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Thermal Analyses for the Korean Reference HLW Disposal System

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1. Introduction

Since 1997, Korea Atomic Energy Research Institute(KAERI) has been developing the technology related to a deep geological disposal as a long term spent fuel management strategy. As a result, KAERI proposed a Korean Reference high level waste disposal System(KRS) which is based on the concept of a permanent disposal. Since the recent trend is considering the retrieval of spent fuels, KAERI is currently developing the A-KRS(Advanced KRS) which enables the retrieval of spent fuels and enhances the densification factors of spent fuels. Hence, the design concept of the canisters is modified by corresponding to the A-KRS.

Basically, KRS consists of an engineered barrier and a natural barrier. The main components of the engineered barrier are the canister and buffer. Since a thermal performance is directly related to diverse aspects of the KRS, it should meet the requirement that the maximum temperature at the interface between the buffer and the canisters is below 100°C to maintain the physical and chemical properties of the buffer that acts as an essential barrier of the disposal system.

In this research, disposal canisters for KRS and A-KRS are used and the maximum buffer temperature is calculated by varying the disposal tunnel spacing and disposal hole pitch for thermal integrity and optimized layout of the KRS.

2. CANDU Disposal Canister

As noted above, design concept of a CANDU disposal canister is modified by corresponding to the disposal concept. Fig 1 shows a CANDU spent fuel canister that has been developed for KRS. The disposal canister being developed consists of two major components:a massive cast insert and a corrosion-resistant outer shell. Outer shell surrounds the 9 fuel storage baskets(33 CANDU fuel bundles in a storage basket) and the space between the fuel storage basket and the outer shell is carbon steel, called cast iron. Fig 2 shows a CANDU spent fuel canister that has been developed for A-KRS. Unlike the CANDU disposal canister for KRS, it surrounds the 7 fuel storage baskets(60 circular tubes for CANDU fuel). And an outer shell is composed of cast iron with a 7 cm thickness and a copper coating with a 1 cm thickness.

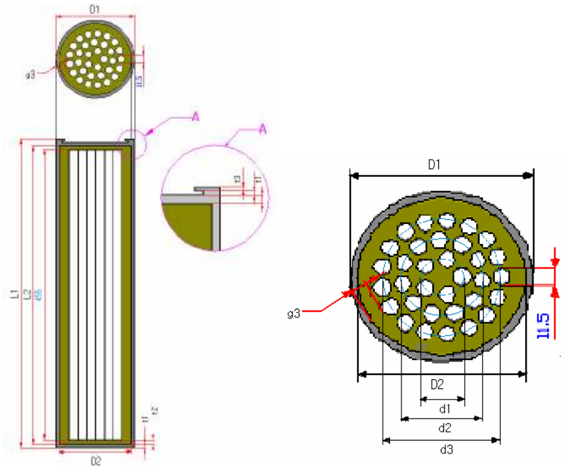

Fig. 1. Schematic diagram of the CANDU disposal canister for KRS

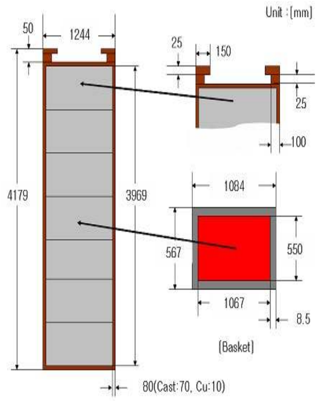

Fig 2. Schematic diagram of the CANDU disposal canister for A-KRS

3. Thermal Analyses for a CANDU spent fuel disposal canisters

3.1 Initial Boundary conditions for thermal analyses

At first, decay heat emitted from CANDU spent fuels is derived using ORIGEN-ARP by assuming the cooling times for CANDU spent fuels are 40 years. ORIGEN-ARP used in this research is a sequence of SCALE systems to perform point-depletion calculations with the ORIGEN-S using point-dependent cross section. Decay heat from CANDU spent fuel is treated as an important parameter for the thermal analyses. For the thermal analyses, NISA program which is a general purpose finite element analysis developed by Engineering Mechanics Research Corporation(EMRC) of the United States is used.

