Concept Evaluation of Pyroprocess Waste Storage System

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1. Introduction

KAERI has been developing pyroprocessing technology for recycling useful resources from spent nuclear fuel [1]. Various wastes are generated from the pyroprocess. The wastes should be fabricated into stable waste forms considering their radioactivity and decay heat characteristics for the safety management of long-term storage and final disposal. The purpose of this study is to assess the concept of a waste storage canister and facility for securing the design data.

2. Concept Evaluation of Storage Canister

Considering the high heat capacity of the Cr/Sr waste form, a new concept of a storage canister with optimized capacitiy was developed. A concept evaluation of the canister was conducted on the basis of a universal canister [2] which is used as a package for wet reprocessing waste in France. The canister is 430 mm in diameter and 1.4 m in height. The total decay heat of the canister is about 2 kW and the temperature limit of the waste form is 500 ℃. Volumetric heat generation of the universal canister is 16.7 kW/㎥. Volumetric heat generation of Cs/Sr waste from the pyroprocess is about 21.2 kW㎥, which exceeds the value of a universal canister. Thermal analyses of the canisters have been conducted to determine the optimal dimension and maximum decay heat of the waste form, which satisfies the temperature limit requirement. Table 1 shows the thermal analysis model and conditions. Thermal analyses were conducted as a variation of the waste diameter and decay heat. Fig. 1 shows the maximum waste form temperature according to the diameter and decay heat of the waste. The optimal waste form dimension was determined to be ϕ350 x 900 mm(H) with a maximum decay heat of 1.9 kW. Fig. 2 shows the design concept of the canister. The outer dimension of the canister is ϕ370 x 1320 mm(H).

Table 1. Thermal analysis model and conditions for waste form canister

		Model-1 (Φ40.8cm)	Model-2 (Φ35cm)	Model-3 (Φ30cm)
Canister dim.	Outer dia.	ϕ430 mm	ϕ370 mm	ϕ320 mm
	Inner dia.	ϕ418 mm	ϕ360 mm	ϕ310 mm
	Thick.	6 mm	5 mm	5 mm
	Height	1340 mm	1320 mm	1320 mm
Waste form dim.	Diameter	ϕ408 mm	ϕ350 mm	ϕ300 mm
	Height	918 mm(H)	885 mm(H)	885 mm(H)
Decay heat per canister		1.8~3.6 kW	1.3~2.6 kW	0.95~1.9kW
Volumetric heat for waste form		15 ~ 30 kW/㎥		

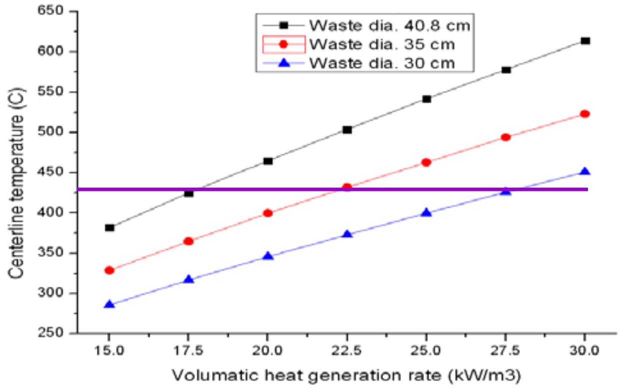


Fig. 1. Maximum waste form temperature according to the diameter and decay heat of the waste form.

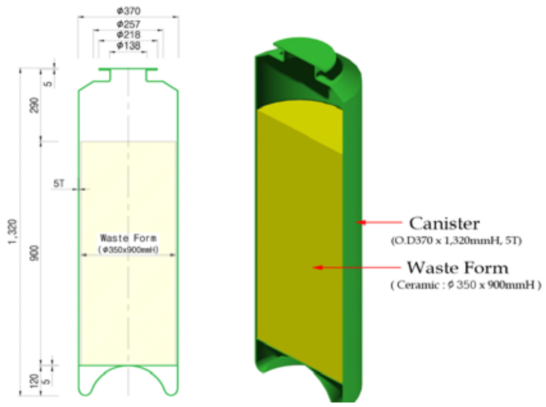


Fig. 2. Design concept of waste form storage canister.

3. Concept Evaluation of Storage Facility

There are four types of storage system for high level radioactive waste: vault, silo, metal cask, and concrete cask system [3]. The vault type was selected as a pyroprocess waste storage facility because it has a superior heat removal performance. The concept of an integrated storage facility for pyroprocess waste was proposed into three storage sections, as shown in Fig. 3. The first section is a decay storage area for Cs/Sr waste. The second storage section is for metal waste of NFBC (Non Fuel Bearing Components) and cladding hulls. In addition, the third storage section is for long-lived nuclides of I-129, Tc-99, C-14, and anode sludge waste.

Fig. 4 shows the storage facility of the Cs/Sr waste forms. 12 x 12 storage tube arrays are installed in the module, and their heat removal must be secured for each module. Each storage tube contains three canisters. The storage tube has an outer diameter of 400 mm, a height of 4 m, and a thickness of 10 mm. The distance between the tubes is 200 mm, the wall thickness of the concrete is 900 mm, and the height of the stack is 20 m.

