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REPOSITORY THERMAL LOADING FOR TSPA-VA CALCULATIONS

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Introduction

The characteristics of repository thermal loading are described for both drift- and mountain-scale thermal-hydrologic models currently being used in support of the Total System Performance Assessments-Viability Assessment (TSPA-VA) calculations. The differences in the thermal loading requirements for each model type are considered.

The drift-scale thermal-hydrologic models require heat decay information for specific waste package (WP) and fuel assembly types. Drift-scale models include a discrete representation of individual (and different) waste package types placed in the model domain. This may include various age commercial fuels from pressurized water reactors (PWR) as well as boiling water reactors (BWR). The individual types include 21 PWR , 12 PWR, 44 BWR, and 24 BWR waste packages. The number identifier indicates the quantity of fuel assemblies occurring within a waste package. Each of the waste package types make up a specific (known) percentage of the total waste packages in the potential repository (CDA, 1997). The total repository mass for the commercial waste is 63,000 metric tons of uranium MTU (CDA, 1997). The total mass emplaced has associated with it a total number of fuel assemblies with each category of assemblies possessing distinctive heat decay characteristics. In addition to the commercial waste, individual heat decay data are required for the co-disposal and direct disposal waste packages. It is assumed that the co-disposal waste package contains five defense high level waste (DHLW) glass logs and one canister of DOE spent nuclear fuel (DOE SNF) while the direct-disposal waste package contains varying numbers of DOE SNF canisters. The total mass emplaced of non-commercial wastes in the potential repository is approximately 7,000 MTU (CDA, 1997). The DHLW accounts for approximately 4,667 MTU and the DOE SNF accounts for 2,333 MTU. The non-commercial containers make up about 25% of the total waste packages in the potential repository.

The mountain-scale models require information related to the average thermal load for all of the wastes emplaced at Yucca Mountain. This model incorporates a smeared source of heat based on average fuel characteristics. Knowledge of the approximate total number of assemblies of each fuel type (commercial and non-commercial) are used to determine the average repository thermal load. Therefore, the total (averaged) thermal load includes contributions from all of the PWR and BWR assemblies (M&O, 1997a). It also includes a component representative of the total number of DHLW glass assemblies expected to be emplaced in the potential repository. Finally, it includes a component representing the total number of assemblies of DOE SNF (N-Reactor fuel) expected to be placed into the potential repository.

This paper describes the methods used to compute the initial areal power density for the mountain-scale models and a discussion of the selection of a representative drift segment for the drift-scale models.

Calculation of the Repository Area

The initial thermal load is based on the areal extent of the repository. For an 85 MTU/acre repository with 63,000 MTU of commercial waste (M&O, 1997b), the repository area, A_{rep}, is:

$$A_{rep} = \frac{63{,}000\,MTU}{85\,\dfrac{MTU}{acre}} = 741.2\ acre \qquad (1)$$

The areal mass loading of 85 MTU/acre includes only the commercial waste. Therefore, the non-commercial wastes (direct- and co-disposal) will be placed in-between commercial waste packages such that they do not maintain their own space in the potential repository or the mass loading calculation.

They are placed in the spaces already allocated for the commercial waste packages. However, the heat output of the non-commercial wastes *are* included in the drift-scale model formulations as well as in the average repository thermal load for the mountain-scale models.

Calculation of the Potential Repository Thermal Load

The thermal load, *TL*, for the total repository is computed as the following:

$$TL = \frac{Q}{A_{rep}} \qquad (kW/acre) \qquad (2)$$

where Q is the total (average) heat output of all repository wastes at the time of waste emplacement ($t = 0$). The thermal load is obtained as follows (M&O, 1997a; CDA, 1997; personal communication, 1997[1]):

$$TL = \frac{73{,}668.93\,kW}{741.2\,ac} = 99.4\,\frac{kW}{acre} \qquad (3)$$

where the total Q in kW contains the heat output from 8314 assemblies of DHLW glass, 433 assemblies of DOE SNF N-Reactor fuel, 94,847 PWR assemblies, and 124,269 BWR assemblies. The total heat output is based on the average characteristics of each individual fuel type multiplied by the total number of assemblies. It is assumed in equation (3) that the DHLW glass waste is emplaced without aging (M&O, 1997a). Equation (3) also assumes that the total heat output of the other forms of DOE SNF is small in comparison to the total heat output associated with the N-Reactor fuel component. This is assumed to be reasonable since the N-Reactor fuel makes up approximately 90% of the 2,333 MTU of DOE SNF emplaced in the repository. The repository heat output (given in kW) is given for times (out to approximately 1,000,000 years) in Figure 1. Figure 1 is to be used for the total heat output of the repository when performing mountain-scale calculations that treat the thermal load of the potential repository as a smeared thermal load simultaneously emplaced.

