A Design Concept of Underground Facilities for the Deep Geologic Disposal of Spent Fuel

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1. Introduction

Spent nuclear fuel from nuclear power plants can be disposed in the underground repository. In this paper, a concept of Korean Reference HLW disposal System (KRS-1) design is presented. Though no site for the underground repository has been specified in Korea, but a generic site with granitic rock is considered for reference spent fuel repository design.

To implement the concept, design requirements such as spent fuel characteristics and capacity of the repository and design principles were established. Then, based on these requirements and principles, a concept of the disposal process, the facilities and the layout of the repository was developed.

2. Design Requirements & Principles

2.1 Spent fuel

Since Kori unit 1 in 1978, there are 19 operating nuclear power plants in 4 sites. There are 4 CANDU reactors in Wolsong and totally 15 PWR reactors in Kori, Younggwang and Uljin sites. Also 1 unit is under construction and 8 reactors in the planning phase.

The total amount of spent nuclear fuel from nuclear power plants was presented in Table 1.

Table 1. The total amount of spent fuel in Korea.

Fuel	Amount (tU)	Assemblies	Bundles	Canisters
PWR	20 000	45 000		11 375
CANDU	16 000		842 000	2 835
Total	36 000			14 210

The heat generation of the canisters is 1 540 W for the PWR and 760 W for the CANDU canister and the temperature at the canister surface shall not rise above 100 ºC. From this condition, the disposal tunnel space(40 m) and the deposition hole pitch(PWR 6 m, CANDU 4 m) were calculated.

2.2 Site data

Depth of the repository was assumed to be 500 meters. The repository site has not been chosen yet. The aim is to find a geologically stable and intact host rock volume with a surface area of approximately 8 km^2. In general, the host rock area should be free from significant structures. It should have suitable hydrogeological and geochemical characteristics and good mechanical and thermal properties.

The thermal gradient of the Korean bedrock depends on the area. Thermal gradient of 30 °C/km shall be used as a design basis for this concept.

Fracture zones are divided into four classes (Table 2). The repository shall be constructed so that the whole repository fits inside intact bedrock bordered by regional fracture zones (order 1). The disposal tunnel panels should be placed so that they will have 50 m safety distance to local major fracture zones (order 2). The disposal tunnels can penetrate local fracture zones (order 3), but there shall be certain safety distances to the nearest disposal holes.

Table 2. Classification of fracture zones

	Order	Length (m)	Width (m)	Interval (km)	T (m^2/s)	Safety distance (m)
Regional fracture zone	1	>10,000	>100	>4	1E-05	100 (to unit facility)
Local major fracture zone	2	1,000 -10,000	5 - 100	1 - 4	1E-06	50 (to deposition tunnels)
Local minor fracture zone	3A	500 - 1,000	1 - 5	1<	1E-07 - 1E-08	5 (to dep. holes)
	3B	<500	<1			3 (to dep. holes)
Bedrock fracture system	4	<10	<0,01	-	<1E-9	-

2.3 Disposal facilities

The repository consists of the disposal area, technical rooms and connections to the ground in the controlled area and technical rooms and connections to the ground in the uncontrolled area.

Disposal area consists of disposal tunnels, panel tunnels and central tunnel. Panel tunnels connect disposal tunnels and the central tunnel. Central tunnel leads from controlled area to uncontrolled area and connects panel tunnels to each other. Technical rooms in the controlled area include four shafts: canister shaft, personnel shaft and two ventilation shafts. Technical rooms in the uncontrolled area include correspondingly access tunnel, personnel shaft and two ventilation shafts.

2.4 Design principles

The underground repository shall be built safe, flexible, technically feasible, and acceptable by the public and the repository shall be built in a stepwise manner (one disposal tunnel panel pair at a time) taking into considerations the geology of the repository area.

The fuel canisters shall be handled in the controlled area of the repository. The excavation, the disposal hole drilling and the tunnel backfilling shall always take place in the non-controlled area.

The volume of the sedimentation pool should be such that it can treat water in case of a 48 hours long interruption in pumping.

The repository shall have two escape routes (access routes) from the underground facilities to the ground surface. A person shall be able to exit the repository within one hour.

3. Disposal Process

3.1 Canister properties

Canisters consist of two materials. Insert is carbon steel and outer shell is made from copper or Nickel alloy. Dimensions of PWR and CANDU fuel canister are equal:

- Canister outer diameter is 1,22 m
- Total length of canister is 4,83 m
- Canister weight with the fuel is about 39 100 kg

3.2 Disposal processes

Canisters are not designed in such a level that canister handling could be presented very detailed. Key procedures in canister handling could be:

- Canister is lowered to the repository in a carriage which is in the canister lift. Canister is in vertical position.
- Carriage is driven from the lift to loading station.
- Canister transfer vehicle picks up the canister and turns it to horizontal position.
- Canister transfer vehicle drives canister to the disposal tunnel.
- Canister transfer vehicle lowers the canister and simultaneously turns it to vertical position.

