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Disposal Container Concepts and Disposal Effectiveness Analyses According to the Spent Fuel Cooling Time for a Deep Geological Repository

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1. Introduction

A deep geological repository concept for the disposal of spent fuels from reactors involves emplacing heat-generating disposal containers with spent fuels at a depth between 500 to 1000 m in a plutonic rock mass. Extremely high and long-time scale radioactivity of them led to the idea of deep geological repositories in stable geological formations. The objective is to isolate the spent fuels from the biosphere for as long as they could be harmful to the people's health and the environment

Further delaying the spent fuels disposal results in a further decay of the radioactivity, in turn, reducing the intensity of the heat source of the waste.

In this study, based on the reference disposal concept which has been developed, to improve the disposal density, the correlations between spent fuel cooling times and the heat capacity of a disposal container satisfying the thermal requirement were reviewed. From this review, the concepts of a disposal container were proposed. According to the concepts of the disposal container, the effectiveness of the repository such as the area and disposal density was analyzed. The results of this study can be used in the design of a deep geological disposal system for a high level radioactive waste.

2. Requirements of a disposal system

2.1 Limitation of the repository for spent fuels

Though a geological disposal system consists of a multi-barrier, a natural barrier and an engineered barrier, there are a lot of uncertainties in a natural barrier. So, an engineered barrier should be implemented to establish the reliability of its safety.

The main requirement of an engineered barrier is to maintain the buffer temperature below the 100˚c. This is a major limitation for an underground repository layout to maintain the integrity of the repository system.

2.2 Unit disposal area

The concept of the unit disposal area considering the area between a disposal tunnel and a disposal pit spacing were set up as shown in Fig 1. Therefore, the overall scale of the repository can be estimated by multiplying the unit disposal area and the number of disposal packages. Also, the total disposal tunnel length can be estimated by multiplying the disposal pit with the number of disposal containers. From an economical point of view, it is desirable to set up the disposal tunnel spacing and the disposal pit spacing so that the repository area can be minimized and the disposal density can be high.

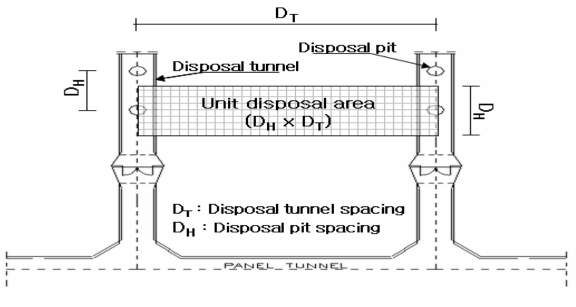

Fig. 1. Concept of the unit disposal area.

2.3 Reference spent fuels disposal concept

A long-term R&D program for a spent fuel direct disposal technology development in Korea was launched in 1997 and the Korean Reference spent fuel deep geological disposal System(KRS-V) has been developed. Table 1. shows the characteristics of the PWR spent fuels.

Table 1. Characteristics of the PWR spent fuels

	Amount (tU)	No. of Assembly	No. of Disposal Container
PWR	20,000	45,500	11,375

According to the thermal calculations to meet the requirement, the minimum distance between two deposition holes for the PWR disposal container was 6 m and the distance between the disposal tunnels was 40 m. These distances were determined by assuming that the heat generation of the containers was 1,540 W for a PWR.

3. Concepts of a disposal container and the relevant analyses

3.1 Concepts of a disposal container

Based on the reference concept, the assumption was that the heat generation of the container, 1540 W, can meet the requirement with the distance between disposal tunnels, 40 m and the deposition hole, 6m. So, if the cooling time of the spent fuels is longer than the reference concept, the number of spent fuels loaded in the disposal container can be increased. Table 2 shows the number of spent fuels in the disposal containers that meet the thermal requirement according to the cooling time. And also the concept of the disposal containers can be seen in Fig. 2.

Table 2. No. of spent fuels in a disposal container

Cooling Time (yr)	P(t) (W/4-ass.)	P(t) (W/5-ass.)	P(t) (W/6-ass.)
40	**1540.371**	1925.46	2310.557
54	1227.128	**1533.91**	1840.691
69	1019.162	1273.95	**1528.744**
Cooling Time	P(t) (W/7-ass.)	P(t) (W/8-ass.)	P(t) (W/9-ass.)
84	**1536.607**	1756.122	1975.638
100	1346.480	**1538.834**	1731.188
117	1195.487	1366.271	**1537.055**`
140	1043.516	1192.589	1341.663

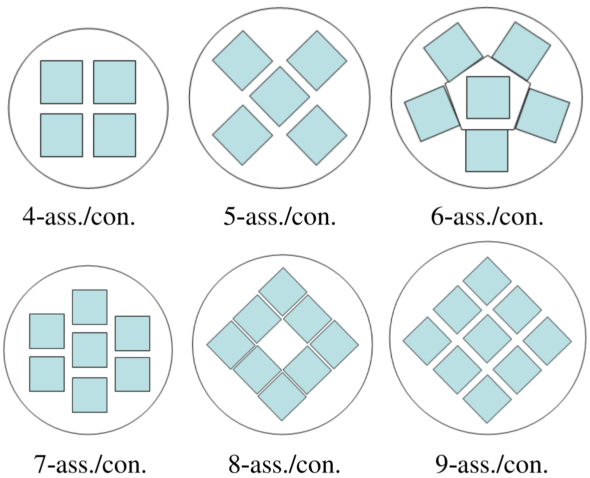

Fig. 2. Concepts of a disposal container.

3.2. Analyses of the disposal effectiveness

According to the disposal container concepts, certain kinds of disposal effectiveness were analyzed. They were the disposal area, the total length of the disposal tunnel, and the U density. The results are shown in Table 3 and 4.

Table 3. No. of disposal containers and the total length

	No. of Disposal container	Total length of Disposal Tunnel (m)
4-ass. /con.	11,375	68,250
5-ass. /con.	9,100	54,600
6-ass. /con.	7,583	45,500
7-ass. /con.	6,500	39,000
8-ass. /con.	5,688	34,125
9-ass. /con.	5,056	30,333

Table 4. Disposal area and U-density

	Disposal area (m^2)	U-density (kgU/m^2)
4-ass. /con.	2,730,000	7.33
5-ass. /con.	2,184,000	9.16
6-ass. /con.	1,820,000	10.99
7-ass. /con.	1,560,000	12.82
8-ass. /con.	1,365,000	14.65
9-ass. /con.	1,213,333	16.48

4. Conclusions and future plans

In this study, based on the reference disposal concept which has been developed, the correlations between the spent fuel cooling times and the heat capacity of a disposal container satisfying the thermal requirement were reviewed to improve the disposal density.
According to the concepts of the disposal container, the effectiveness of the repository such as the area, total length, and disposal density was analyzed.
The result shows that the repository volume and area can be reduced significantly (e.g., approximately more than a factor of two) by increasing the cooling time of the spent fuels from 40 to 120 years prior to a disposal.

The results from this research are expected to be implemented in the design of an HLW underground repository emplacement. Furthermore, more detailed analysis for real site characteristics data is required to minimize any uncertainties of a future site.

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