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Thermal Analysis of a Temporary Storage System for Metal and Salt Ingots

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1. Introduction

Spent fuel generated by nuclear power reactors has a high radioactivity and heat source. Therefore, the development of an advantage management technology of the spent fuel is an important and essential task, worldwide.

The Spent Fuel Conditioning Process (ACP) can be applied as a conditioning process for a long-term storage and eventual disposal of PWR spent fuel, for the heat, volume and radioactivity of the spent fuel can be decreased with an oxide reduction and selective separation of high heat-load fission products.

The radioactivity, decay heat and volume of spent PWR fuel are reduced to about a quarter by the ACP[1]. In the electrolytic reduction process, $LiCl-Li_2O$ molten salt is used as a reaction media. After the process, the waste molten salt contains high heat load elements such as $SrCl_2$ and CsCl, as well as other fission products and rare earth elements. The metal ingot from a smelting process is the final product of the ACP.

Metal ingots and salt waste are to be packed into a canister and stored at the storage vault in the ACPF hot cell temporarily, and then transported and stored in the monolith of Radioactive Waste Treatment Facility (RWTF). In this study, temporary storage concepts have been established for the metal and salt ingots. And thermal analyses were performed for the temporary storage concept.

2. Concept of the Storage Canister

The process batch size is considered as 20 kg of spent fuel for an ACP demonstration. G23 spent PWR fuel assembly will be used in the ACP demonstration. G23 fuel has a cooling time of 19 years and a burn-up of 35,500 MWd/tU. And the reference fuel for an operation of the ACPF hot cell has a cooling time of 10 years with a burn-up of 43,000 MWd/tU.

The metal and salt ingots generated by the ACP demonstration are to be packed into a canister. Table 1 shows the description of the metal and salt ingots. Fig. 1 shows the storage canisters for the metal and salt ingots.

Table 1. Description of the Metal and Salt Ingots

	Metal ingot	Salt ingot
Quantity	20 kg / batch	90 kg / batch
Dimension	Φ160 x 70 mm L	Φ 168 x 180 mm L
Weight/ingot	20 kg	6 kg
Heat capacity	8.54 W	1.59 W

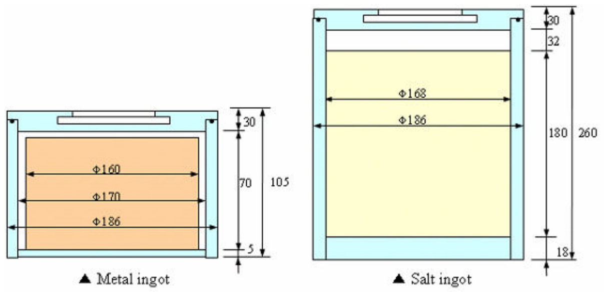

Fig. 1. Storage Canister for the Metal and Salt Ingots.

3. Thermal Analysis for the Storage Vault of ACPF

Thermal analysis has been conducted for the temporary storage vault of the ACPF hot cell by using the FLUENT[2] code. Fig. 2 shows the vault storage model for the metal and salt ingots. The storage vault has six racks with a diameter of 200 mm and a height of 525 mm. Ten salt ingots are stored in the five racks. And five metal ingots are stored in one rack.

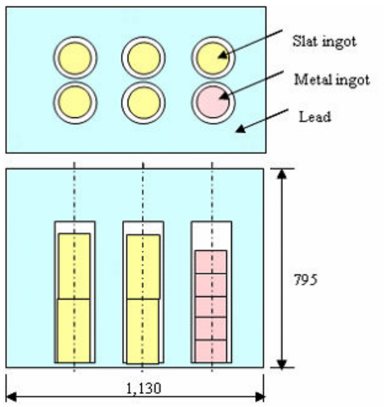

Fig. 2. Vault Storage Model.

The side and bottom parts of the storage vault are located under the hot cell floor. Therefore, a heat transfer is only considered in the upper part of the storage vault. An environmental temperature of 35 ℃ has been applied in the hot cell. The decay heat from the five metal ingots and ten salt ingots was applied on 42.7 W, 15.9 W, respectively.

Table 2 and Fig. 3 show the thermal analysis results for the storage vault. The maximum lead temperature was calculated as 52℃. Maximum metal ingot temperature was calculated as 74℃, which is lower than the allowable value. The temperature limit of the metal fuel was determined as 150℃ with reference to the magnox fuel[3-4]. Maximum temperature of the salt ingot was calculated as 74 ℃, which is lower than the melting point. Therefore, it was found that thermal integrity was maintained for the temporary storage.

Table 2. Thermal Analysis Results for Storage Vault

Location	Calculated temperature (℃)	Allowable Value(℃)
Metal ingot	74	150
Molten salt	57	614
Lead shield	52	327
Upper plate	48	-

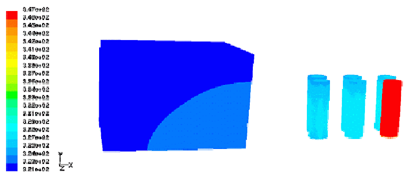

Fig. 3. Temperature Contours for Storage Vault.

4. Thermal Analysis for Storage of Monolith

Temporary storage concept of the monolith has been established for the storage of metal and salt ingots. The monolith consists of 189 wells with a 27 x 7 array and a pitch of 1.25 m. A total of seven solid waste containers are stored in the one well. Two salt ingots or five metal ingots are stored in one container. Therefore, a temporary storage model was established for the storage of 12 salt ingots and 5 metal ingots. Fig. 4 shows the monolith storage model. Heat generation from the metal and salt ingots was applied as 42.7 W, 19.1 W. It was assumed that the infinite array of the well and heat transfer is only considered from the upper surface of the model. In the thermal analysis results, metal ingot temperatures were calculated from 126 ℃ to 129 ℃. And salt ingot temperatures were calculated from 119℃ to 122 ℃. The calculated temperatures were lower than the allowable values.

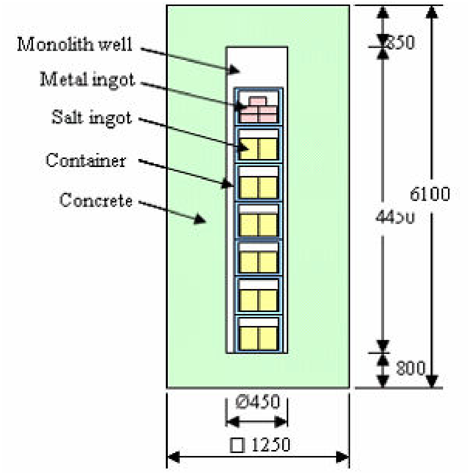

Fig. 4. Monolith Storage Model.

5. Conclusions

Temporary storage model for the storage vault of ACPF and the monolith of RWTF were established for the application of metal and salt ingots. Thermal analyses have been carried out for the storage vault and the monolith storage system. The maximum temperatures of the metal and salt ingots were lower than those of the allowable values. Therefore, the temporary storage concept will be applied for the metal and salt ingots from the aspect of a thermal safety.

Acknowledgement

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