Preliminary Evaluation on Effect of Application of Pyro-processing on CANDU SNFs in the Perspective of Source Term

In-Young Kim[a*], Heui-Joo Choi[a], Jong-Youl Lee[a], Hyun-Ah Kim[a], Min-Soo Lee[a]
[a]*Korea Atomic Energy Research Institute, 111, Daedeok-daero 989 beon-gil, Yuseong-gu, Deajeon*
[*]*Corresponding author: iykim@kaeri.re.kr*

1. Introduction

To reduce volume and toxicity of the PWR SNFs, the pyro-processing connected with the SFR is under development in KAERI. Up to date, the pyro-processing of CANDU SNFs is not subject of researches because of its low fissile content as a result of using natural uranium fuels. The demands on quantitative analyses of influence of pyro-processing of CANDU SNFs such as disposal area, institutional management periods, etc. are magnified, however, as background materials for the public engagement process on SNF management. In this study, preliminary evaluation on effect of application of pyro-processing on CANDU SNFs in terms of source term is conducted in advance of designing its disposal system and evaluation of disposal influences.

2. Methods and Results

2.1 Assumptions and Modeling

To evaluate source term of CANDU SNF and waste from the pyro-processing, the SCALE6 (Origen-arp) program and assumptions below are used.

- Reference fuel: CANDU 37 (0.711 wt.% of initial U-235 enrichment, 8,100 MWd/MtU SNF of discharge burn-up, 23.668 MW/MtU SNF of specific power)
- Material balance of the pyro-processing: MB 2.6.0 (identical with PWR pyro-processing, no available MB for CANDU SNF)
- Target waste: LiCl-KCl monazite ceramic waste
- Cooling time: 10 years before the pyro-processing and 20 years before the disposal for the pyro-processing scenario (cf. 30 years for direct disposal scenario)

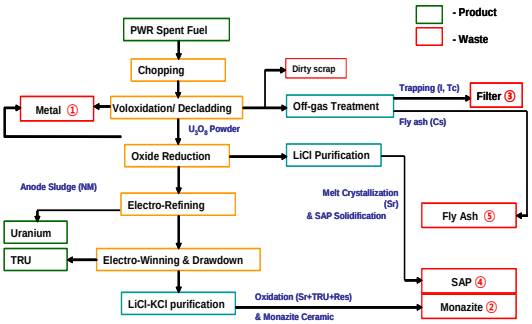

Fig. 1. Wastes stream and the classification in the pyro-processing (material balance 2.6.0, for PWR fuels) [1]

2.2 Composition of the CANDU SNF

The actinides of the reference CANDU SNF composed of 99.59 % of uranium, 0.40 % of plutonium and 0.01 % of minor actinides at ten years after reactor discharge. The composition of U-235 is 0.20 % which is similar with the depleted uranium from enrichment facilities. The composition of Pu-239 and Pu-241 are 0.26 % and 0.02 % and the plutonium purity is about 70.3 %.

The composition of actinides except U-238 of PWR and CANDU SNF are represented in Figure 2. The ratio of TRU to the actinides of CANDU is 1.04 % less than that of the PWR and the plutonium purity of CANDU is 8 % higher than that of a PWR. This low concentration of TRU reduces the economic profit of the pyro-processing of CANDU SNF. The possibility of misunderstanding and declination of the credibility on non-proliferation can be incurred due to the recovery of high purity plutonium with the lack of economic benefits.

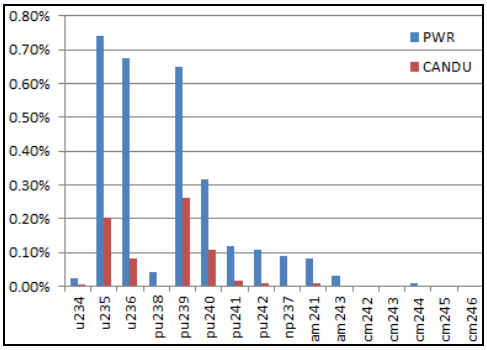

Fig. 2. The actinides composition except U-238 of PWR and CANDU SNF (Cf. PWR SNF: Plus7, 4.5 wt.% of U-235, 55 GWd/MtU)

2.3 Characteristics of waste from the pyro-processing of CANDU SNF

The calculated decay heat, radioactivity and toxicity of the reference CANDU SNF and its ceramic waste from the pyro-processing are calculated using the Origen-arp program, and presented graphically in Figure 3, Figure 4 and Figure 5 respectively. Considerable reduction in decay heat, radioactivity and toxicity by applying the pyro-processing on CANDU fuels are identified. For example, the decay heat, radioactivity of ceramic waste from the pyro-processing

of 1 MtU CANDU SNF at the time of disposal is 5.6 W and $1.7x10^3$ which is about 1/30 of CANDU SNF. The decay heat and radioactivity of the pyro-ceramic waste decrease rapidly after hundreds years after discharge due to the removal of the uranium and the TRU elements. By adopting pyro-processing on CANDU SNF, the disposal hole pitch can be reduced because the dimensioning of repository is controlled by mainly decay heat and subsidiarily structural safety.

