Analysis on the Deep Geological Disposal Concepts for CANDU Spent Nuclear Fuels

Jongyoul LEE[a*], Heuijoo CHOI[a], Changsoo Lee[a], Dongkeun CHO[a]
[a]*Korea Atomic Energy Research Institute, 989-111, Daedeokdaero Yuseong-gu Daejeon-city,34057*

**Corresponding author: njylee@kaeri.re.kr*

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1. Introduction

In Korea, two types of spent nuclear fuels are generated from two types of nuclear power plants, PWR type and CANDU type. The research and development related to direct disposal of spent nuclear fuel has been mainly conducted focusing on PWR spent nuclear fuel, but in this paper describes research results related to direct geological disposal of CANDU spent nuclear fuel.

The development of geological disposal concepts for CANDU spent nuclear fuel, which was heavy water reactor spent nuclear fuel generated along with PWR spent nuclear fuel, was also carried out through the development of the Korean Reference disposal System (KRS)[1]. After then, two concepts of CANDU spent nuclear fuels for direct deep geological disposal were proposed in KRS$^+$[2].

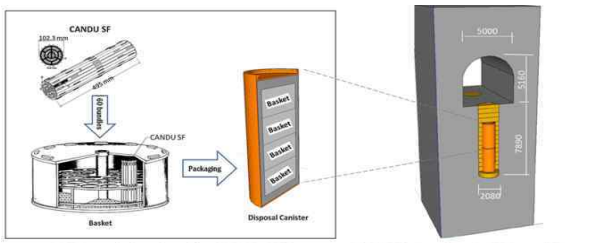
In this paper, to propose a reference concept, the two disposal concepts for CANDU spent nuclear fuels were analyzed.

2. Two Disposal Concepts for CANDU SNF

For the CANDU type spent nuclear fuels, two disposal concepts considering the disposal container concept with interim storage baskets (60 bundles/basket) were developed in KRS$^+$ during the long-term R&D program for spent nuclear fuels for safe management.

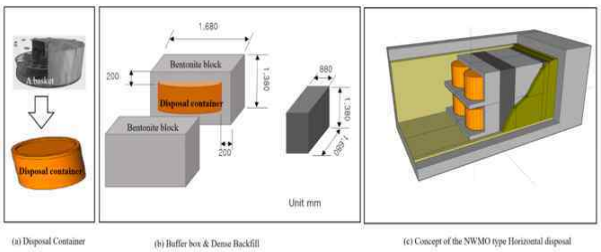
In a vertical type disposal concept of high burnup CANDU spent nuclear fuels, 4 baskets of 60 bundles (total 240 bundles) were loaded in a disposal container. The container material was a double layered of a cast iron inner vessel for structural support at the disposal depth environment and a copper outer shell for corrosion resistance. Also thickness of the copper outer shell for corrosion resistance was10 mm by cold spray coating or 3-D printing technology. Two disposal container with spent nuclear fuels would be emplaced in a deposition hole drilled at the floor of the disposal tunnel excavated in stable rock at a depth of 500 m. This disposal concept was shown in Figure 1.

Another disposal concept for CANDU spent nuclear fuels was a horizontal type disposal[3]. In this horizontal type disposal concept, 1 basket of 60 bundles was loaded in a disposal container. The container material was the same as the vertical type concept for the same purposes. A disposal container was surrounded by compacted bentonite buffer box, which was called supercontainer concept. This supercontainer assembly was emplaced horizontally in a disposal tunnel in stable rock at a depth of 500 m. This disposal concept was shown in Figure 2.



(a) Disposal Container for CANDU SNFs (b) KBS-3 Type Vertical Disposal System

Figure 1. Vertical type disposal concept



(a) Disposal Container (b) Buffer box & Dense Backfill (c) Concept of the NWMO type Horizontal disposal

Figure 2. Horizontal type disposal concept

3. Comparative analysis of two Disposal Concepts

As described above, two types of KRS$^+$ disposal concept for CANDU spent nuclear fuel have been proposed. Assuming that a disposal facility is built in rock with the same site conditions, the difference between the two disposal concepts is the engineered barrier. Therefore, in this paper, the differences in the engineered barriers of these two disposal concepts were compared and a reference disposal concept was selected based on the result of comparison[4].

The main components of the engineered barrier in a deep geological disposal system are the disposal container and the buffer material. The disposal containers and buffer materials of the two disposal concepts for CANDU spent nuclear fuels were compared quantitatively and qualitatively from the viewpoint of safety, economic feasibility/environmental friendliness, and technical maturity. The results of the

comparison were summarized in this chapter.

- Regarding the corrosion characteristics of disposal container in safety viewpoint, the lifespan of the copper container in the horizontal type concept was calculated to be slightly good, but considering the regulation, it was judged to be of little significance.
- Regarding the radionuclide migration in bentonite material in safety evaluation, the delay performance of engineered barriers for important nuclides after disposal site closure had almost same delay effect. In horizontal emplacement concept has a little bit favorable effect due to the thickness of the buffer material.
- The proportion of CANDU spent nuclear fuel disposal area in the entire disposal area including PWR spent nuclear fuel generated will be very low. So, it was judged that the difference in disposal area of the two concepts would not be significant from the viewpoint of the same amount of spent nuclear fuels. Due to differences in the way unit modules were packaged, the vertical emplacement type of disposal concept was judged to be more advantageous in terms of the material quantity required to produce an engineered barrier.
- For technical maturity, the vertical emplacement concept(KBS-3V) proposed by Sweden in the 1980s has been developed to the commercialization stage with construction license in Sweden and Finland. And the horizontal emplacement concept(NWMO type) similar to NWMO Canada concept has been currently in the full-scale production and demonstration test stage. Also, in Korea, research on direct disposal of spent nuclear fuel has been conducted mainly for the vertical type concept. Although there were many experiences in development of vertical type concept, it was judged that there would be no significant difference between vertical type concept and horizontal type concept in terms of technical maturity. Additionally, it was judged that the two concepts would be similar in terms of licensing.

4. Conclusions

A reference disposal concept for CANDU spent nuclear fuel was determined based on the criteria selected in this paper, and this may change depending on the disposal site environment or various method selection criteria. In this paper, considering the current situation where no project has yet been processed on the real disposal site, a concept was selected by analyzing the characteristics of the engineered barrier of the disposal concepts. The comparison results of the two disposal concepts are summarized in Table 1. Although the superiority of the two disposal concepts cannot be quantitatively compared, considering the current status of each country's disposal project, the vertical type disposal concept was judged to be slightly superior and would be better be selected as the reference disposal concept.

Table 1. Results of Comparison for two concepts

	Vertical Concept	Horizontal Concept
Safety	◎	◎
Eco-friendliness	◎	○
Technical Maturity	◎	○
Comprehensive evaluation	◎	○

◎ very good, ○ good

In addition, in consideration of various changes that are difficult to predict for the future, it is considered desirable to conduct additional research on the horizontal disposal concept, if necessary, as an alternative disposal concept.

References

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