Preliminary Critical Analysis for Review of Multipurpose Utilization of PWR Spent Nuclear Fuel Disposal Canister

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1. Introduction

Most of countries are developing and using a variety types of cask for efficient and safe management of Spent Nuclear Fuel (SNF). In particular, the Disposal Cask used in the final management phase provides a primary barrier to isolate spent fuel and maintains airtightness in deep environments during its design lifetime to prevent leakage of internal radionuclides.

The disposal casks or system should make sure that nuclear criticality accidents never occur at any circumstances and transportation or storage should be designed to prevent nuclear criticality from both normal and abnormal accidents [1][2][3].

In this study, the spacing and vessel diameter of the fuel assemblies satisfying the criterion of effective multiplication factor which is less than 0.95 in transportation, storage and disposal are established. Furthermore, the basic data of the multi-purpose canister is used for safety analysis.

2. Method and Assumption

2.1 General Information of Disposal Cask

The inserting channel of SNF was designed with a width of 23.5 cm and a height of 454.8 cm, which can facilitate APR-1400, WH fuel, and standard type with a width of 20.7 cm and a height of 453 cm (Fig.1). The loading capacity of SNF is 4 bundles made of corrosion resistant copper outside and cast nodular iron inside [4].

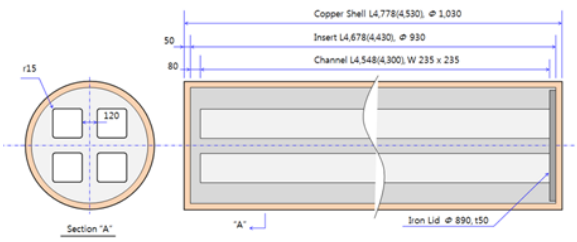


Fig. 1. Disposal Canister for KORAD EBS.

2.2 General Assumption

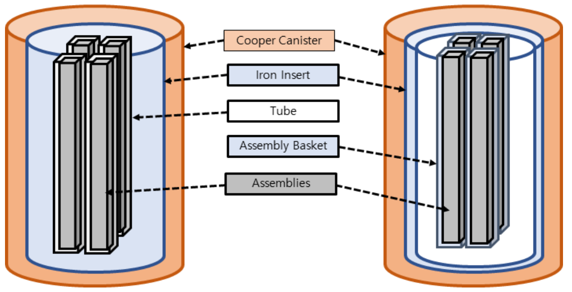
Based on the study by the KORAD (Korea Radioactive Waste Management Corporation), the Basis Fuel for the nuclear criticality analysis is selected as CE type PLUS7 with the initial concentration of 4.0%, the emission combustion of 45 GWD/ MTU and the cooling period of 40 years. Only the major actinide nuclear species was considered as a composition of SNF in order to assume the combustion state and Burnable Rod and Control Rod were excluded to secure maintenance.

The analytical conditions are as follows: both normal condition (dry internal cask and rock maintaining the integrity of the disposal system) and accident(flooding)condition (rock, bentonite, and the submerged interior making the optimal deceleration condition by groundwater).

2.3 Special Assumption

In this study, the IRON INSERT of the disposal cask in the previous research is named 'internal canister'. Furthermore, in order to utilize it for transportation or storage, some assumptions are established with its inside structural change as shown in Fig. 2.

- For simulating the weight reduction and immersion conditions in transport and storage use, to change the inside of the canister to empty space, change the fuel loaded tube to the basket
- To alter material of the changed inner canister to stainless steel, and to maintain the thickness of the outer wall with the upper thickness of 5 cm of the original canister and the lower thickness of 8 cm.
- Considering the uncertainty about long-term material quality, neutron absorbers used in canisters for transportation and storage are not applied.



(a) Original model (b) Modification model

Fig. 2. Design modify of Disposal Cask and Canister.

3. Result

The pitch and canister diameter of the fuel assemblies that can be used for transportation and storage of the IRON INSERT of the disposal cask which cannot guarantee the long-term storage due to not applying neutron absorber were calculated (Table 1).

Table 1. Criticality of Modification model

(Unit: k_{eff})

Gap	Conditions / Fuel irradiation		Criticality	Satisfaction
3cm	Normal	Spent	0.21476	○
		Fresh	0.27652	○
	Accident	Spent	0.74676	○
		Fresh	1.06053	X
6cm	Normal	Spent	-	○
		Fresh	-	○
	Accident	Spent	-	○
		Fresh	0.94889	X
7cm	Normal	Spent	-	○
		Fresh	-	○
	Accident	Spent	0.65556	○
		Fresh	0.92590	○
12cm	Normal	Spent	0.18870	○
		Fresh	0.24940	○
	Accident	Spent	0.61455	○
		Fresh	0.86455	○

First, in the case of the changed model with a 12 cm fuel gap, both the combustion fuel and the new fuel meet the nuclear critical criteria for transportation, storage and disposal, even under normal and accident conditions. According to the results, the empty changed canister- type vessel(inner diameter 71 cm) with the 3 cm fuel gap satisfied the assumptions under the dried condition, but in the case of the new fuel by the accident (flooding) exceeded effective multiplication factor. The changed canister- type vessel with the 6 cm fuel gap(inner diameter 77 cm) was evaluated as 0.94889 by the accident (flooding) and the dry condition was all possible and but when applying the nuclear critical uncertainty of 0.0085 calculated in the KORAD21, transportation cask exceeded effective multiplication factor. Lastly, The changed canister- type vessel with the 7 cm fuel gap(inner diameter 78 cm) met the criticality criteria for both combustion and new fuel under normal and accident conditions.

4. Conclusion

The preliminary nuclear criticality safety analysis was carried out to examine the multipurpose utilization by changing the internal structure of the four-assembly disposal cask developed by the existing research. When the internal diameter was 78 cm and the fuel gap was 7 cm, both the combustion fuel and the new fuel did not exceed the nuclear critical standard value (0.95) under the normal - accident condition.

With the nuclear criticality analysis method, it is possible to derive the basic specifications of the canister meeting all the transportation, storage and disposal standards. Also, it is considered that the optimum multi-purpose canister can be developed by analyzing the shielding, heat and structure.

ACKNOWLEDGEMENT

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