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EBSPAC: A COMPUTER CODE FOR EVALUATING PERFORMANCE OF ENGINEERED BARRIER SYSTEM FOR HLW DISPOSAL

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INTRODUCTION

Two basic goals of the U.S. Department of Energy (DOE) proposed repository at Yucca Mountain, Nevada (YM) are to ensure containment of radionuclides within waste packages (WPs) for several thousand years and to limit potential releases from the repository[1]. The DOE has formulated several attributes of the repository system that, if verified, would demonstrate that waste can be isolated at the proposed YM site for sufficiently long periods of time. Two of the attributes pertaining to performance of the engineered barrier system (EBS) include (i) containment of waste within WPs for thousands of years and (ii) limited release of radionuclides through the engineered barriers. This paper outlines the Engineered Barrier System Performance Assessment Code (EBSPAC)[2] developed to provide a means and methodology to independently evaluate these attributes and to provide a source term module for total system performance assessment. By conducting sensitivity analyses of WP performance, the DOE demonstration of the validity of these attributes can be quantitatively assessed.

The major component of the EBS is the WP, which includes the waste form, fuel cladding, filler, canisters, and disposal overpacks. In addition to the WP, the EBS may include backfill, concrete inverts, WP emplacement pedestals, drip shields, and other components used in the design and construction of emplacement drifts. Some of these components affect waste containment and isolation indirectly through their effects on the near-field environment (e.g., concrete inverts, steel sets, rock bolts). Other components affect containment directly (e.g., overpacks), while other components have both direct and indirect effects (e.g., backfill).

CONCEPTUAL MODEL

In formulating conceptual model for EBSPAC, it was assumed that percolating water reaches the drift walls, flows through the backfill material and then contacts the WP surface. Simultaneously, heat generated by the radioactive decay of the waste causes groundwater in the backfill and the rock media surrounding the drift to vaporize and be driven away from the vicinity of the WPs, leading to formation of a dry-out zone. With attendant cooling, condensation of water vapor may occur at a certain distance from the drift walls, reestablishing partially saturated conditions. When this condensate, enriched in salts (arising from rock-water interactions and affected by increased temperature), refluxes through fractures, it may lead to corrosion and subsequent failure of the outer steel overpack and, eventually, to penetration of the inner container. Upon breaching the containers, the original groundwater and modified by the presence of soluble corrosion products will interact with the waste form leading to the release of radionuclides that can be transported to the water table and atmosphere.

CONTAINER LIFETIME

An important consideration in EBSPAC is the modification with time of the physical and physicochemical characteristics of the environment surrounding the emplaced WP. The temperature evolution at the WP surface is obtained from the thermal model and the time when the surface begins to be covered with a water film is calculated by modeling the near-field environment. The environment model (outside of EBSPAC) provides the relative humidity (RH) reached at a given temperature of the WP. In addition, pH and chemical composition of the liquid phase contacting the WP are calculated, mainly in terms of predominant anionic species such as Cl^-. The onset of aqueous corrosion (i.e., the surface wetting time) is determined by a critical value of RH at which the surface is assumed to be covered by a water film. Below this value, air oxidation in the presence of water vapor is modeled as the dominant process for the steel overpack in parallel with the evaluation of mechanical failure as a result of thermal embrittlement of the steel promoted by long-term exposure to temperatures above 150 °C. If the RH is higher than the critical value, the occurrence of aqueous corrosion of the steel overpack is evaluated. No distinction is made in this version of EBSPAC between humid air and aqueous corrosion. The corrosion models calculate the rates of uniform and localized corrosion. The corrosion process at any given time period depends on the corrosion potential and the critical potential required to initiate a particular localized corrosion process. Following penetration of the outer container, electrical contact of the inner and outer container coupled in the presence of an electrolyte path such as that provided by modified groundwater promotes galvanic coupling. The galvanic corrosion model determines whether penetration of the inner container by localized corrosion is possible or, otherwise, if uniform passive corrosion or mechanical fracture becomes the predominant failure mechanism.

RELEASE RATE

Once penetration of the inner container occurs, containment is assumed to be lost. The RH criterion is then applied to ascertain whether air oxidation or aqueous dissolution of the spent fuel (SF) is the next process to be evaluated. Air oxidation of SF leads to gaseous release of C-14 predominantly from the fuel cladding, whereas I-129, Cl-36, and C-14 are released as gases from the fuel pellets and the pellet-cladding gap. Two models are generally considered for aqueous release of radionuclides: the bathtub model and is the flow through (model based on groundwater dripping on the SF). Only the bathtub model is included in the current version of EBSPAC. Finally, plausible mechanisms for the aqueous release of transuranics and certain fission products are considered, including solubility limited release, and dissolution rate limited release. Finally, advective release out of the WP as well as diffusive release out of the EBS are considered.

The EBSPAC code is based on simplified models to allow fast computation when it is used as a part of the NRC Total-system Performance Assessment code. This paper presents the results of calculations performed for an example problem to illustrate the capability of EBSPAC module.

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