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Thermal Analysis on the Aboveground Long-term Dry Storage Facility

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1. Introduction

Currently, it is being forecasted that the capacity of temporary storage of the spent fuel in nuclear power plants of Korea will be saturated by 2016. It will be necessary to develop interim storage facilities for long-term storage of the spent nuclear fuel and high-level wastes to be additionally generated until establishment of final treatment plant. In the process of developing the long-term dry storage facility, thermal analysis serves as an important evaluation criteria for permission and authorization process as well as in project execution. In this study, we proposed and simulated a sample thermal analysis methodology for an aboveground long-term dry storage facility.

2. Modeling and Analysis

Aboveground long-term dry storage facility is a facility built on the ground for long-term dry storage of high-level wastes. This facility uses cooling system by natural convection. Also, the outer walls of canister that wraps up wastes are cooled with air buoyancy by temperature difference from external air. Also, the canister is installed with over-pack to shield radiation. Since this facility is installed above the ground, it is affected by the amount of solar radiation and atmospheric temperature. (Fig. 1)

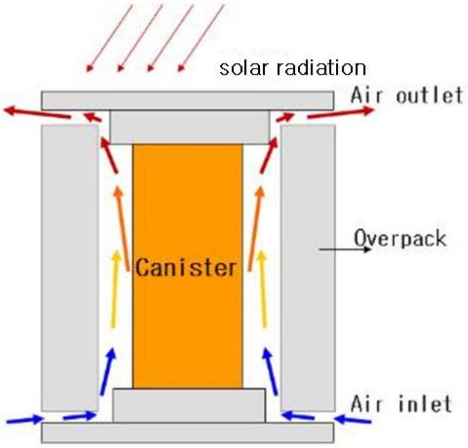

Fig. 1. Modeling of aboveground dry storage facility

2.1 Modeling of Aboveground Dry Storage Facility

The aboveground dry storage facility was modeled on the basis of HI-STORM. Analysis model was created on the basis of the commercialized long-term dry storage facility as of the above in order to supplement uncertainties in areas not discussed in this study, such as radiation shielding and structural analysis, etc.

2.2 Boundary Condition

For the aboveground long-term dry storage facility, assumptions were made for the ambient air temperature to be 40°C and amount of solar radiation to be 400W/m^2 on horizontal and vertical surfaces. As for the amount of solar radiation, the highest of data in the past 5 years was conservatively applied.
For the initial temperature of the aboveground long-term dry storage facility, it was assumed that container temperature of the above facility model was 40°C. Then, the maximum temperature on the surface of the container over 16 days was calculated. The results of this calculation indicated that there was almost no change in surface temperature of the storage container after approximately day 10. Considering that the lifespan of dry storage facility is about 20~40 years, the time of 10 days is a very small period. Therefore, the initial temperature of the aboveground long-term dry storage facility was set through thermal analysis in normal state in relation to the amount of decay heat in the initial phase.

2.3 Analysis of Facility Gap Sensitivity

The gaps of aboveground facility was divided into 1m unit up to 4~9m. Then, the maximum surface temperature of storage container and over-pack temperature were calculated.

The results of calculation indicated that temperature change in the gap of 4m or more of the long-term dry storage facility was insignificant. This is because, as shown in Fig. 2, impact of the air heated in the aboveground facility exerted on the surrounding environment was insignificant.

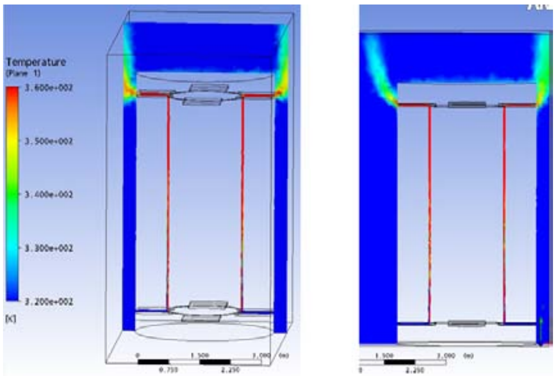

Fig. 2. Temperature distribution of external air

2.4 Analysis of Flow Path

For analysis of flow path sensitivity of the aboveground facility, we calculated temperature of the external walls of the internal storage container by expanding air inlet area in horizontal and vertical directions while maintaining the flow path inside the facility. Fig. 3 shows the analysis model of aboveground long-term dry storage facility. This facility is exposed to the atmospheric temperature of 40℃ and the internal heat source was applied with the initial decay heat amount of PWR spent fuel cooled for 10 years. In thermal analysis, effects of all types of thermal transmission, such as convection, conduction and radiation were considered.

