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Effect of excavation damaged zone on gas migration in a KBS-3H type repository at Olkiluoto

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Abstract

The quantities of steel in the KBS-3H disposal concept with long horizontal deposition holes are moderate but the gas production rates are significant. Based on current understanding of the geological situation at the Olkiluoto site in Finland, a simplified model of gas pressure evolution and migration of corrosion gases in the disposal system was developed and the effect of EDZ on the gas transport was evaluated. The results of the analysis suggest that gas is predominantly transported by two-phase flow through the EDZ and the fracture network in the host rock. For the major part of the deposition hole sections, there is sufficient transport capacity for gas to escape through the host rock and EDZ and the calculated gas pressure increases are found to be moderate. In tight deposition hole sections, transport through the EDZ dominates and the gas pressure development is sensitive to EDZ permeability. If the EDZ permeability in tight sections is of the order of 10% of the measured intrinsic permeability, the pressure there may rise to near the minimum principal rock stress. However, if the permeability is of the order of the measured intrinsic EDZ permeability, the pressure will rise only slightly above hydrostatic pressure. The results of the analysis show that the EDZ is capable of transporting the gas gradually out from tight hole sections without significantly disturbing the isolation characteristics of the repository system.

Keywords: KBS-3H; Corrosion gases; Gas migration; Excavation damaged zone; EDZ

1. Introduction

The KBS-3H concept (see Fig. 1), which is being developed by Svensk Kärnbränslehantering AB (SKB) in Sweden and Posiva Oy in Finland in co-operation, is based on boring 1.85 m diameter parallel long (length 200–300 m) horizontal deposition holes. The distance between holes is 25–40 m. The canisters containing spent fuel are embedded in bentonite buffer inside perforated steel supercontainers, which are emplaced in the holes with proper spacing between successive supercontainers. The design has been described in detail by Thorsager and Lingren, 2004. The quantities of steel are moderate, but the gas (H_2) production rates are significant because of the large exposed surface areas. Complete conversion of Fe(0) to oxidized Fe^{2+}/Fe^{3+} species may occur within a few thousands of years. The corrosion process and generated quantities of hydrogen gas have been described by Johnson et al. (2005).

The generation of gases results in a pressure build-up, which is mitigated by gas dissolution, gas diffusion, gas-induced porewater displacement and transport of gas from the hole surface into the surrounding host rock. The transport can take place via fractures in the host rock or excavation-damaged zone (EDZ) to more permeable conductive features in the bedrock (Johnson et al., 2005). If the rock in the vicinity of the corroding material is impermeable, it is likely that the transport of gas will occur via the EDZ to more permeable geological features. The results presented by Johnson et al. (2005) indicate that the volume

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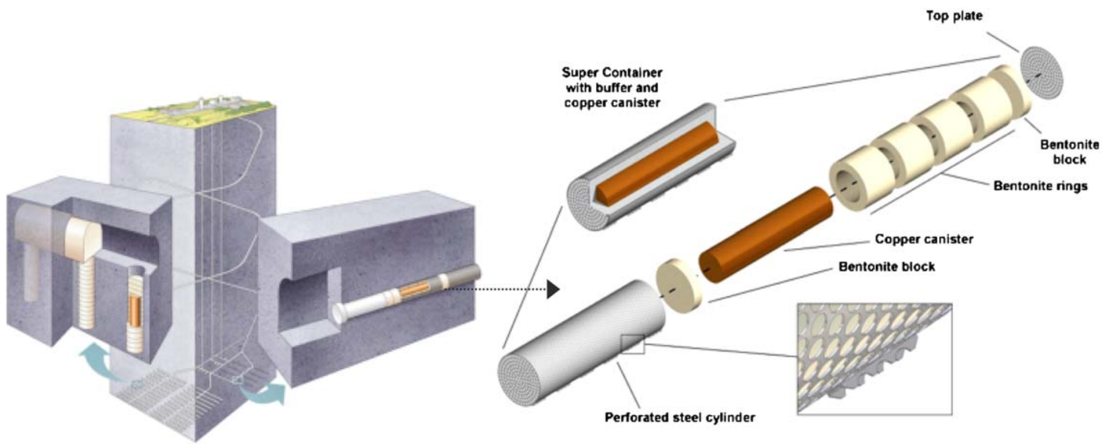

Fig. 1. Principle of KBS-3V and H repository concepts (left) and steel supercontainer in KBS-3H concept (right).

of generated gas is more than one order of magnitude larger than the capacity of gas dissolution and storage.

