

Atmospheric Corrosion of Plain Carbon Steel Below the
Deliquescence Point of Sodium Chloride

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This work investigated the corrosion response of plain carbon steel to sodium chloride deposits at humidity levels below the room temperature deliquescence relative humidity (DRH) of this salt, 75%. Being a major component of sea salt, sodium chloride is widely utilized in laboratory atmospheric corrosion tests. The corrosion behavior of steel contaminated with NaCl at humidity levels at or above its DRH has been well documented. Outdoor surfaces, however, often reach humidity levels well below the DRH. Only a few studies have been reported that have examined or considered the possibility of corrosion at humidity levels below the deliquescence point. Of those that have, conflicting results have been presented as to whether or not significant corrosion occurred and why.^{1,2} The objective of this work was to quantify the extent of corrosion attack below the DRH of NaCl and elucidate the mechanisms that might enable it. The results will provide empirical data critical for development of next generation cyclic accelerated tests along with process-based atmospheric corrosion models that rely on RH as an environmental parameter.

In this work, coupons of 1010 carbon steel were polished to a 0.01 μ m colloidal silica finish and cleaned. An aqueous solution of sodium chloride was printed³ onto the coupons in the form of arrays of picoliter-sized drops, resulting in chloride loading densities of up to 5 μ g/cm². After NaCl deposition, the coupons were placed in sealed, room temperature isohumidity chambers at RH set points of 0%, 23%, 33%, 53%, 64%, 71%, 75%, 85%, and 90%. Coupons were removed at intervals from the chambers for periods of up to 30 days. After exposure, optical microscopy and white light interferometric profilometry were used to characterize and quantify corrosion attack morphology, depth and volume loss.

The results of this study provide evidence for sustained corrosion down to 33%RH. Volume loss was greatest after 30 days for those samples subjected to 71% and 75% RH. In all cases the corrosion rate was greatest at the beginning of the exposure and considerably slowed or halted as exposure progressed. Unlike volume loss, maximum pit depth monotonically increased with increasing relative humidity. At the highest humidity levels, 85% and 90%, corrosion attack was characterized by large diameter, deep pits that sparsely covered the surface. Attack became more filiform in nature with decreasing humidity levels and resulted in more closely spaced and shallow pits.

The corrosion behavior observed in this work will be discussed in the context of a number of phenomena that enable electrolyte presence below the DRH of sodium chloride. These phenomena include: 1) salt crystallization hysteresis caused by nucleation and growth limitations during drying, 2) alteration of deliquescence behavior due to the contribution of corrosion chemistry, 3) adsorbed or trapped electrolyte on the salt and alloy surfaces. It is

currently thought that all three of these phenomena contribute to corrosion below the deliquescence point and work is underway to elucidate their roles.

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