Thermal Performance of HCSM for the SNF Assemblies

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1. Introduction

Since the dry storage of SNF (Spent Nuclear Fuel) assemblies has many merits, such as easy maintenance, low operational cost, few corrosion problems, low probability of radioactivity release, and no production of the secondary waste, it has been widely accepted by nuclear power plants in many countries, and becomes the major operational management trend of spent fuel before permanent disposal. Therefore, it is necessary to develop the optimal design technology of the dry storage system of SNF assemblies for the purpose of the domestic application. One of the key points related to the development of dry storage systems for SNF with high burn-up is that the decay heat should be efficiently removed by passive cooling.

This paper represents the thermal performance of HCSM (Horizontal Concrete Storage Module) that is generally categorized into vault-type storage system.

2. Methods and Results

In this section, the methods applied to evaluate the thermal performance of HCSM are described and followed by its results.

2.1 Thermal Conditions

Dry storage system of SNF should prove its satisfaction of the safety requirements under the normal, off-normal and accident conditions in accordance with the domestic and international standard regulations. The thermal conditions specified in 10CFR72 are summarized as follows [1].

Table I: Thermal Conditions

Conditions	Air Vent Condition	Insolation	Decay Heat
Normal Condition (steady state)	100% opened	Considered	Max.
Off-Normal Condition (steady state)	50% blocked	Considered	Max.
Accident Condition (transient)	100% blocked	Considered	Max.

2.2 Thermal Analysis Model

A half symmetric, 3-D. finite volume model for HCSM is developed using FLUENT version 6.2 [2]. As illustrated in Fig.1, this model represents one module containing a canister among an array of modules. Its maximal heat load amounts to 27.12kW.

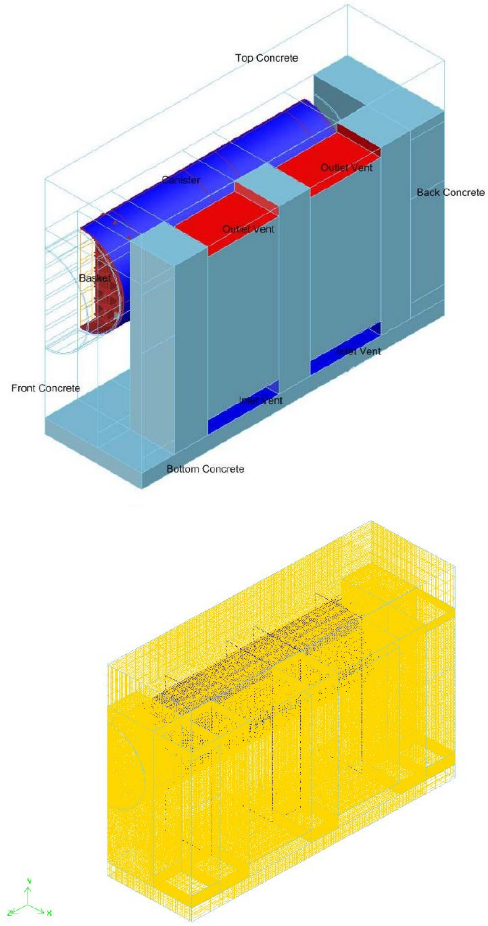

Fig. 1. Geometry and mesh structure model of HCSM

The analysis model consists of a reinforced concrete module and a stainless steel canister which can load 24 SNF assemblies. The structural support for SNF inside of the canister is provided by the basket compartments and 25 support disks, which are located by equal spaces over the full length of the basket. The concrete module has 2 inlet vents and 2 outlet vents located on the both side-walls.

2.3 Heat Transfer Characteristics and Boundary Conditions

The cooling of the canister within the concrete module occurs mainly as a result of airflow passing through the module via the so-called ‘stack effect’. This buoyancy effect is driven by the density differences due to the temperature differences between the indoor air and the outdoor quiescent air.

In this analysis, the convection and radiation boundary conditions are considered on the exposed surfaces of HCSM to simulate the exchange of heat with its surrounding via convection and radiation.