The top and bottom boundary conditions used to calculate the temperature profile were set at ground level and 1,000 m below ground level, respectively. It was assumed that the surface temperature is maintained at 15°C and increases by 3°C every 100 m in depth as an initial boundary condition. And the reference tunnel length and the tunnel pitch are considered as 40 m and 4 m, respectively.

3.2 Calculation Results

Thermal Analyses for 2 different types of disposal canisters are performed with a reference disposal tunnel spacing length and tunnel hole pith as 40 m and 4 m, respectively. Each canister satisfied the thermal criteria suggested above. With the A-KRS CANDU canister, a case with 40 m and 4 m for the tunnel spacing length and tunnel hole pitch showed a maximum buffer temperature as 88.9°C at 31 years and the other case showed 76°C at 18 years. And with the KRS CANDU canister, a case with 40m and 4m for the tunnel spacing length and tunnel hole pitch showed a maximum buffer temperature as 80.66°C at 60 years and the other case for A-KRS showed 61.08°C at 20 years. The buffer temperature for each case is shown in Fig 3 and Fig 4.

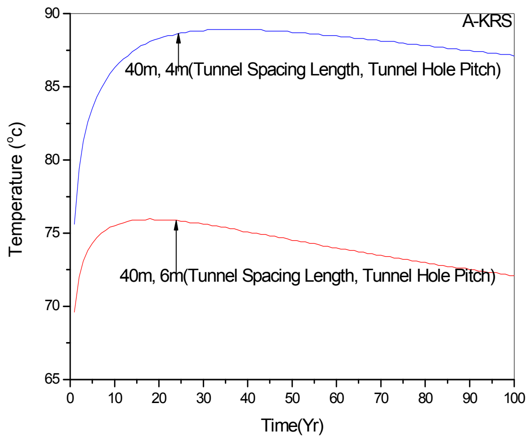

Fig 3. Buffer temperature with the A-KRS CANDU canister

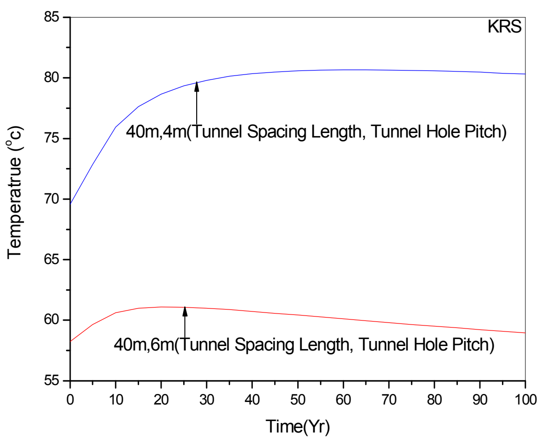

Fig 4. Buffer temperature with the KRS CANDU canister

Since the A-KRS CANDU canister is a modified disposal canister for enhancing the densification factor, thermal analyses for additional cases of A-KRS are performed. Currently, KRS concept considers disposing of CANDU spent fuels at a depth of 500 m. However, there may be a requirement for an additional repository in the future. 100 m below the reference depth is assumed in this case. Thermal analysis for the first case considers disposing the CANDU spent fuels at 500 m and 600 m each. And other case considers disposing the CANDU spent fuels at a depth of 500 m at first and disposing the additional CANDU spent fuels at a depth of 600 m 100 years after the first disposal. Like the previous thermal analyses, buffer maximum temperature is derived for each case and the reference tunnel spacing length and tunnel hole pitch is used.

Thermal analyses for the first additional case with the A-KRS CANDU canister showed a maximum buffer temperature as 82.47°C at 570 years for disposing the CANDU spent fuels at a 500 m depth and 85.45°C at 570 years at a 600 m depth. For the second additional case, a maximum buffer temperature is shown as 79.06°C at 840 years for disposing at a 500 m depth and 81.79°C at 850 years for disposing at a 600 m disposal.

4. Conclusion

Thermal analyses for the Korean Reference HLW disposal system are performed with the CANDU canister developed for disposal systems. Maximum buffer temperature calculated in this research satisfied the thermal requirement of the KRS. And additional case studies with a A-KRS CANDU canister were performed. Results from this research are expected to optimize the Korean Reference HLW disposal system and enhance the densification factor of the CANDU canister.

Acknowledgement

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