Drift-Scale Models

Drift-scale thermal-hydrologic models require more specific waste package heat loading data than the mountain-scale models. Heat decay curves for individual waste package types are required for the discrete waste package models. The 3-D drift-scale models use a discrete number of waste packages in the modeled domain in order to approximate the entire distribution of waste packages of a particular type (e.g., 21 PWR) in the entire repository. An approximate description of an emplacement drift segment is given as the following. It contains a balanced number of waste packages of specific types expected to be placed in the potential repository. It matches, on a percentage basis, the repository emplacement of each of the waste package types. Based on CDA values for expected numbers of waste packages, a seven waste package drift segment nearly approximates the appropriate percentage emplacement of the entire repository. A seven waste-package model contains three 21 PWRs, two 44 BWRs, one-half 12 PWR, one co-disposal (contains 5 DHLW glass logs and 1 zero heat output DOE SNF canister), and one-half direct-disposal waste package containing 4 canisters of N-Reactor DOE SNF. The individual waste package selection process is performed for the drift-scale models such that the average thermal load of the repository is maintained at the time of waste emplacement of this discrete drift section. The initial thermal load for the seven discrete waste package model (3-D drift-scale model) is approximately 99.89 kW/acre, only slightly larger than the average thermal load applied in the mountain-scale simulations. The difference is a result of the discrete nature of the drift-scale model containing only a small portion (i.e., 7 WPs) of the total amount (i.e., over 10,000) of waste packages in the potential repository.

Conclusions

The average repository thermal load is dependent on the waste stream and other characteristics of the fuel such as age, enrichment, burnup, numbers of assemblies, and fuel type. Previous mountain-scale thermal-hydrologic studies have assumed a 1 MTU $\cong$ 1 kW conversion factor to transition from mass loading in MTU/acre to areal power density in kW/acre. As can be seen from equation (3) and the established working mass loading of 85 MTU/acre, this assumption will result in a total repository thermal load

[1] personal communication with Chris Stockman and Ron McCurly, INEEL modeling information and heat decay data for the N-Reactor fuel data, September 1997.

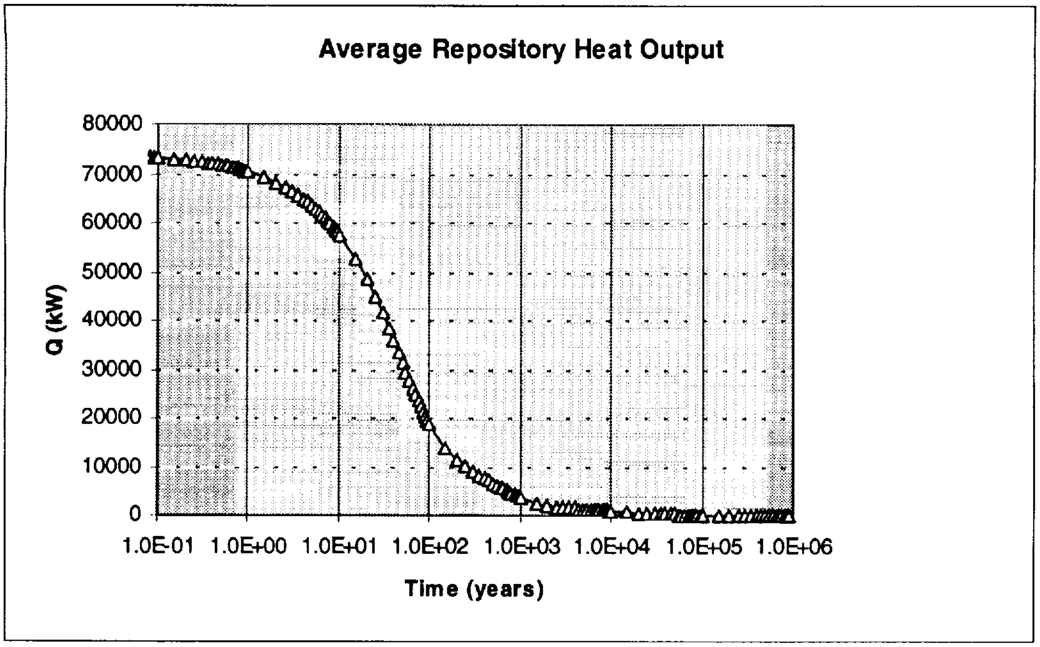

Figure 1. Total Repository Heat Output Based on Average Characteristics of Individual Fuels Types

considerably lower than the base case value established for this reference waste stream and associated fuel characteristics. The initial thermal load is a function of the power output of all wastes emplaced divided by the total emplacement area. Therefore, if mountain-scale calculations are being performed in support of TSPA-VA, the applied repository thermal load should be 99.4 kW/acre with the decay characteristics given in Figure 1.

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