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THERMAL ASPECTS OF WASTE EMPLACEMENT IN LAYERED TUFFS, B. M. Bulmer and A. R. Lappin, Sandia Laboratories, Albuquerque, NM 87185

An analysis of the thermal response of layered tuffs occurring at Yucca Mountain, Nevada Test Site, to the emplacement of heat-producing nuclear wastes has been completed. This modeling study represents the early stages of methodology development aimed at investigating the suitability of tuffs as a geologic waste disposal medium. The objectives of this study are:

1. To develop rationale for determination of acceptable power densities of $UO_2$ spent fuel and processed high-level waste in tuff.
2. To investigate effects of several parameters on acceptable power densities determined by a defined criterion. These parameters include in-situ boiling temperature, local geothermal heat flux, location of the heat-producing zone relative to a marked stratigraphic discontinuity (characterized by a significant difference in thermal conductivity), and uncertainties in assigned material properties of the tuff.

The multi-layered stratigraphy considered here is based on a 10-layer generalization of lithologic logs of the Yucca Mountain hole (Ue25A#1). Of particular interest is the presence of a marked discontinuity in stratigraphy at 711 m depth, which separates the partially welded Bullfrog Member of the Crater Flat Tuff from the overlying Prow Pass Member. The Bullfrog tuff is assumed to be the desired burial zone, since the thermal conductivity of nonwelded tuffs is assumed to be unacceptably low to serve as a repository medium. Thermal properties for the initial phases of this study were estimated from limited data and include the effects of porosity and water saturation. More recently, laboratory measurements of core samples from hole Ue25A#1 have been incorporated into the analyses as available.

Geometrical limitations in thermal modeling are an important consideration. The present study centers only on the far-field repository scale. For both one-dimensional and two-dimensional global calculations, the waste is treated as a uniform heat source, i.e., "smeared" evenly throughout a heat-producing zone. As a result, no intrarepository details can be inferred from these calculations; efforts to define the thermal field within the respository horizon will rely heavily on three-dimensional codes.

Various assumptions concerning in-situ boiling behavior and its effects on thermal properties are discussed. A particular boiling criterion determines the maximum power density above which the temperature effects of water volatization and of liquid and vapor transport outside the immediate heat-producing zone must be considered. The criterion as used here implies that boiling very near the waste horizon (i.e., within approximately 10 m of the waste itself) is acceptable. Note that any criterion of acceptable power densities based upon boiling is very sensitive to in-situ fluid pressures, which are largely unknown at depth and are a function of in-situ hydrostatic head and the liquid and steam permeabilities of the rock.

Insofar as boiling limits the applicability of "nominal" thermal properties, three in-situ boiling criteria are examined. The bounding minimum criterion is atmospheric boiling, in which the surrounding rocks are considered to be sufficiently permeable to avoid any volatile over-pressuring; it is implied that the repository is located above the water table. At the other extreme, boiling is assumed to be limited by the lithostatic load (i.e., fluid and solid confining pressures are the same), where the tuffs are totally impermeable and have no tensile strength. This assumption is applicable both above and below the water table. An intermediate criterion is defined by the local hydrostatic head, in which boiling is controlled by the potential height of standing water between the disposal horizon and the local water table (i.e., "fissure equilibrium" is assumed).

Heat transfer analyses considering the layered stratigraphy indicate minimum rock thicknesses required to minimize stratigraphic effects on peak rock temperatures occurring on either side of the repository. Calculated minimum thicknesses are approximately 145 m for HLW and 195 m for spent fuel; these do not appear to be a function of initial power density, but do depend upon the waste decay half-life.

It was determined that a unique burial depth relative to the stratigraphic interface at 711 m exists for each waste form, at which temperatures are predicted to be at a minimum. This circumstance is due to the fact that lower temperatures resulting from increased distance from the interface are eventually offset by the increasing ambient temperatures resulting from the local geothermal gradient.

Since constant thermal properties were assumed, the occurrence of boiling represents a limit of validity in the present calculations. No boiling is predicted for any burial depth with power densities up to 150 kW/acre, assuming that boiling is controlled by the lithostatic pressure, whereas extensive boiling for all burial depths will result for any thermal loading of practical interest should volatilization occur at atmospheric pressure. Results derived using the assumption that the hydrostatic head potential controls boiling are shown below. This boiling criterion leads to a fairly complex interplay of depth of burial, geothermal flux, permissible power density (to avoid boiling), and waste form. Note that the geothermal flux measured within Nevada generally varies between 1 and 3 $\mu cal/cm^2s$; for Yucca Mountain in particular, the measured flux is reported at 1.6 $\mu cal/cm^2s$.

Based on an arbitrary criterion that the acceptable power density is limited by the occurrence of boiling at a distance of about 10 m from individual waste canisters, allowable densities range from less than 50 kW/acre for both HLW and $UO_2$ spent fuel for boiling near 100°C, to greater than 150 kW/acre at all depths considered if boiling is controlled by the lithostatic load. Using an intermediate assumption that boiling is controlled by the hydrostatic head, allowable power densities: (1) are a linear function of geothermal heat flux, (2) depend on the depth of burial only slightly, except at distances of 50 m or less from a stratigraphic discontinuity across which there is a significant difference in thermal conductivity, and (3) range from near 100 to greater than 150 kW/acre, depending upon distance to the interface, total burial depth, geothermal heat flux and waste form.

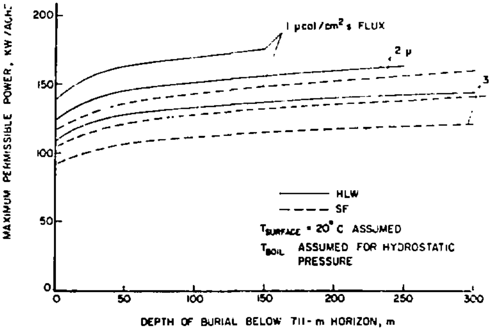

FIGURE 1. Allowable power densities in layered tuffs.

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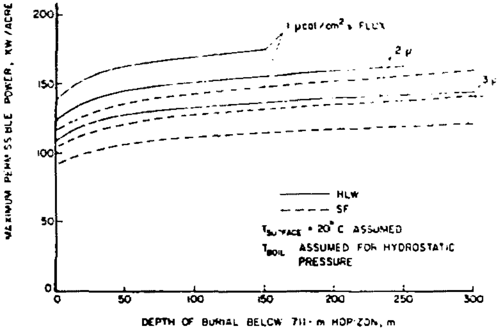

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