Development of a Dynamic Accelerated Corrosion Test Method

Background

Current predictive models of atmospheric corrosion consist of simple correlations among easily measured atmospheric variables (*e.g.*, relative humidity, temperature, salt deposition, pollutant gas concentration) and the observed corrosion rates. Phenomenological models of atmospheric corrosion usually include a major dependence on "deposited chloride" and "distance from the sea." Unfortunately, regression analyses for corrosion rate that consider these "obvious" variables have been uniformly failures, with correlation coefficients consistently near or below 0.5.

We propose that a primary reason for these deficiencies in predicting corrosion rates is the lack of understanding of the surface environments that develop on materials exposed to natural atmospheres. In particular, there has been no explicit account for the speciation, spatial variability, and associated deposition fluxes of chemical species such as chlorine-(Cl) and bromine-(Br) containing compounds that are introduced into the lower atmosphere from both natural and anthropogenic sources and subsequently transformed by reactions involving oxidants such as ozone and hydroxyl radical in the presence of light and water.

The suite of reactive halogen species (RxHal, including halogen ions, acids, and atoms; hypohalous acids; and halogen oxides) include strong oxidants that attack protective films naturally formed on metals. The formation and cycling of these aggressive species has been demonstrated by atmospheric chemists based on both field and laboratory experiments since the early 1990's. The production of sea-salt aerosols by turbulence at the ocean surface is the major global source for tropospheric Cl and Br. Sea salt, together with associated halogenated reaction products, can be transported far inland by prevailing winds. Other important global sources of tropospheric halogens, which may dominate on regional scales particularly at inland continental locations, include deflation of surface soils, biomass burning, fossil-fuel combustion, and incineration. To date, however, this understanding of atmospheric chemistry has not been incorporated explicitly into corrosion-related research efforts. We believe that a more comprehensive evaluation of the associated atmospheric processes will explain much of the observed dependencies of corrosion rates on environmental variables. For example, there are strong gradients in both the deposition of atmospheric halogens and corrosion rates of metals with distance inland from coasts. In addition, the solution concentrations of deposited halogens on surfaces are typically quite high. Based on the hygroscopic properties of sea-salt aerosol and its associated rate of chemical modification, the chloride concentrations in aqueous brine solutions on metal surfaces exposed to coastal air at a typical relative humidity of 80% can be in the range of 5 to 10 M. Finally, the concept of "deposited chloride" as primary a driver for atmospheric corrosion may be misleading because the simple methods currently used by the corrosion community to estimate "deposited chloride" are not appropriate for analysis or interpretation of the full range of gaseous and particulate RxHal species.

Just as critical as the characterization of the surface environments that form as a function of location, the relative importance of the species present must be determined. For example, in previous development of an accelerated test simulant for aircraft lap joint crevices, nearly 30 different chemical species were found during the examination of nearly 100 samples taken from over ten aircraft. However, only four of these species, in addition to the pH, were found to have a statistically significant effect on the electrochemical corrosion behavior of AA2024-T3. The simulant containing only those species was validated in its replication of the damage morphology seen in service and exhibited an acceleration of the rate of damage.

Tasks:

1) Task 1 – Determine the effects of static vs. cyclic wetness and UV radiation on the corrosion of relevant metals (AA7075-T6, AA5083-H116). (years 1 – 4) Of critical interest are:
    a. Effect of these variables on the location of corrosion (inside or outside of a crevice formed at a coating or lap joint interface)
    b. Effect of these variables on pH within the electrolyte layer on a boldly exposed surface and within an occluded region.
    c. Effect of these variables on the rate and morphology of the corrosion damage.

2) Task 2 – Using chemistry data from cyclic environmental chamber and outdoor exposures, develop a relevant solution chemistry capable of simulating atmospheric corrosion of boldly exposed and occluded surfaces of AA7075-T6 and galvanic couples of, for example, AA7075-T6 with silver. (years 2 - 4) Of critical importance are:
    a. Identification of the chemical species (individual or combinations) that critically affect relevant electrochemical parameters (OCP, Epit, E_{rpass}, i_{corr}, i_{pass}).
    b. The critical relationship between chemistry on a bold surface and that which forms within an occluded region based on the external chemistry.

3) Task 3 – Perform exposure chamber testing to verify relationships identified in Tasks 1 and 2 above. (years 4 – 5)