Thermal Analysis for Spent Nuclear Fuel Temporary Storage System in Pyroprocessing Facility

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1. Introduction

A temporary storage system is needed to safely store the spent nuclear fuel assemblies until the process starts after the SNF (Spent Nuclear Fuel) assemblies are brought into the pyroprocessing facility.

In this paper, thermal analysis was performed on an imaginary SNF storage vault system using the concept of cooling by using natural convection.

2. Analysis Model for Spent Nuclear Fuel Temporary Storage System

The natural convection cooling system is economical and efficient because it does not use forced convection using power. The natural convection cooling system is applied to MACSTOR (Modular Air Cooled STORage) which is interim storage facility constructed at Wolsong nuclear power plant.

In case of applying this natural convection cooling system to pyroprocessing facility as a temporary storage system, it should be designed so that the decay heat generated from the SNF is sufficiently cooled because it is necessary to maintain the temperature of SNF cladding and concrete to be lower than the limit temperature.

In this paper, thermal analysis was performed on the present SNF storage vault system to verify its cooling capability.

ANSYS CFX, a commercial computational fluid dynamics analysis tool, is used to obtain the mass flow of the inlet and outlet and MELCOR is used to obtain the cladding and concrete temperature.

The established analysis model for ANSYS CFX is shown in Fig. 1. The dimension of the present temporary storage system is shown in Table 1.

The established thermal analysis model using MELCOR are shown in Fig. 2. The heat transfer of the present SNF temporary storage system is mainly performed by the flow from the inlet to the outlet. In addition, the heat conduction to the upper space which is a hot cell with air atmosphere is considered in the present analysis model.

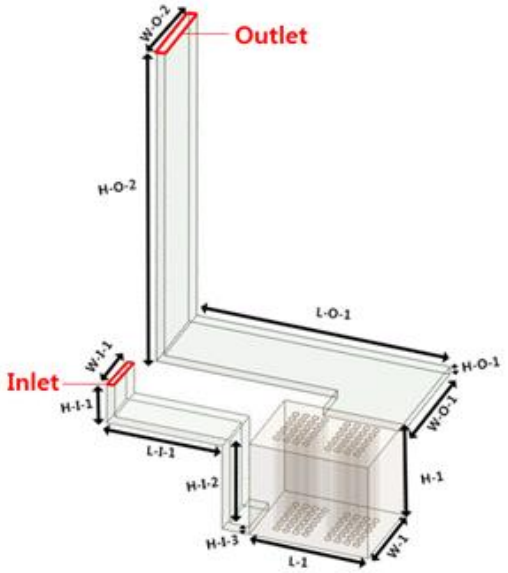

Fig. 1. Analysis domain of ANSYS CFX (flow only).

Table 1. Main dimension of the present temporary storage system

W-1(in Fig. 1)	7.4 m
L-1 (in Fig. 1)	5.5 m
H-1 (in Fig. 1)	5.5 m
W-I-1	3,000
L-I-1	7,200
H-I-1	2,500
H-I-2	5,500
H-I-3	500
W-O-1	7,200
W-O-2	5,000
L-O-1	15,800
H-O-1	500
H-O-2	20,500

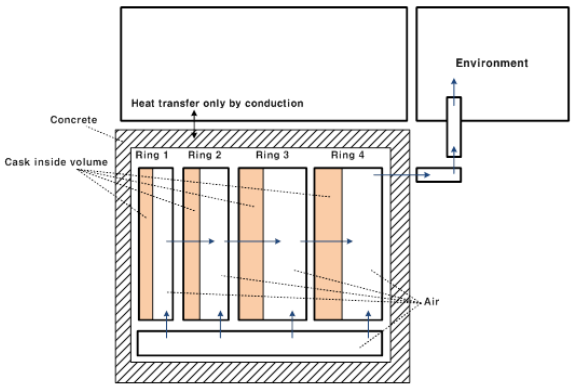

Fig. 2. Analysis domain of MELCOR (heat transfer).

The initial and boundary conditions for the present analysis are shown in Table 2.

Table 2. Initial and boundary conditions

Inlet/outlet boundary condition	Opening (1 atm)
Ambient temperature	30.7°C
Heat flux of SNF	140.591 W/m^2 (=1.06 kW/SNF)

3. Numerical Results

The analysis results are shown in Table 3. The resulted cladding temperature is compared with the temperature limit of the interim dry storage system of Wolsong nuclear power plant [1] and the resulted concrete temperature is compared with the temperature limit of ACI 349-06 [2].

Table 3. Maximum temperature during normal operating condition

Location	Maximum Temperature	Temperature limit
Cladding	118.8°C (21% margin)	150.5°C [1]
Concrete	40.5°C (37% margin)	65.0°C [2]

As a result, the resulted cladding and concrete temperature are lower than those of the limit values. Therefore, it is concluded that there exists sufficient temperature margin compared to those temperature limit values.

However, the present facility is designed at normal air atmosphere including moisture, not dry air atmosphere. Despite the short storage period (up to one year), it is considered necessary to further examine whether the application of the dry air atmosphere is necessary, such as the long-term dry storage facility of Wolsong nuclear power plant.

4. Conclusion

It was investigated that the imaginary SNF storage vault system for pyroprocessing facility using the concept of cooling by using natural convection. Computational flow and thermal analysis were conducted to verify its cooling capability. As a result, it was concluded that there exists sufficient temperature margin between the obtained maximum temperature and those temperature limit values. Application of the dry atmosphere is required to be discussed in the future and further analysis for the accident condition will be needed to be conducted.

REFERENCES

[1] Kim, Y. J, "Preliminary Study for the Evaluation of the Safety of Spent Nuclear Fuel in Dry Storage System in Wolsong," Korea Radioactive Waste Society Conference, Oct. 2015.

[2] ACI 349-06, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary, Appendix E - Thermal considerations.