Development of DGR System Concept for Radioactive Waste from Pyro-processing of CANDU SNFs

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1. Introduction

To reduce volume and toxicity of PWR SNFs, the P&T technology using pyro-processing and SFR is under development in KAERI. CANDU SNFs are not considered as a subject of P&T because of its low fissile content caused by use of natural uranium as a fuel material. However, contention that not only PWR SNFs but also CANDU SNFs must be re-used is raised constantly. To evaluate impact of application of P&T on CANDU SNFs in the perspective of disposal, DGR system concept for radioactive waste from pyro-processing of CANDU SNFs based on material balance version 2.6.0 is developed in this study.

2. Methods and Results

2.1 Assumptions

To develop DGR system concept, assumptions and programs below are used.

- Amount of CANDU SNFs: 842,000 bundles from four CNADU reactors for 40 years of operation
- Reference SNF: CANDU 37 which has 0.711 wt.% of initial enrichment, 8.1 GWd/MtU of discharge burn up after 342 days of operation
- Cooling time: 10 years for pre-pyro-processing and 20 years for pre-disposal
- Pyro-processing Scenario: no material balance for CANDU SNFs, Identical material balance for PWR(MB 2.6.0) is applied due to absence of MB for CANDU SNFs. Only LiCl-KCl waste is considered as an object waste.
- Waste Characterization: same as previous study [1]

2.2 Design of waste form, package/disposal canister

To design waste form, the mass ratio of nuclides to binding additives is assumed to be identical to PWR pyro-waste based on MB 2.6.0. From the pyro-processing of 10 MTU PWR SNFs, 665 kg of LiCl-KCl waste is generated and it contains 117 kg of radioactive nuclides and 548 kg of binding materials [2]. According to previous source term characterization study, 11.14 kg of radioactive nuclides are generated from pyro-processing of 10 MTU CANDU SNFs. Assuming same ratio of radio-nuclides to binding material of PWR SNF pyro-processing based on MB 2.6.0, 80.3 kg of binding materials are needed to make solid waste form and total waste mass from pyro-processing of 10 MTU CANDU SNFs is estimated to be 97.5 kg.

Specifications, decay heat and quantity of waste form, packing and disposal canister from pyro-processing of 842,000 CANDU SNF bundles are determined in the same manner of design of KRS and A-KRS system and each value are described in Table 1.

Table 1. Specification and quantities of waste from, packing/disposal canister

Components in EBS		Values
Waste form	Dimension	Φ260 x 250 mm(H)
	Mass	48.75 kg
	Decay heat	28 W (30 yrs after discharge)
	Amount	2 ea (97.5 kg – 10 tU)
		3,200 ea (16,000 tU)
Storage vessel	Dimension	Φ267 × 610 mm(H)
	Contents	2 Vitrified Unit
	Mass	127.0 kg
	Amount	1 ea (10 tU)
		1,600 ea (16,000 tU)
	Decay heat	56 W (30 yrs after discharge)
Disposal canister	Dimension	Φ1,031 × 1,725 mm(H)
	Content	Storage vessel 14 ea
	Mass	1.75 ton + canister itself
	amount	115 ea (16,000 tU)
	Decay heat	784 W

* Density of vitrified waste: 3,670 kg/㎥

2.3 Thermal dimensioning and layout

A basic requirement for determination of disposal hole and disposal tunnel spacing is that the maximum temperature of bentonite blocks around a canister in a disposal hole should maintain below 100℃. Followings are the assumptions for a thermal analysis of a disposal system.

- Emplacement of two disposal canisters (at the time of disposal, decay heat is 1,568 W) per one disposal hole located in a floor of disposal tunnel at the depth of 500 m.
- The thermal properties of each material are shown in table 2.

- The temperature of surface and thermal gradient are assumed to be 10℃ and 30℃/km respectively.

Table 2. Thermal properties used in thermal analysis

Items	Density (kg/m^3)	Thermal Conductivity (W/m℃=J/s/m℃)	Specific Heat (J/kg℃)
Copper shell	8,900	386	383
Cast insert	7,200	52	504
Buffer	1,970	0.8	1,380
Backfill	2,270	2	1,190
Rock	2,600	3.0	900

A model for thermal analysis is shown in Figure 1. This analysis was carried out with fixed Disposal tunnel spacing (A) of 40 m and variable disposal hole spacing (B) of 1 m increment from 6 m to 9 m. Figure 2 shows a thermal analysis result with time. In the case that the disposal hole spacing are 6 m and 7 m, the maximum temperature of bentonite block is over 100℃, so requirement are not satisfied in these. The case that the disposal hole spacing is over 8 m meets the design requirement. Based on the thermal analyses results, 40 m of disposal tunnel spacing and 8 m of disposal hole spacing were determined as an optimum dimensioning for disposal system.