According to NUREG-1536, the insolation is assumed as a constant heat flux on the surfaces exposed to the environment. The solar heat flux is adopted from the averaged value over a 24-hour period in 10CFR71 [3,4].

2.4 Results

Fig. 2 shows an isometric view of the predicted temperature distribution under the normal condition. The analysis predicts a maximum temperature of 329℃ at fuel assembly region. Also, the peak temperature at the exhaust vent is 69.5℃, while the average exhaust air temperature is 52.6℃. From these results we can recognize the predicted temperature increase of the air passing through the concrete module is 14.6℃ and the predicted flow rate amounts to 0.7624kg/sec. The analysis also indicates that 22.9kW (i.e., 84.5%) out of the total decay heat load 27.12kW is removed via the air stream.

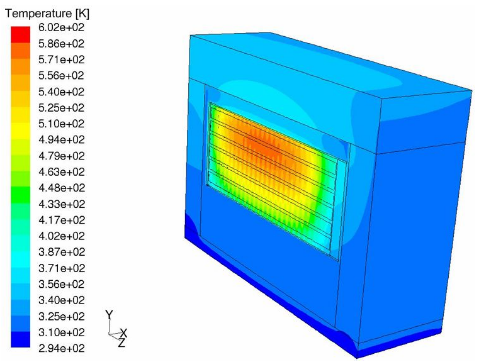

Fig. 2. Temperature distribution under normal condition

As shown in Fig. 3, the predicted peak temperature under the off-normal condition is 4℃ higher than the peak temperature under the normal condition. The predicted temperature increase of the air is 25℃ and the predicted airflow amounts to 0.3921kg/sec. Therefore, 74.4% of the total decay heat load 27.12kW is removed via the air stream.

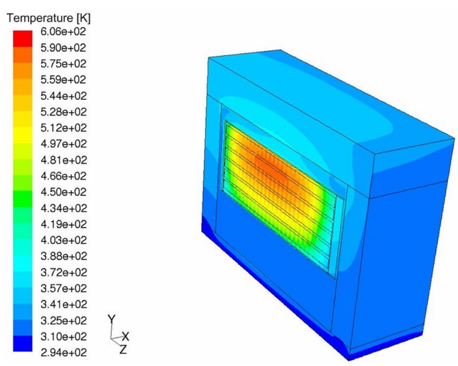

Fig. 3. Temperature distribution under off-normal condition

The transient simulation of the blocked vents constitutes the accident case of HCSM. The typical temperature distribution under the blockage of the vents is presented in Fig. 4. The predicted peak temperature reaches 377℃ asymptotically at 66.2 hours after blockage of vents.

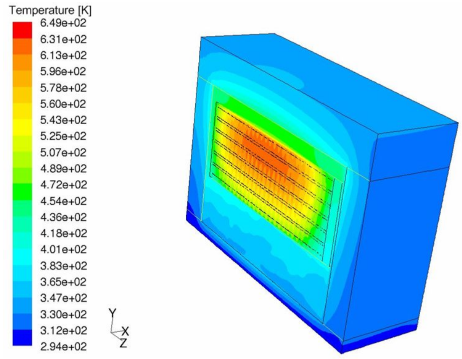

Fig. 4. Temperature distribution under accident condition

3. Conclusions

The thermal behavior of HCSM for SNF assemblies has been evaluated for the normal, off-normal and accident conditions specified in 10CFR72, respectively. The analysis demonstrates that the operational temperature limits of HSCM, important measures for the safety, are not exceeded with enough margin for all conditions of storage. Therefore, it can be concluded that the thermal performance of HCSM satisfies the allowable design criteria specified in 10CFR72 and NUREG-1536.

REFERENCES

[1] Title 10 of the Code of Federal Regulations Part 72 (10 CFR Part 72), Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste, April 1996.

[2] FLUENT Computational Fluid Dynamics Software, Fluent, Inc., Centerra Resource Park, 10 Cavendish Court, Lebanon, NH 03766.

[3] Title 10 of the Code of Federal Regulations Part 71 (10 CFR Part 71), Packaging and Transportation of Radioactive Materials, April 1996

[4] NUREG-1536, Standard Review Plan for Dry Storage Systems, USNRC, 1997