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Preliminary Thermal Analysis of a Dry Storage Canister for the PWR Spent Fuel

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1. Introduction

PWR spent fuel discharged from nuclear power stations in Korea, has been stored in temporary storage facilities in each nuclear power station. Since the temporary storage capacity is expected to be full in 2016, interim storage facilities are to be required. In Korea, it is expected that dry storage technology will be adopted as an interim storage method. To develop a dry storage facility, thermal analysis is essential and detailed information about the dry storage facility is required. However, even the type of the dry interim storage facility has not been decided yet in Korea. The objective of this study is to propose a numerical analysis method which will be able to be applied to the various types of dry storage facilities and by using the thermal analysis method, a temperature limitation of a dry storage canister is calculated preliminary.

2. Thermal Analysis Method

Most dry storage facilities are composed of two parts [1]. The analysis model is composed of two parts. One is inside of the canister (Model 1) and the other is outside of the canister (Model 2). The two models are connected at the inner surface of the canister.

2.1 The Inside of the canister (Model 1)

The canister is composed of a shell, a lid, a basket, dummy weights and heaters. In the canister, helium gas is filled. Helium is an inert gas that has good heat conductivity. Supposing that the influence of natural convection on temperature distribution is small, heat conduction analysis is adopted for this area. Taking account of the radiation effect, an equivalent value of heat conductivity is used for helium. Heat is generated in the heater part homogeneously in the model. The rod and the tube of the dummy weight are round but it is assumed that they are square which have the same area. The basket is a assembly of stainless steel hollow block. But, in the model, it is assumed that the hollow block is a stainless steel block.

2.2 Process of the thermal analysis

To analyze the thermal safely of a dry storage facility, with this thermal analysis method, and with the various conditions expected during the lifespan of the facility, such as normal operation, fire, seismic and so on, firstly, the temperature inside the canister is calculated by Model 1. From this result, a relation between the maximum PWR cladding temperature and the maximum temperature at the inner surface of the canister shell is obtained. Secondly, with the various conditions, temperature of air, cask and canister shell and velocity of air, are calculated by Model 2. Then, the maximum PWR cladding temperatures at the various conditions are calculated easily by the result of Model 1. Figure 1 shows the construction of the thermal analysis method.

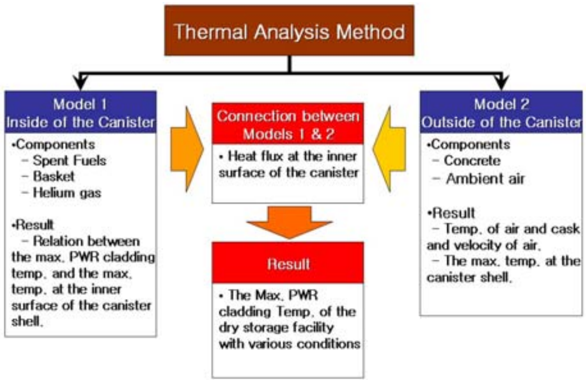

Figure 1 Construction of the thermal analysis method.

3. Preliminary Thermal Analysis of a Dry storage Canister for the PWR Spent Fuel

3.1 The PWR Spent Fuels

The Korea Standard PWR Spent Fuel, which has been proposed by KAERI [2], is considered in this study. And it is assumed that the PWR spent Fuel is cooled for 10 years. Table 1 show the specification of the Korea Standard PWR Spent Fuel.

Table 1. The Specification of the Korea Standard PWR Spent Fuel.

Item(Unit)	Dimension
Assembly Array	16*16
Enrichment (wt. %)	4.5
Assembly Area (cm^2)	21.4 * 21.4
Length(mm)	453
Burn-up(GWD/MTU)	55
Decay Heat per Assembly Cooled for 10 years (W)	938.8

3.2 Dry storage canister

The dry storage canister model is based on the commercial canister, which is made by Holtec Inc. Figure 2 shows the models 24-PWR and 32-PWR.

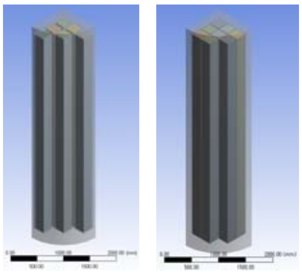

Figure 2. Models 24-PWR and 32-PWR

In this study, the two canisters are considered. The total heat fluxes are 22.5 kW and 30.04 kW, respectively.

3.3 Boundary Condition

Concerning the boundary condition of the inner wall of the canister, fixed temperature (400 K, 500 K, 600 K, 700K and 800 K) conditions are applied to the wall except for the symmetrical plane.

3.4 Calculation and Result

According to the ISG-11(Cladding Consideration for the Transportation and Storage of Spent Fuel, Interim Staff Guidance-11, Revision 3) and NUREG-1567(Standard Review Plan for Spent Fuel Dry Storage Facilities), the temperature limits of the PWR fuel cladding, within normal operating condition and accident condition, are 400 ℃ and 570 ℃, respectively.

This numerical calculation was performed according to the above mentioned method. The calculation is a steady state analysis. Figure 3 shows the result of this calculation.

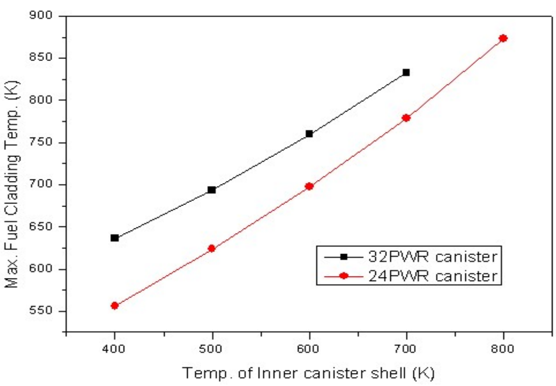

Figure 3. Result of the Calculation

The result shows that with the normal operation condition, the limit temperatures at the inner surface of the 24-PWR and 32-PWR, are 293℃ and 191℃, and with the accident condition, the limit temperatures at the inner surface of the 24-PWR and 32-PWR, are 494℃ and 440℃, respectively.

3. Conclusions

For the thermal evaluation of a dry storage facility, the calculation method was developed and proposed. The model consists of two parts. One is inside of canister (Model 1) and another is outside of canister (Model 2). Model 1 is based on a heat conduction analysis, and Model 2 is based on a thermal hydraulic analysis. By using the above thermal analysis method, preliminary thermal analysis was performed. The analysis used the part 1 method (Model 1). The result shows the limit temperature at the inner surface of the canisters. The calculation results are conservative for several parts.

In this paper, the calculation only for Model 1 is described. In the near future study, the calculation for Model 2 will be performed with various conditions.

REFERENCES

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