# Conceptual Study on Thermal Analysis for Disposal System of Spent Nuclear Fuel


Seunghyun Kim*, Jeonghwan Lee, and Jeonghyoun Yoon

Korea Radioactive Waste Agency, 168 Gajeong-ro, Yuseong-gu, Daejeon 34129, Republic of Korea

*shkim@korad.or.kr


## 1. Introduction

One of the basic options in spent nuclear fuel management is a geological repository. Many phenomena and processes have to be understood when considering the safety of the engineering barrier system (EBS) of the spent nuclear fuel repository. In a conceptual design the repository is in the depth of 500 m. the maximum temperature in a canister is limited to the design temperature of 100 °C. Due to uncertainties in thermal analysis parameters and natural variation in thermal analysis parameters the allowable calculated maximum canister temperature is set to 90°C causing a safety margin of 10 °C [1]. A single canister causes a maximum temperature of 75 ~ 90°C in the heat generating canister depending on the decay heat power. Fig. 1 shows the dimensions and layout of the disposal hole and backfill from the SKB. In this study, thermal analysis results for the KBS-3(V) type are verified and based on this model, the results of the thermal analysis for determining the interval of the disposal space to minimize the area of the Korean HLW repository system. The spacing between disposal holes is one of the important factors in minimizing the disposal area. Therefore, the result of thermal analysis over time is an important parameter to determine the spacing between disposal holes. For this, Numerical thermal heat analysis was performed by finite element method (FEM). The present paper briefly describes the thermal analysis of steady state and transient analysis of spent nuclear fuel canister are also presented in this results.

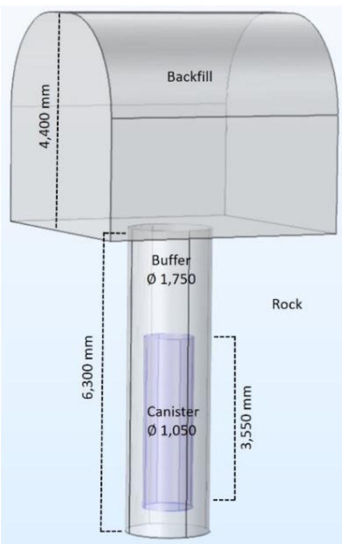


Fig.1. Dimensions of disposal hole and backfill of SKB.

## 2. Governing equations and boundary conditions

### *2.1 Governing equations, Heat transport*

Heat transport by conduction must be included in the model, because in many cases there is a heat source of some kind in the system. The temperature field, T(x, t) obeys the equations. All other outer boundaries are perfectly insulated. The convective and conductive heat transfer inside the canister is described by the following equation.

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (-k\nabla T) = -\rho C_p u \cdot \nabla T + Q \quad (1)$$

where $C_p$ denote the heat capacity (J/(kg·K)), $k$ is the thermal conductivity (W/(m·k)), and Q refers to the power density (W/m$^3$) in the canister that serves as a heat source.

### *2.2 Boundary conditions*

The container is emplaced vertically in boreholes drilled into the emplacement gallery floor and surrounded by buffer. The copper container is represented as a in order to ensure no-flux boundary conditions at the container wall. Table 1. Summarizes thermos-mechanical properties of solid materials used in the analysis [3]. At the inner surfaces of canister, radiation is descrived by surface-to-surface radiastion. This mean that the mutual irradiation from the surfaces that can be seen from a particular surface an radiation to the surroundings are accounted for. At the outer surfaces, radiation is described by surface-to-ambient radiation, which means that there is no reflected radiation from the surroudings. The canister was assumed to be homogeneous with uniform power generation over its volume and the contents of it was not modelled in detail.

