Thermal Analysis of Transportation and Storage Cask of Spent Nuclear Fuel for Forced Gas Drying Condition

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1. Introduction

The national high level radioactive waste management plan indicates that dry storage systems are to be installed for expending on site storage capacity of NPPs and establishing a centralized interim storage.

A Test grade Forced gas Drying equipment (TFD) is being developed as the drying process system to remove moisture in a cask.

As a part of the dry storage of the spent nuclear fuel (SNF), a canister of a dual-purpose cask (DPC) is loaded with the SNF under water. After draining the majority of the water, the remaining water in the canister must be removed using drying system to prevent corrosion and hydrating of the SNF.

The NUREG-1536 describes that the maximum calculated fuel cladding temperature should not exceed 400℃ for normal conditions of storage and short-term loading operations, including cask drying and backfilling.

Thermal analysis of DPC of PWR SNF during drying operation by TFD was conducted to identify compliance with the drying criteria after completing detailed design of TFD.

This paper presents thermal analysis results of transportation/storage cask during cask drying with the TFD to identify drying performance and fuel cladding integrity.

2. Thermal analysis

2.1 General information

The design features of TFD are as follows

- Flow rate: 65㎥/hour
- Operating pressure: 70 psig
- Inlet /outlet temperature: 150℃/180℃
- Cooling temperature: Max. - 20℃

The Fig. 1 shows a simplified TFD diagram including canister.

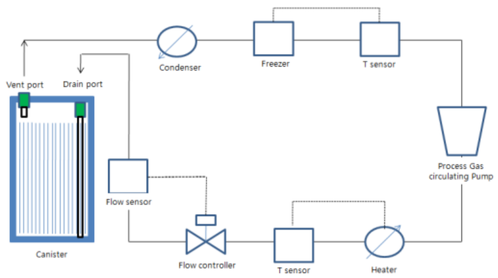

Fig. 1. Simplified diagram of TFD.

The key specifications of KORAD-21 DPC are provided in the Table 1.

Table 1. Design specifications of DPC

Item	Specification
Storage capacity	21 PWR (WH & CE)
Maximum Burn up	45 GWd/MTU
Max-average enrichment	4.5wt.% U-235
Minimum Cooling time	10 years
Max-decay heat	16.8 kW /canister
Free volume of canister	6,456 L

2.2 Thermal analysis model

The heat transfer modes in each process are provided in the Table 2.

Table 2. Heat transfer modes in each process

Item	Internal environment of canister		
	Wet	Drying	Dry
Medium	Water	-	He
Transfer mode	-Conduct -Natural convect	-Forced convect -Conduct	-Conduct -Convect -Radiat

Based on the canister drying condition and the heat transfer mode, a three-dimensional finite volume model was constructed to perform the thermal analysis. The thermal analysis was carried out using FLUENT 13.0.

The modeling included all components such as the SNF assembly, neutron absorber, basket, disk, canister, cask body, neutron shield, and canister lid. Especially, the thermal analysis model for the SNF assembly was modeled in the form of a homogeneous model, so as to simulate heat transfer characteristics of the assembly.

Simulations were performed with 21 hours of transient analysis under 3 conditions. During drying process, the inlet and outlet boundary condition of canister was established and modeled to describe the drying gas circulating process.

Thermal analysis conditions of each process are shown in the Table 3.

Table 3. Thermal analysis conditions of process

Item	Process		
	Wet	Drying	Dry
Duration(hr)	15	3	3
Medium	Water	Water/He	He
Ambient(℃)	38	38	38
Initial condition	46 ℃ equiv.	From former	From former
Decay heat	Maximum	Maximum	Max.

The drying operation process occurs in the spent fuel facility and the cask is installed vertically.

Boundary condition in the form of convection and radiation heat transfer was defined at the cask surface.

2.3 Analysis results

Short term loading operations consists of wet process (loading SNF in the pool), cask drying process (Helium recirculation and moisture removal) and dry process (backfilling). The analysis results of calculated maximum cladding temperature in each process are shown in the Table 4 and Fig. 2.

Table 4. Calculated maximum cladding temperature

Process	Wet	Drying	Dry
Temperature (℃)	152.1	179.4	184.1

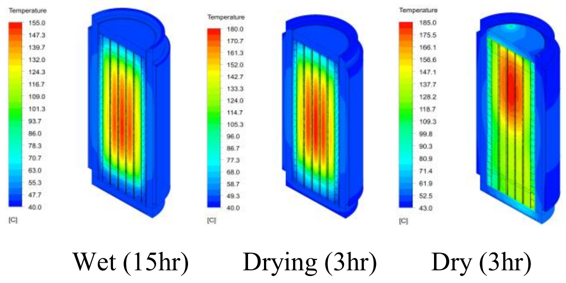

Fig. 2. Temperature distribution in the DPC at the end of the each process.

3. Summary

The thermal analysis of transportation and storage cask for SNF was conducted during short term loading operations for forced gas drying condition.

The fuel cladding temperature in 6 regions of SNF in the cask during the short term loading operations for forced gas drying condition is shown in the Fig. 3.

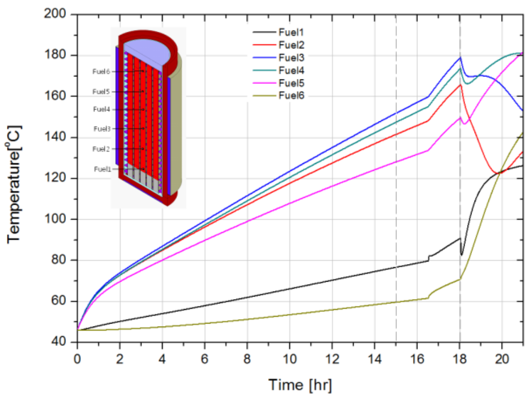

Fig. 3. Fuel cladding temperature history in 6 regions of SNF.

The thermal analysis results of calculated maximum cladding temperature in each process demonstrate that operating scenario of TFD in detailed design maintain well below the temperature limits of 400℃.

REFERENCES

[1] NUREG-1536 Revision 1 Standard review plan for spent nuclear fuel dry storage system at a general license facility.