2. Conceptual model and mathematical formulation

Based on current understanding of the geological situation at the Olkiluoto site in Finland, a simplified model of gas pressure evolution and migration of corrosion gases in the disposal system was developed (Johnson et al., 2005). The conceptual model includes gas generation, pressure build-up, pore water displacement, dissolution and diffusion of gas in the aqueous phase, capillary leakage within fractures in the host rock, formation of gas pathways along the deposition holes and gas breakthrough to major geological features of enhanced transmissivity (see Fig. 2) as described in detail by Johnson et al. (2005). In the model, gas leakage is assumed to occur within the fracture network in the host rock and in the EDZ when the corrosion gas pressure exceeds the sum of formation pore pressure and gas entry pressure. The latter is calculated using measured properties of microfracturing in the EDZ.

The mathematical formulation is based on the mass balance for gas contained in one canister section, presented in Eq. (1). The gas leakage rate through the EDZ is presented in Eq. (2). It is calculated based on the assumption of Darcy flow of a compressible fluid (gas) in a homogeneous porous medium (EDZ). The rate determining parameters are the gas permeability and the gas entry pressure of the

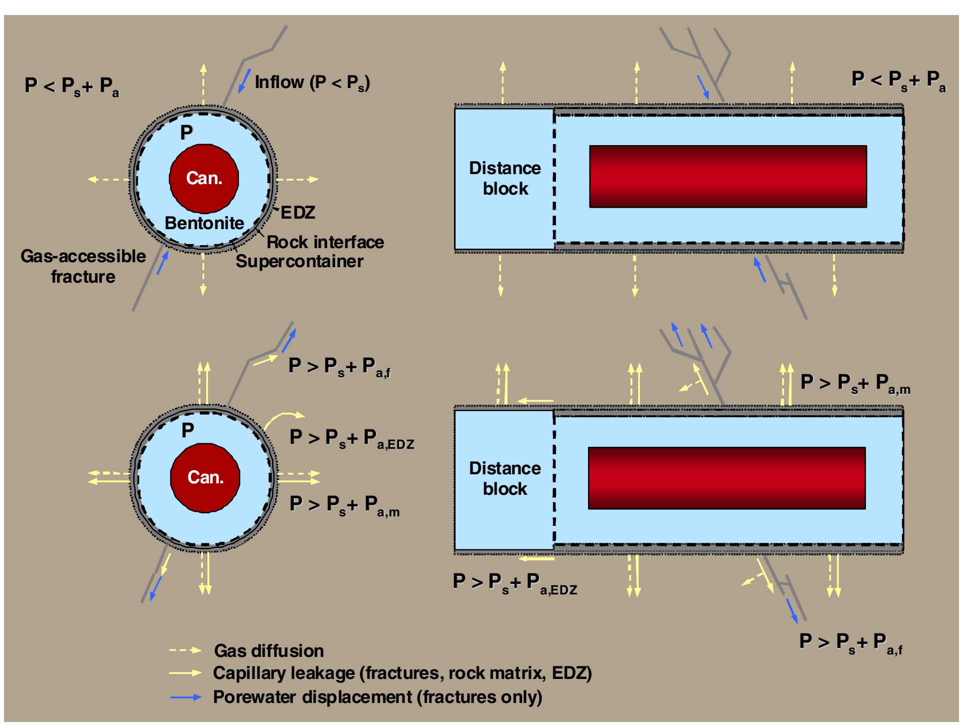

Fig. 2. Different gas transport routes and repository domains.