Analysis on Effect of Decreased Decay Time on Thermal Dimensioning of SNF Direct Disposal System

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1. Introduction

After declaration of reappraisal of HLW management basic plan in Aug. 2017, launching a new public engagement process for SNF management is expected in 2019. As a part of reassessment, various disposal scenarios could be considered. For instance, early disposal scenarios which contain finishing disposition of every SNFs in this century along with policy on transition of energy mix could be considered as a one option. For quantitative evaluation of these various disposal scenarios, effect of decreased decay time on thermal dimensioning of SNF direct disposal system need to be analyzed. In this study, minimum disposal hole pitches for SNFs which have shortened decay time in comparison with 40 years normal decay time are evaluated. And then management options for this hot SNFs are discussed.

2. Methods and Results

2.1 Thermal Analysis Model

In this study, the KRS SNF direct disposal system which depicted in Figure 1 is adopted [1]. In the KRS, four SNFs are disposed in a double-layer canister which is composed of inner cast iron canister and outer copper canister. Canisters are emplaced in the vertical boreholes and bentonite buffer fills space between canister and rock. Spacing of the KRS is strongly affected by decay heat of SNFs and minimum hole pitch is determined not to exceed 100℃ of bentonite peak temperature.

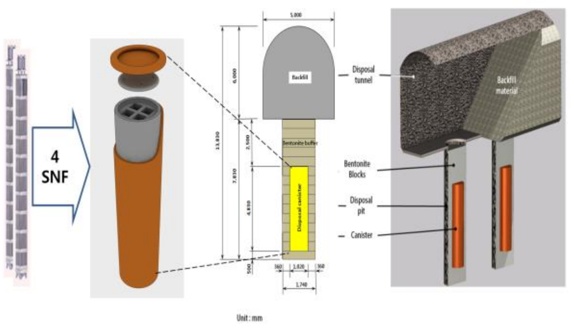

Figure 1. EBS concepts of KRS PWR SNF disposal system[1]

The Plus7 fuels having initial enrichment of 4.5 wt.% and discharge burn-up of 55 GWd/MtU were considered a representative fuel and cooling period was assumed to be between 10 years to 40 years [2]. Decay heat of representative fuel is calculated using ORIGEN-ARP. Thermal properties of the repository materials are given in table 1. Tunnel spacing of 40 m is analyzed only in this study. Considering symmetry condition, only quarter region of system is modeled in ABAQUS FEM models because of assumptions that every disposal canister is disposed at once and every bentonite is saturated immediately [2]. Based on measurement at KURT, geothermal gradient is assumed to be 30℃/km. Temperature of ground surface are assumed to be 10℃ [3].

Table 1. Thermal properties of system materials [3]

	Density [kg/m3]	Thermal conductivity [W/mK]	Specific Heat [J/kgK]
Cast Iron	7,200	52	504
Copper	8,900	386	383
Ca-bentonite	1,970	0.8	1,380
Backfill	2,270	2.0	1,190
Rock	2,600	3.0	900

2.2 Results

Bentonite peak temperatures depending on disposal hole spacing are depicted in Figure 2. Bentonite peak temperatures of system which contains 10-year-cooled SNFs exceed 140℃, even though disposal hole pitch is assumed to be 40 m compared to 9 m of reference design [2]. Until cooling time is increased to 30 years, bentonite peak temperatures do not decrease under 100℃. Bentonite peak temperatures can be decreased under 100℃ when decay time is over 35 years. Minimum hole pitch at this decay time is about 14 m. To dispose SNFs in KRS system, decay time of SNFs must be more than 32 years.

Until disposal hole pitch reaches 20 m, bentonite peak temperature decreases as hole spacing increases. Over 20 m of hole pitch, bentonite peak temperatures hardly decrease, despite increase of disposal hole pitch. Thus, increase of disposal hole pitch more than 20 m is ineffective in the perspective of thermal dissipation.

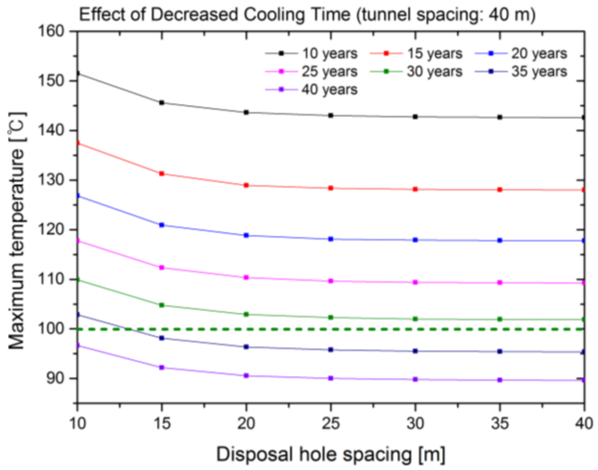

Figure 2. Peak temperatures of bentonite depending on disposal hole spacing

Figure 3 shows bentonite peak temperatures depending on depending on decay time. To dispose SNFs in the system having 10 m of disposal hole pitch, more than 37 years of decay time are needed. And minimum 32 years of decay time is necessary for system having 40 m of disposal hole pitch. Again, more than 32 years of decay time is required to dispose SNFs in KRS system and increase of disposal hole spacing over 20 m has no effect.

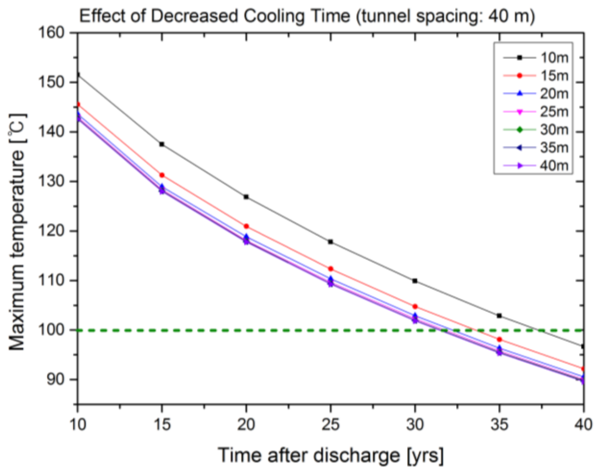

Figure 3. Peak temperatures of bentonite depending on decay time of SNFs

There are several ways to manage this hot SNFs. The easiest way is mixing SNFs with old SNFs which have enough decay time. This means controlling of maximum thermal power of canisters. For Instance, combination of SNFs which have 1900 W/canister can be disposed in the system having 40 m of tunnel spacing and 9 m of hole spacing. Another less efficient way is disposing canisters with vacancy. Conditioning of SNFs which include oxide reduction can be considered a last resort.

3. Conclusions

In this study, thermal dimensioning of systems containing SNFs having shortened decay time less than 40 years is analyzed to produce quantitative evaluation data for early disposal scenarios. It is verified that minimum decay time of SNFs must be more than 32 years to dispose SNFs in the KRS system and increase of disposal hole spacing over 20 m is ineffective in the perspective of heat dissipation. Controlling of maximum thermal power of canisters that means mixing SNFs with old SNFs is the most effective way and conditioning of SNFs can be considered a last resort to manage hot fuels. Results of this study can be used as a background material for reassessing various disposal scenarios for a new public engagement program.

Acknowledgement

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