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An Assessment of Long-Term Container Corrosion in a Generic Disposal System of High-Level Nuclear Waste

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Abstract

Staff at the U.S. Nuclear Regulatory Commission has been studying generic disposal systems for many years (Ahn, 2016; He et al., 2015), along with the Center for Nuclear Waste Regulatory Analyses (CNWRA). Studies have included long-term container corrosion mostly under anoxic/reducing conditions (He et al., 2018; He and Ahn, 2017). This paper presents recent progress made focusing on (1) energetics, repassivation, phase transformation and precipitation, associated with the persistence of passive film on carbon steel in alkaline groundwater, (2) appropriate test methods for hydrogen-induced cracking of carbon steel, and (3) test results and modeling of copper corrosion in the context of clay/bentonite repository/backfill. Copper corrosion includes chemical dissolution in addition to electrochemical dissolution.

In considering the role of passivity in corrosion, more recent models by Bataillon et al. (2012; 2010), Leistner et al., 2013) and Seyeux et al. (2013) are evaluated along with an earlier one (Macdonald and Urquidi-Macdonald, 1990). The current conclusion of these existing models is that a steady state can be achieved. This paper presents energetics associated with capacitance and strain energy. The paper also presents repassivation, phase transformation of passive film, and precipitation of dissolved species. Operational experience in reactors at higher temperatures is discussed for bench-marking long-term behavior of passive film at lower repository temperature. This additional experience is likely to support the previous models. In the hydrogen-induced cracking of carbon steel, slow strain rate tests (Ahn and Soo, 1995) and the recent U-bend static tests (He and Ahn, 2017) are compared. It is believed that the static tests are more appropriate considering unrealistic dynamic behavior (e.g., dislocation dynamics) of the slow strain rate tests. The tests of copper corrosion are focused on the effect of chlorides (He and Ahn, 2019). Since dissolved copper species diffuse slowly through clay/bentonite, the concentration of copper species next to the copper container will reach the solubility limit quickly. Therefore, the overall copper corrosion rate is controlled by the diffusion rate of dissolved copper species in clay/bentonite medium. This diffusion control is supported by the transport time exercise for dissolved species in clay (Mallants et al., 2001). Therefore, the tests have used two types of tests, both activation process (Electrochemical Impedance Spectroscopy, EIS, tests) and diffusional process (immersion tests). When compared to additional literature (Rosborg, present; Scully and Hicks, 2012; Beverskog, 1998), currently a wide range of copper corrosion rates are reported.

Disclaimer:

The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of any licensing action that may be under consideration at the NRC.

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