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APPLICATION OF GEOTHER/VT4 TO ASSESS GROUNDWATER TRANSIENTS IN A HIGH LEVEL RADIOACTIVE WASTE REPOSITORY

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ABSTRACT

The GEOTHER/VT4 code has been developed at the Pacific Northwest Laboratory in support of Basalt Waste Isolation Project (BWIP) effort. This code is based on the GEOTHER code[1] but has been modified and improved to make it suitable for the high level radioactive waste (HLW) repository applications. The objective of this work is to assess groundwater flow coupled with nuclear heating effects in the HLW waste package and its surroundings using GEOTHER/VT4. The waste package is an engineered barrier used to isolate HLW from the accessible environment. The groundwater and thermal conditions are important for decision-making on waste package container corrosion, and packing material swelling, and for evaluation of the near-field geochemical conditions. The container corrosion and packing material swelling behavior is very different between a steam and water environment.

The GEOTHER/VT4 code(2) is a three-dimensional, two-phase groundwater simulation code. It solves the mass, momentum, and energy equations for vapor and liquid water and a heat conduction equation for porous/nonporous materials, such as waste container and host rock. The governing equations for water are reduced to two nonlinear partial differential equations (PDE's) in which the dependent variables are fluid pressure and enthalpy. The velocity terms are replaced in favor of pressures through Darcy's law. The PDE's are approximated by finite-differencing using a fully implicit scheme solved by the Newton-Raphson iteration method. The solution is based on the slice successive overrelaxation method, as in the GEOTHER code, employing a direct matrix inversion in the x-z plane for each iteration for the y-direction.

The water thermodynamic properties functions developed by Electric Power Research Institute(3) are used in the code. The properties are valid in the range of pressures from 700 to 4×10^7 Pa and specific enthalpies from approximately 5×10^5 to 4×10^6 J/kg.

The code has been applied to a two-dimensional single waste package container simulation to predict the steam formation. In this simulation, the waste packages are assumed to be situated in the Cohassett geological flow of the BWIP site bounded by the flow top and flow bottom. The pressures are assumed to be invariant at the flow top and bottom after the container emplacement. Because of the two-dimensional simplification, the containers are modeled as heat slabs.

The preliminary calculation indicates that the maximum steam formation occurs at about 10 years after waste package emplacement. The steam zone extends about 2 m above and below the waste package surface, and about 2.5 m on the side of the container. The two-phase (steam-liquid mixture) zone extends further into the host rock at 8 m above the container, 3 m below it, and 4.5 on the side. This is the first and only work in the HLW repository that predicted and assessed the two-phase conditions.

The average waste package temperature is initially at the ambient temperature of 52°C at the time of emplacement. It goes through a rapid heat up after backfill because of the much slower heat loss through the backfill and host rock. As time increases, the heat generation rate due to radioactive decay becomes less than the heat loss rate immediately adjacent to the containers and the container temperature starts to decrease gradually.

It should be noted that the above predictions are preliminary in nature and the refinement of the analysis is continuing. However, the code does demonstrate its capability for serving its mission.

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