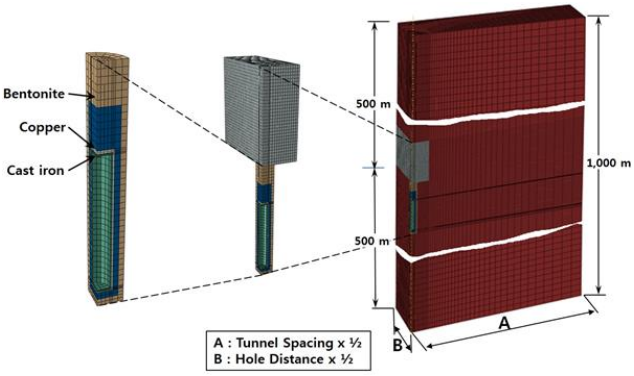

Figure 1. ABAQUS 3D model for thermal analysis

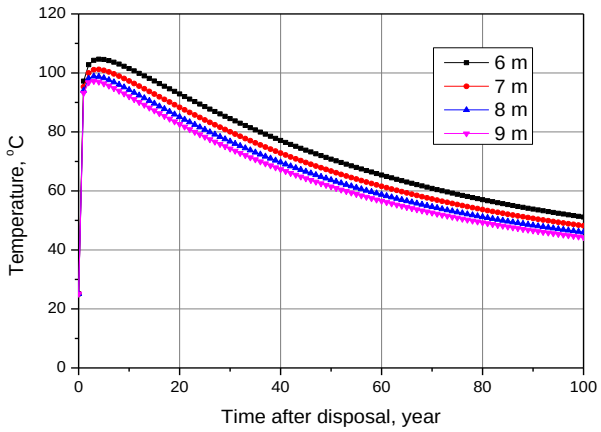

Figure 2. Results of thermal analyses

Figure 3 shows concept and specification of LiCl-KCl waste, packing, disposal canister, disposal hole, disposal tunnel and layout of DGR system for pyro-processing of 842,000 CANDU fuel bundles. For the disposal of the CANDU pyro-ceramic waste, two disposal tunnels (260 m length) are needed and the disposal area is about 20,800 m^2.

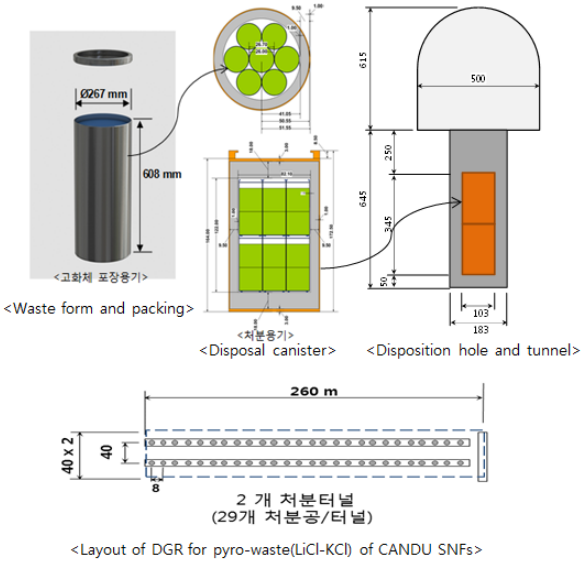

Figure 3. DGR system for CANDU LiCl-KCl waste

3. Conclusions

In this study, DGR concept for radioactive waste from pyro-processing of CANDU SNFs is developed. Identical material balance for PWR (MB 2.6.0) and mass ratio of radioactive nuclides to binding material for LiCl-KCl waste is applied to determine specification of waste form, packing/disposal canister. Optimum thermal dimensioning is estimated to be 40 m for disposal tunnel and 8 m for disposal hole pitch through ABAQUS thermal analyses. The disposal area is expected to be about 20,800 m^2 for disposal of 842,000 CANDU fuel bundles. In the future work, impact of CANDU SNF P&T will be evaluated based on these results.

REFERENCES

[1] In-Young Kim et. al, Preliminary Evaluation on Effect of Application of Pyro-processing on CANDU SNFs in the Perspective of Source Term, Proceeding of 2016 spring Korea Nuclear Society.
[2] Heui-Joo Choi, Jong-Youl Lee et al., (KAERI/RR-3417/2011) High-Level Waste Long-term Management Technology Development – Development of a Geological Disposal System, KAERI, p. 312, 2011.