4. Concept of the Underground Repository

4.1 Basic Concept and Factors

The concept of the disposal tunnel and disposal hole is shown in the Fig. 1. Based on this concept, the layout of the repository was established.

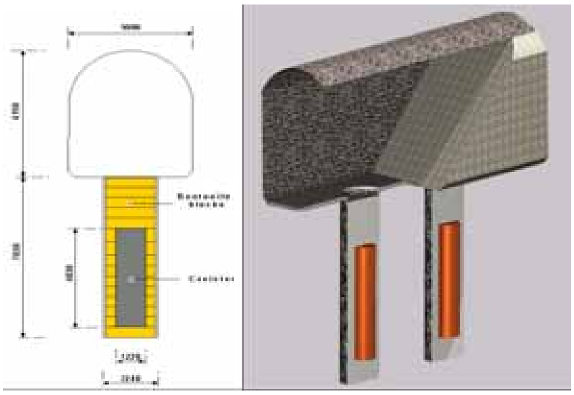

Fig. 1. Concept of the disposal tunnel and disposal hole.

Determining factors affecting layout have been:

- To divide repository to controlled and uncontrolled areas. Canister handling will always be performed in the controlled area. Excavation and backfilling will be done in the uncontrolled area.
- Border between controlled and uncontrolled area will move during the lifespan of the repository.
- Disposal and panel tunnels will be excavated and backfilled in phases during operation phase of the repository.
- Two escape ways from all the tunnels except disposal tunnels which are dead end tunnels.

4.2 Repository layout

The CANDU area contains 54 deposition tunnels with the length of 251 meters. The PWR area contains 323 deposition tunnels with the length of 251 meters. About 30 meters in the mouth of the tunnel is needed for concrete plug and fire wall. Plug is a massive concrete structure that can withstand the water pressure of 5 MPa and also the swelling pressure of the tunnel backfill material. Dimensioning of the deposition tunnels is presented in Table 3 and Fig. 2.

Table 3. Dimension of the disposal tunnels.

Deposition tunnels	Length 251 meters: PWR: 37 holes => 36 x 6 m + 30 m + 5 m = 251 meters CANDU: 55 holes => 54 x 4 m + 30 m + 5 m = 251 meters 30 meters is for concrete plug and fire wall in the mouth 5 meters is for equipments and vehicles in the end Width 5.00 meters Height 6.15 meters
Number of the deposition tunnels	PWR: 1,05 x 11 375 = 11 944 places for holes 11 974 / 37 = 323 deposition tunnels CANDU: 1,05 x 2 835 = 2 977 places for holes 2 977 / 55 = 54 deposition tunnels Totally 377 deposition tunnels

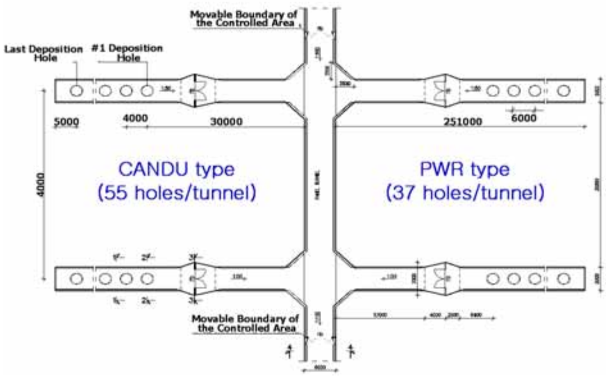

Fig. 2. Disposal area concept for CANDU & PWR fuels.

5. Conclusion

A concept of the underground repository for spent fuels was developed as a reference high level radwaste disposal system. To implement the concept, design requirements and design principles were established. Also, a disposal process and the facilities layout were established based on the requirements.

This design concept for the HLW disposal system can be used to evaluate feasibility of designed high-level waste disposal system, to serve as a guide for technical studies, to develop project planning and to help budget and funding calculations.

REFERENCES

[1] KAERI 2002. Progress Report on the R&D Program for the Disposal of HLW in Korea. Korea Atomic Energy Research Institute. August 20, 2002.

[2] Kukkola, T., Saanio, T., Choi, J. & Kang, C-H. 2003. KAERI's Spent Fuel Repository. Design Evaluation and Cost Estimation. T&K-report 2003-02.

[3] C. H. Kang, J. W. Choi, High-Level Radwaste Disposal Technology Development, KAERI/RR-2336/2002, KAERI