sample received with salt sprays occurring every three or four days.

² Trade Name