The storage facility has a passive cooing system. Air inlet and outlet ducts are installed at the bottom and stack of the storage facility for a natural cooling system.

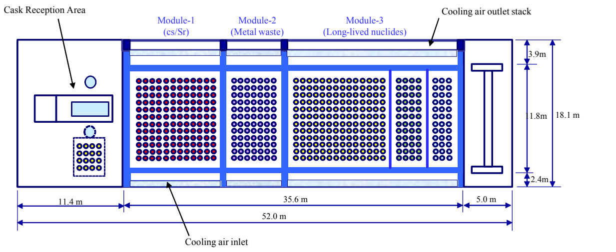


Fig. 3. Integrated storage facility for pyroprocess waste.

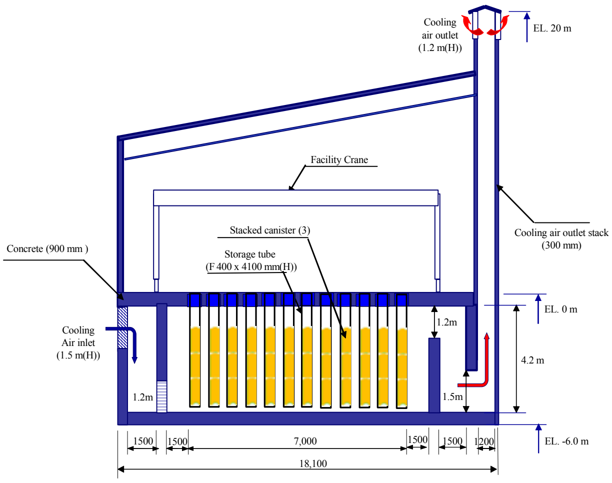
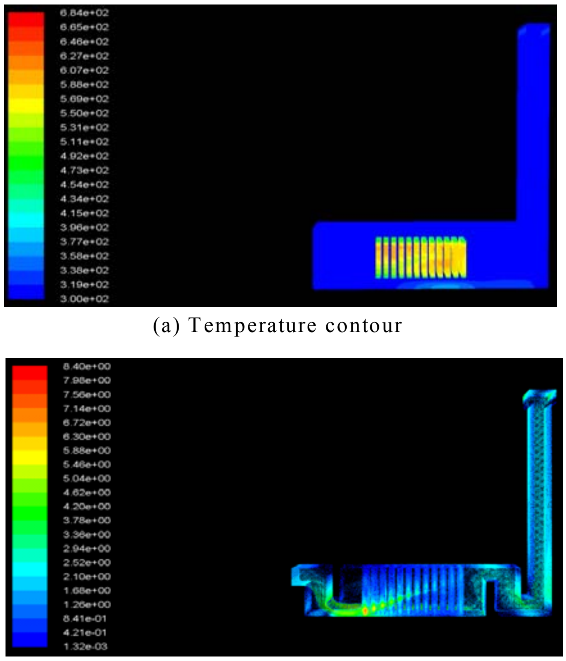


Fig. 4. Side view of storage facility for Cs/Sr waste form.

4. Thermal Analysis of Storage Facility

A thermal analysis was performed for the storage system of the Cs/Sr waste form. The commercial CFD code, FLUENT [4], was used for the thermal analysis. The storage module has 12 x 12 storage tube arrays with a symmetrical structure. A thermal analysis model was used a three-dimensional half model with 12 x 6 storage tube arrays and a symmetric boundary condition. The decay heat of the canister is 1.87 kW and that of the storage tube is 5.613 kW. Therefore, the total decay heat from the storage facility was considered to be 404 kW. Heat transfer from the interior of the storage tube is accomplished by a combination of conduction, convection, and radiation. Heat rejection from the tube surface is primarily accomplished by a convective heat transfer due to a buoyancy driven air flow. A thermal analysis was carried out under normal condition with an ambient temperature of 27 °C.

Fig. 5 shows the temperature contour and velocity vector for the storage facility under a normal condition. The maximum temperature of the waste form was calculated as 411 ºC, which is lower than the allowable value of 500 ℃. The maximum temperatures of the canister and concrete were calculated as 341 ºC and 118 ºC, respectively. About 94% of the heat was removed by the natural convection to the chimney of the storage facility. It is shown that natural convection through air circulation is very dominant during heat transfer of the storage facility. In addition, it was found that the cooling efficiency is superior.



(a) Temperature contour

(b) Velocity vector

Fig. 5. Temperature and velocity for storage facility.

5. Conclusions

The design concepts of the waste form storage canister and facility were developed for the storage of pyroprocess waste. The optimal waste form dimension was determined as ф350 x 900 mm(H) with a maximum decay heat of 1.9 kW. In addition, the canister concept was proposed with an outer dimension of ф370 x 1320 mm(H). The concept of an integrated storage facility was proposed for a vault storage system. It shows that the thermal integrity of the storage facility was maintained under normal condition. In addition, it was found that the cooling efficiency of the storage facility is superior. The results of this study will be used as basic data for the design of the KAPF.

REFERENCES

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