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STATUS OF THERMAL LOADING EVALUATIONS FOR A POTENTIAL REPOSITORY

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INTRODUCTION

The effect that thermal loading has on the natural and engineered systems needs to be understood and demonstrated with reasonable assurance in the Viability Assessment and the License Application process for a potential underground high level waste repository at Yucca Mountain. Thermal loading can be defined in a number of ways but it basically is the amount of decay heat from the spent nuclear fuel produced per unit area and is related to the emplacement density of fuel. This paper provides an overview of the status of the development of the technical basis for a thermal loading decision for a potential repository at Yucca Mountain and emphasizes recent analyses conducted.

BACKGROUND

The Site Characterization Plan (SCP) (DOE, 1988) proposed an areal power density (APD) of spent nuclear fuel in the potential repository of about 14 W/m^2 (57 kW/acre) (although in a local area of an emplacement panel APDs as high as 17 W/m^2 were possible) which allowed for emplacement operations and retrieval. Additionally, the SCP recognized that heating could impact both the natural and engineered barriers and placed "should not exceed" thermal goals on the system. The thermal goals have been reevaluated (M&O, 1993) with a few changes to include a wall temperature goal for emplacement in drift, added a goal to protect the Paintbrush Tuff member, provided for stricter limits of surface temperature change of ≤2°C, and deleted a couple of goals. The thermal goals still emphasize protection of the natural barriers from high heating.

A thermal loading system study was conducted in 1993 with the objective of evaluating a range of thermal loading options and to narrow that range if possible. The evaluations recommended that the range of thermal loading be narrowed to areal mass loadings (AML) less than or equal to 24.7 kgU/m^2 (100 MTU/acre) since above this essentially all thermal goals were violated (Saterlie and Thomson, 1994). Since postclosure performance is primarily related to AML (Buscheck, Nitao, and Saterlie, 1994), most work now describes thermal loading in terms of AML rather than APD which changes with fuel type and time.

A proposed thermal strategy was developed during 1995 with the objective of focusing program activities where possible. The proposed strategy is to "focus current design activities on a reference design thermal load that will permit emplacement of at least the statutory maximum within the primary repository area" (M&O, 1995). The strategy recommended focusing design in the AML range of 19.8 to 24.7 kgU/m^2. Additionally, "as a working hypothesis, the strategy will maintain prudent levels of flexibility by including alternative areal mass loadings."

RESULTS

Planning has been initiated (DOE, 1995) and is in the process of being revised (Statton, 1995) to develop a thermal test program which will combine laboratory testing, in-situ thermal tests, and natural analog studies with analytic modeling to develop the necessary information for the Program. A Thermal Loading Study, with the objective of performing sensitivity studies which would provide recommendations to the testing program to help focus the planning, was completed in 1995 (Saterlie, et. al., 1996). Study findings of parameters and/or issues where variations produced significant changes in temperature or water concentrations were the following:

- Bulk permeability should be measured during testing and the presence and extent of heat pipes may possibly be used as diagnostics.

- The temperature, duration of boiling, and relative humidity of the waste package environment are not very dependent on the choice of such rock matrix properties as liquid saturation and porosity but show a sensitivity to capillary suction pressure and measurements need to be taken to estimate this.

- Three-dimensional site scale predictions indicate that the Ghost Dance and Solitario Canyon Faults may provide major pathways for transport of gas and heat which could reduce duration of boiling and temperatures. Thus, in-situ measurements of rock properties around faults are needed.

- Enhanced binary gas-phase diffusion may modestly increase the overall cooling of the repository. Limited investigation of binary gas-phase diffusion is probably warranted for high thermal loadings.

- Calculations relying on borehole samples and geostatistical models determined 20 to 30°C temperature differences could be caused by spatial variations in conductivity and/or heterogeneity in material properties.

- Using separate fracture and matrix permeabilities rather than a single bulk permeability was found to have an impact on the temperature predictions and thus measurements of matrix and fracture properties are needed.

- At high thermal loadings, dehydration of zeolytes such as clinoptilolite in members like Calico Hills can produce significant quantities of mobilized water based on laboratory measurements of heated core samples. The porosity in Calico Hills was found to increase as well at high thermal loads due to irreversible crystallization of clinoptilolite to analcime. These results should be considered in the next Total System Performance Assessment (TSPA) and in-situ testing in Calico Hills may be warranted for high thermal loadings.

- Overburden depth (200 to 400 m in the Primary Area) can be important at high AMLs since the shallower depths cool faster. This effect should be considered in TSPA and performance confirmation testing.

- Thermomechanical calculations showed potential drift stability problems between 20.5 and 27.4 kgU/m^2 (83 to 111 MTU/acre) so heating to at least 200°C rock temperatures should be done.

- Based on an examination of scaling, a stochastic approach was recommended and measurements at various scales should be carefully evaluated to establish validity of scaling.

- Laboratory studies of core samples were used to evaluate optional expansion areas. The study concluded that Optional Area D (just west of Solitario Canyon) and the area south of the Primary Area, at least as far south as drill hole G/GU-3, appear to have stratigraphic features, thicknesses, and mineralogic characteristics which fall within the range of parameters that exists in the Primary Area. As such, these areas may be relatively easily characterized. Optional Area C (to the west of D) may be significantly different from the Primary Area and could be harder to characterize.

CONCLUSIONS

Future efforts, including design activities, will require input from systems analyses and a TSPA which relies on measurements and validated models. Thermal test planning should be completed and it is recommended that results of such emerging studies as the 1995 Thermal Loading Study be incorporated in this planning. Where possible, flexibility should be maintained to mitigate risk until sufficient information is available to make a thermal loading decision which will be a key aspect of a Viability Assessment and the License Application.

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