In normal operation state, the maximum surface temperature of container was of 293℃ or less in case of 24-PWR and 191℃ in case of 32-PWR. Of the calculation results, $25 \times 70\text{cm}^2$ was found to be the smallest flow path area that could maintain normal operation state in relation to two different internal heat sources. Here, the maximum surface temperatures of 24-PWR and 32-PWR were calculated to be 159℃ and 185℃ respectively. Also, it was found that the change of maximum container temperature in relation to the horizontal width of the flow path was larger than that to the height of the flow path.

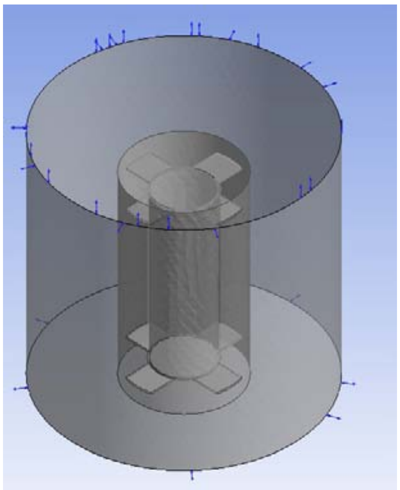

Fig. 3. Analysis model of aboveground dry storage facility

2.5 Thermal Analysis for Long-term Operation

The results of calculation indicated that the maximum container surface temperature by initial decay heat was the highest. The surface temperature of container also exponentially decreased according to the decay heat of the spent nuclear fuel. In other words, for thermal safety of aboveground facility, the most conservative values can be obtained only when analysis is administered on the basis of the initial decay heat. (Fig. 4)

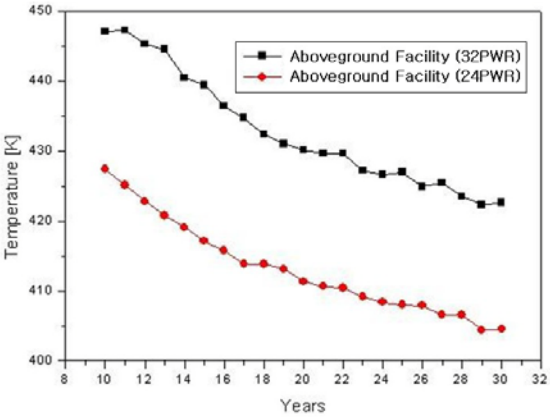

Fig. 4. Surface temperature charge of aboveground facility which follows in operation duration

3. Conclusions

In this study, we conducted analysis on thermal sensitivity of cooling flow path and facility gap sensitivity of an aboveground long-term dry storage facility prior to thermal analysis according to analysis conditions. The results of thermal sensitivity analysis of cooling flow path indicated decrease in the surface temperature of container as the air inlet area became expanded. Surface temperature of container quickly decreased when the area of air inlet was expanded in the width. However, there was no significant change in surface temperature in case of height expansion. In other words, it was found that horizontal expansion of air inlet, even of the same area, exerted greater impact on surface temperature. Also, it was observed that the inclination of surface temperature change became smaller as the area of air inlet became expanded. Therefore, in order to find the appropriate flow path, it is advantageous to calculate surface temperature of container first through horizontal expansion of air inlet. Results of facility gap sensitivity analysis indicated that it was difficult for facility gap to exert thermal impact as aboveground and underground dry storage facilities have the characteristic of discharging most of the heat as they use natural convection through air. On the contrary, it was found that the ideal way of determining facility gap was from the perspective of facility maintenance.

REFERENCES

[1] S. N. Kim, J. H. Cha, et. al, Development of the Thermal Safety Analysis Method for the Long Term Dry Storage of HLW, KINS/HR-852, KINS, 2008.

[2] J. W. Choi, H. J. Choi, et. al, Development of HLW deep geological disposal system", Technical Report, KAERI/RR-2765/2006, KAERI, 2006.