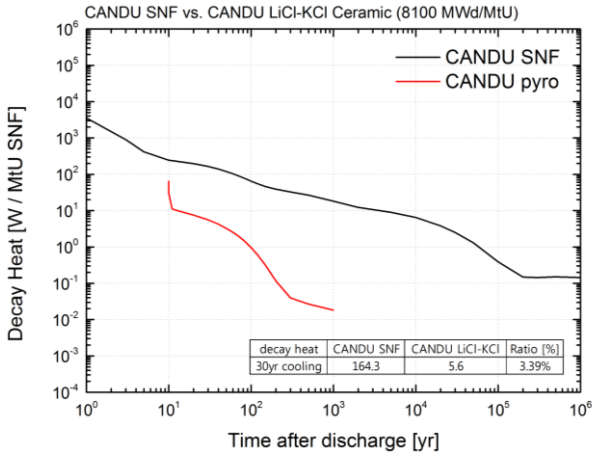

Fig. 3. Decay heat of CANDU SNF and pyro-ceramic waste

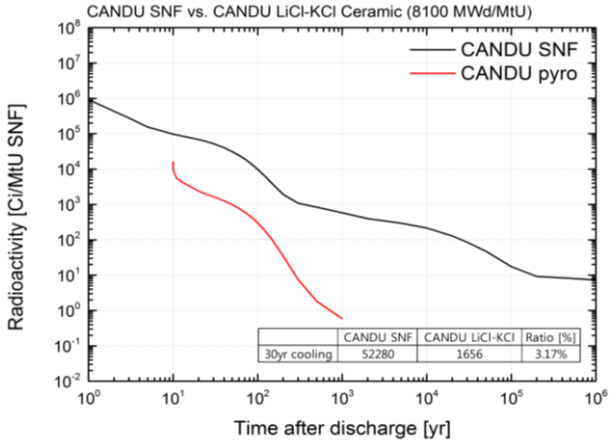

Fig. 4. Radioactivity of CANDU SNF and pyro-ceramic waste

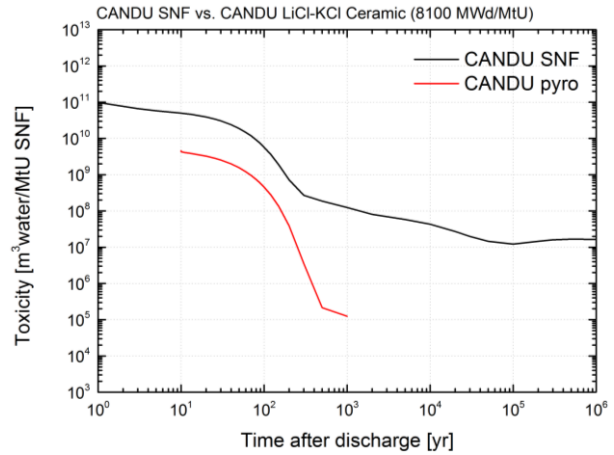

Fig. 5. Toxicity of CANDU SNF and pyro-ceramic waste

To analyze the safety of the repository and determine the institutional management period, it is essential to know the period under consideration. The significant period of the waste hazard can be determined by comparing toxicity of waste and natural uranium. The toxicity of ceramic waste and CANDU SNF reaches $1.1x10^7$ [2], which is the toxicity of natural uranium, at about hundreds of years and a few hundred thousand years respectively.

3. Conclusions

In this study, the preliminary evaluation on effect of application of the pyro-processing on CANDU SNFs in terms of source term is conducted. Though its low economic profit and vulnerability on non-proliferation due to the low concentration of TRU and high plutonium purity of CANDU SNF, the pyro-processing of CANDU SNF reduces decay heat and radioactivity as a factor of 1/30. The possibility of decrease in space of repository and institutional management period is identified from these results.

The designing of the repository for the waste from the pyro-processing of CANDU SNF will be conducted as a follow-up work to evaluate its effect on the disposal footprint area quantitatively. To design repository, composition and specification of the waste form and the engineering barrier system will be determined according to various scenarios and then dimensioning of deposition hole for each scenarios will be determined to comply with the limitation of the maximum buffer temperature.

In this study, the material balance 2.6.0 of the pyro-processing for the PWR SNFs is used because there is no available material balance for the CANDU SNF, although the source term greatly varies depend on material balance. To obtain reliable results, the material balance for the pyro-processing of the CANDU SNF must be developed and the source term re-evaluation based on the corresponding material balance must be accompanied in the future.

REFERENCES

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[2] Jong-Won Choi et al., (KAERI/TR-4525/2011) Geological Disposal of Pyroprocessed Waste from PWR Spent Nuclear Fuel in Korea, KAERI, p. 53, 2011