A Study on the Thermal Design of the Advanced Multi Purpose Canister

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1. Introduction

The storage, transportation and disposal of pressurized water reactor (PWR) spent fuel is an important issue in nuclear industry for safe and extended nuclear power plant operation. However, since wet-storage facilities almost reach to their capacity, dry-storage method, especially using a Multi Purpose Canister (MPC), has been highlighted because it gives better economic and safety point of view.
In this study, an advanced design of MPC was proposed through an increase in storage capacity from 26 to 37 PWR fuel assemblies per MPC. Thermal analysis was also carried out by FLUENT 6 code to confirm the temperature criteria of the MPC. From the results, conceptual design of 37 PWR fuel assemblies can reduce the mass per fuel assembly ratio about 19 % compared to the 26 assemblies, and maximum temperature developed at the center of fuel assemblies shows within the range of design criteria. Based on the analysis, it is considered that the advanced MPC design well conforms to the safety requirement and it gives rise to economical gain because of reduction in mass per fuel assembly ratio.

2. Methods and Results

2.1 Conceptual Design Model

2.1.1. Scope of the design consideration

Before starting to study about the conceptual design consideration of the large size of the canister, the scope must be defined. In this study, the geometries of the canister are used from NAC-STC model. Its geometries will not be changed except the fuel assembly size to increase the design capacity. The material of the canister also will not be changed. The NAC-STC is fully licensed as both a storage cask and a transport cask The NAC-STC has a steel/lead/steel cask body with a solid neutron shielding material known as the NS4FR. All exposed interior and exterior surface are stainless steel. The cask is capable of containing 26 pressurized water reactor (PWR) fuel assemblies having lengths up to 165 in. and enrichments up to 3.3% U-235. Decay heat is 1kw/m^3. Other data can be seen from Table 3. From these data, we can calculate the mass per assembly ratio. It is about 4.46 MT/assembly.
2.1.2. Design features

Design features are summarized as following.

Design characteristic		
Cask body material		SS
Gamma shield material		Lead
Neutron shield material		NS4FR
Weight	Empty cask (ton)	108.7
	Loaded on fuel (ton)	133.5
Cavity length (mm)		4,191
Cask diameter (mm)		3,312
Cavity diameter (mm)		2,404
Capacity (number of assemblies)		37 PWR
Burn up (MWD/MTU)		35,000
Cooling time (yrs)		10

Table 1. Conceptual design data

2.2 Analysis of the conceptual model using FLUENT code

A FLUENT code analysis is done in the design consideration of the advanced MPC. A geometry construction and a 3-dimensional volume meshing using gambit is done in the volume meshed 24,840 cells. As mentioned above, the advanced MPC is cooled by air. Therefore Buoyancy-Driven Flows are used. When heat is added to a fluid and the fluid density varies with temperature, a flow can be induced due to the force of gravity acting on the density variations. Such buoyancy-driven flows are termed natural-convection, which was modeled by FLUENT 6.1 code. Natural convection is a little hard to get exact data from FLUENT, symmetry concept are used. In this study, quarter of the conceptual design model is used to represent. There are several assumptions. To simplify the geometry fuel is defined as a homogeneous fuel and grids are removed. And shielding material is not considered.

2.3FLUENT code result

2.3.1. Variations of temperature

The maximum temperature was developed at the center of the fuel assemblies, showing 544.36 K, and the inner shell temperature ranged from 385.5 to 458.8 K. On the contrary, there was no significant temperature fluctuation in axial direction.

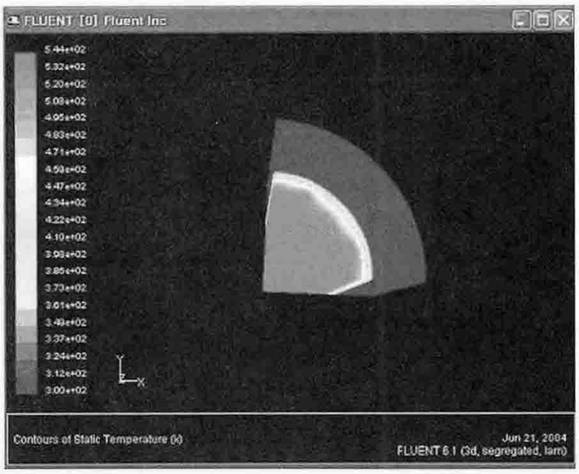

Figure 1. The variations of simulated temperature

2.3.2. Variations of air velocity

Natural circulation results in a very low air velocity, showing that the minimum and maximum velocity is 0.01 and 1.05 m/s, respectively. Flow patterns and movement of the air can be seen.

3. Conclusion

In this study, the conceptual design consideration of the advanced MPC was studied. Major findings are summarized as follows:

• Study on a design consideration of the advanced MPC

• Conceptual design consideration of the large capacity that has 37 PWR fuel assemblies can reduce the Mass per fuel assembly ratio by 19% compared to 26 PWR assemblies.

• Thermal analysis of the conceptual design was conducted by FLEUNT 6 code

• Maximum temperature is within the range of design criteria.

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