Estimation of CANDU spent fuel disposal canister lifetime

Dong-Hak Kook, Min-Soo Lee, Yong-Soo Hwang, Heui-Joo Choi
Korea Atomic Energy Research Institute, 1045 Daeduk-daero, Yuseong, Daejon

syskook@kaeri.re.kr

1. Introduction

Active nuclear energy utilization causes significant spent fuel accumulation problem. The cumulative amount of spent fuel is about 10,083 ton as of Dec. 2008, and is expected to increase up to 19,000 ton by 2020. Of those, CANDU spent fuels account for more than 60% of the total amounts.

CANDU spent fuels had been stored in dry concrete silos since 1991 and during the past 15 years, 300 silos were constructed and ~3,200 ton of spent fuels are stored now. Another dry storage facility MACSTOR /KN-400 will store new-coming CANDU spent fuels from 2009.

But, after intermediate storage ends, all CANDU spent fuels have to be disposed within multi-layer metallic canister which is composed of cast iron inside and copper outside.

Canister lifetime estimation, therefore, is very important for the final disposal safety analysis. The most significant factor of lifetime is copper corrosion, and Y. S. Hwang[1] developed a corrosion model in order to predict the general corrosion effect on copper canister lifetime during the final disposal period.

This research applied his model to KURT[1] where many disposal researches are being performed actively and the results shows safe margin of the copper canister for the very long-term disposal.

2. Model and Conditions

2.1. Model description

KAERI[2] has developed a final disposal concept for spent fuel named KRS[3]. KRS proposes to emplace spent fuel in a deep geologic formation such as a crystalline rock. Two key engineered barriers are applied to retard the potential release of a radionuclide from an embedded spent fuel; a waste container and an engineered barrier. Such an engineered barrier is composed of domestic Calcium bentonite and the waste container is composed of an outer copper layer and an inner steel layer. The outer layer, a copper layer is dedicated to protect a waste container against corrosion.(Fig. 1)

The main corrosion mechanism to corrode a copper waste container is a pitting whose speed of corrosion is five to twenty five times higher than that of a uniform corrosion.

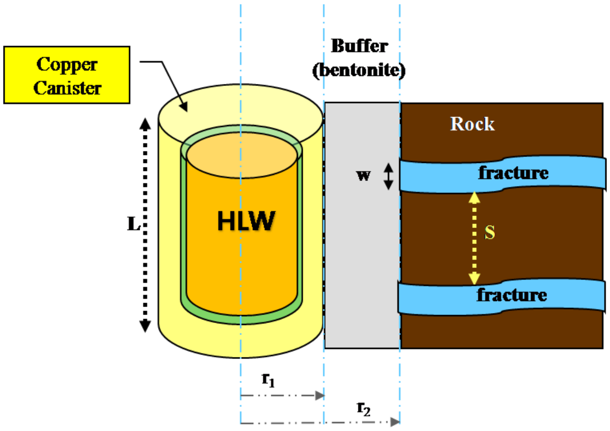

Fig. 1. Disposal concept diagram.

The main agent to corrode a copper container embedded in a reducing condition is sulfide. Sulfide exists in a fracture and a surrounding rock. In the Hwang's model, a special mass transfer resistance model which is equivalent to the theory of an electric resistance is developed to predict the migration of sulfide from a fracture to a waste container surface via a bentonite layer. Based on it, the lifetime of a copper canister layer limited by a pitting corrosion is estimated.

When resistances are identified for different flow conditions represented by a Peclet number[4], their mass transfer rates are predicted. In the case of high Peclet numbers (Pe>4), a dominant mass transfer path is through a fracture in a rock. However, if the fracture flow velocity becomes small enough, which is a case of a smaller Peclet number, the dominant mass transfer path is through a whole rock, which can be expressed as a porous medium.

Based on it, a copper canister lifetime by a uniform corrosion for a length of L and a fracture spacing of S can be estimated.

2.2.CANDU spent fuel disposal canister

High level waste disposal research team in KAERI suggested the new CANDU disposal canister which is improved to raise its efficiency[2]. This canister has 1 cm copper thickness in the most outside.(Fig. 2)

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1 Korea Underground Research Tunnel
2 Korea Atomic Energy Research Institute
3 Korea Repository System

4 Ratio of flow advection to diffusion

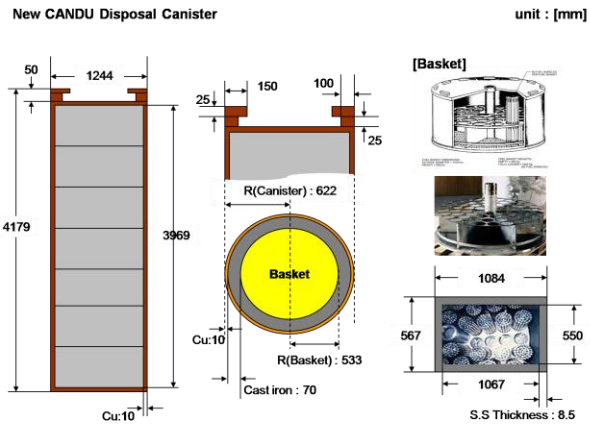

Fig. 2. CANDU disposal canister

2.3. KURT data

The main environmental data in KURT[3] are listed in Table 1. Buffer properties were used from KRS EBS[5] bentonite data.

Table 1. KURT data

Variable	Value
Copper Mass [g]	1.6e6
Sulfide Concentration [g/m^3]	6.5
Buffer porosity [-]	0.41
Buffer pore water Diffusion Co. [m^2/yr]	3.78e-4
Waste Package Radius [m]	0.622
Radial Buffer Thickness [m]	0.5
Atomic Mass Ratio [S:Cu]	1:2

3. Results

The fracture aperture and the ground water velocity are important factors affecting a canister lifetime. Since a wider fracture increases the mass transfer rate, the corresponding lifetime of a canister becomes shorter.

Figure 3 shows that even though rock fracture width has 1 cm and mass transfer condition is high (Pe > 4), the copper canister could maintain its integrity during over 10 million years with 1 cm copper canister thickness.

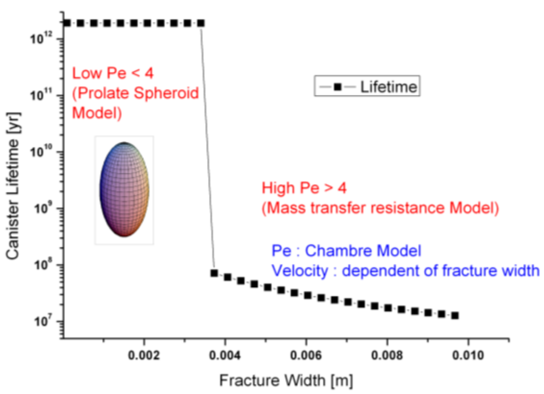

Fig. 3. Canister lifetime estimation

In this case, mass transfer resistance in a fracture is applied with Chambre model, and flow velocity is assumed to be dependent of fracture width. In low Pe number case, the estimation result shows more conservative values because the fracture flow velocity is very small, and therefore, the dominant mass transfer path is through a whole rock with a slow groundwater migration. This graph implies that the copper canister has enough stability to prevent a potential release of a radionuclide under deep geologic conditions where the dominant corroding agent is only sulfide.

4. Conclusion

Results show that under normal conditions, a copper layer of CANDU spent fuel canister can sustain its integrity for up to more than millions of years.

Acknowledgement

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