Table 1. Thermo-mechanical properties used in the analysis [3]

| Parameters | Values | Unit |
|---|---|---|
| Canister conductivity | 390 | W/m/K |
| Buffer conductivity | 1.0 | W/m/K |
| Canister volumetric capacity | 2.4 | $MJ/m^3/K$ |
| Buffer volumetric capacity | 2.2 | $MJ/m^3/K$ |
| Rock conductivity at 60 °C | 2.61 | W/m/K |
| Rock volumetric capacity | 2.15 | $MJ/m^3/K$ |

## 3. Results and discussion

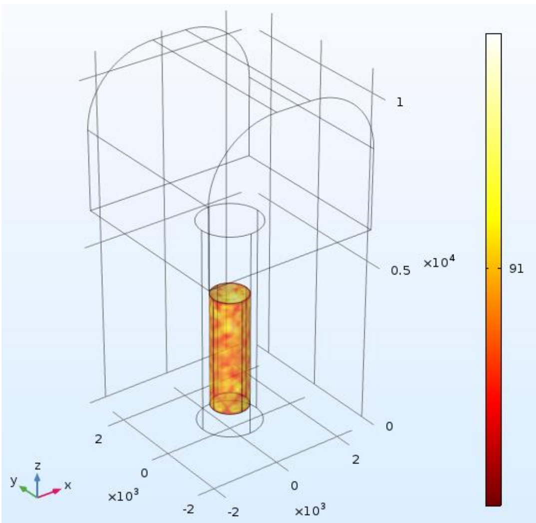

Fig. 2. 3D Temperature profile of canister after 10 years.

Temperature dependence of the conductivity of air, rock, canister material and volumetric heat capacity as shown in Table 1 were applied. Fig. 2 indicate that temperature distribution of bore hole after 10 years operation in the vertical type of canister. The temperature profile is unsymmetrical with the vertical plane of the canister. Thus different height of the buffer above and below the canister and the different conductivity of the backfill tunnel material have minor effect.

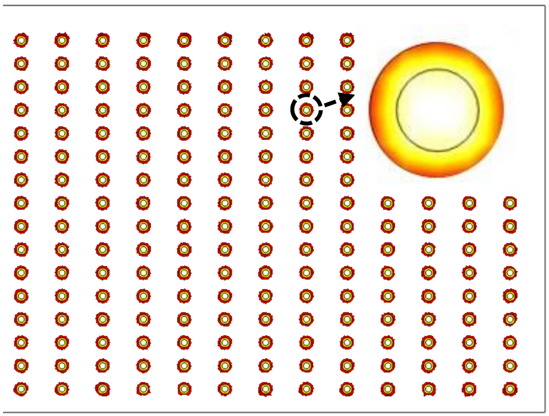
Fig. 3. Temperature distribution of one panel after 20 years operation in the vertical plane. And zoomed temperature profile around canister.

Fig. 3 show the temperature profile after 20 years, when the highest temperature of 92.8°C is encountered and canister spacing is 7 m. Since the copper shell has very high thermal conductivity (390 W/m/K) causing nearly uniform temperature distribution on the outer surface of the canister.

## 4. Conclusion and further studies

The heat source model may thus estimate successfully the temperature of the canister, where the highest temperature is encountered. The numerically and analytically calculated temperature profile histories on the disposal area is an important results, since it proves that the analytic solution using effective design for disposal hole. For more robust representation of the repository, processes such as time dependent defect size, corrosion, water flow and transport of radionuclides from used nuclear fuel and multiple nearby defective containers can be examined in more detail.

## REFERENCES


[1] Koari lkonen, "Thermal analysis of spent nuclear fuel repositoty", POSIVA 2003.

[2] Markus Olin, Merja Tanhua-Tyrkko, Veli-Matti Pulkkanen,"Thermo-Hydro-Mechanical-Chemical (THMC) Modeling of the Bentonite Barriers in Final Disposal of High Level Nuclear Waste", COMSOL Conference, 2008, Hannover.

[3] Agelskog L, Jansson P, "Heat propagation in and around the deep repository", Swedish nuclear fuel and waste management Co. Technical report TR-99-02. 14(1), Jan 35, 1999.