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A FRAMEWORK FOR THE ANALYSIS OF LOCALIZED CORROSION AT THE PROPOSED YUCCA MOUNTAIN REPOSITORY

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INTRODUCTION

The proposed Repository presents a familiar materials performance application that is regularly encountered in energy, transportation and other industries. The widely accepted approach to dealing with materials performance is to identify the performance requirements, to determine the operating conditions to which materials will be exposed and to select materials of construction that perform well in those conditions. A special feature of the proposed Yucca Mountain Repository is the extremely long time frame of interest, i.e. 10,000's of years and longer. Thus, the time evolution of the environment in contact with waste package surfaces and the time evolution of corrosion damage that may result are of primary interest in the determination of expected performance.

Corrosion behavior is a primary determinant of waste package performance at the proposed Yucca Mountain Repository. Corrosion is a most probable and likely degradation process that will determine when packages will be penetrated and the shape size and distribution of those penetrations. In this paper, a framework for the analysis of localized corrosion at the proposed Yucca Mountain Repository is presented. The natural and engineered barriers that affect the corrosion conditions are identified. The corrosion conditions within the proposed repository are described for five significant time periods from emplacement of waste packages until the repository has returned to ambient conditions after 10,000's of years. An approach is presented to the analysis of localized corrosion during a time period when it is possible for waters from drips and seepage to contact the waste package surfaces.

Since no material is immune to all environmental conditions, an approach is to specify a material with sufficient corrosion resistance over the range of expected environments. The objective is to determine the corrosion behavior over a broad range of environments that cover the expected conditions. Thermal-hydrological-chemical models and experiments determine the water chemistry and temperature ranges of interest. The chemical divide processes determine the evolution of water chemistries into the categories of waters, e.g. sulfate brines, carbonate brines and calcium chloride brines. Corrosion resistance of metal is determined by long-term exposure of metal specimens and widely accepted electrochemical tests.

From a corrosion perspective, five key time periods are defined for any waste package. The times for these periods vary from package to package depending on thermal load and heat transfer in the drift and to the surrounding rock. The temperature and relative humidity trajectories for a medium temperature waste package are shown for five key time periods (logarithmic time scale) in Figure 1. In this scenario, forced ventilation (***Period I***) cools the repository for 50 years and then the repository is closed. Heat-up (***Period II***) occurs over approximately 20 years where the waste package outer surface heats to 155 C, the drift wall heats to 130 C and the relative humidity decreases to 15%. A long, slow cool down begins at year 70, and ***Period III*** is determined by the start of cool down until the drift wall has cooled to below the boiling point for water (96 C at Yucca Mountain elevation and year 750 here). ***Period IV*** is defined by a start when the drift wall has cooled below boiling and ends when the waste package surface has cooled below a critical temperature for corrosion of Alloy 22, i.e. 90 C and year 1375 in this scenario. ***Period V*** starts when the waste package has cooled below the critical temperature for corrosion.

The behavior of a binary mixture of NaCl and KNO_3 as a function of relative humidity and temperature is shown in Figure 2. Also shown are the temperature-RH trajectories for examples of mid, hot and cool waste packages, and some key times for Period IV are indicated. The significance of this illustration is to demonstrate that the time-temperature-relative humidity behavior is coupled to the water chemistries that can exist on hot metal surfaces, and the trajectories of aqueous environments can be determined. The inaccessible region is determined by atmospheric pressure in the drifts. All binary salt mixtures below the deliquescence relative humidity line are dry (and no corrosion will occur). Pure NaCl deliquesces at approximately 115 C and RH 40%. Where aqueous solutions are possible, there are constraints on the chemical composition. For example, below approximately 70% RH, the nitrate to chloride ratio must be greater than 0.5:1, and corrosion tests indicate that localized corrosion is inhibited.

When the waste package surface is dry, there is no corrosion, and there is a critical temperature below which localized corrosion of Alloy 22 will not initiate in waters of a specified composition. For the above scenario, a critical temperature of 90 C is specified, and the waste package surface cools below this temperature in year 1375. The time period over which localized corrosion can initiate is constrained by these two limits, i.e. years 750-1375 for this scenario. Furthermore, the water chemistry of mixed salt solutions is the determinant of temperature-relative humidity conditions within this range. The evolution of localized corrosion damage once initiated then depends upon the propagation, stifling and arrest processes. Based on corrosion performance data for Alloy 22, the conditions that will and will not support localized corrosion are delineated. There are large time periods when localized corrosion can not be supported, and no corrosion damage will occur. The analysis can then focus on those time periods when localized corrosion could occur.

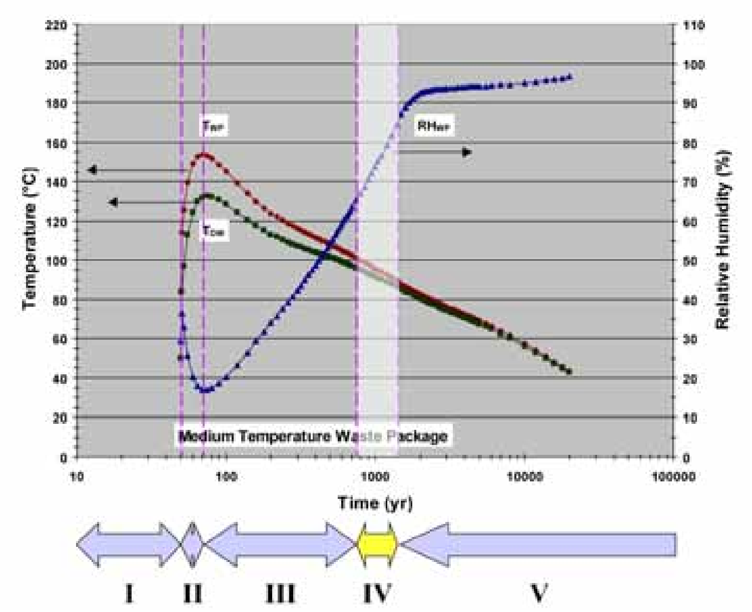

Figure 1. The temperature and relative humidity trajectories for a medium temperature waste package are shown with five key time periods (logarithmic time scale).

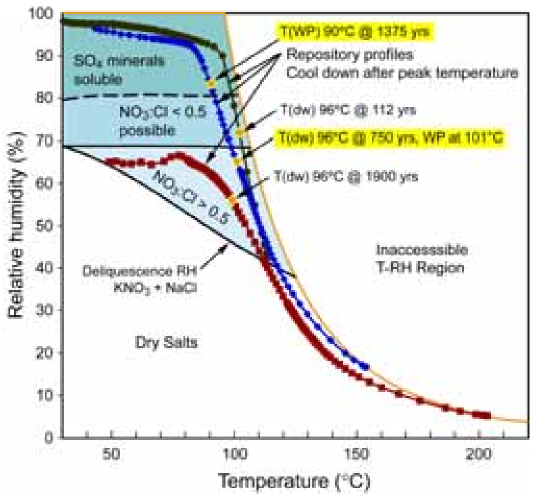

Figure 2. The behavior of a binary mixture of NaCl and KNO_3 as a function of relative humidity and temperature along with the temperature-RH trajectories of three waste packages and Zone IV time periods.