Long-Term Heat Load Calculations for Spent Nuclear Fuel

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1. Introduction

The short-term decay heat at the shutdown of a repository active cooling and the integrated long-term decay heat determine the amount of waste that can be emplaced into the repository [1].

The cumulative amount of heat generated by the spent fuel and/or high-level waste between about 100 years and 1500 years after the spent fuel has been discharged from the reactor are quantified by integrating the individual isotope decay heat over that period. In this study, the DYMOND [2] code tracks the amount of these isotopes (that are destined to the repository) at each time and multiples the mass of each isotope by the corresponding factor to determine the integrated long term decay heat associate with that isotope.

This paper describes a simple methodology for estimating the integrated decay heat integrals for the different isotopes of interest over flexible periods of time, which can be easily implemented into system dynamics codes. Application results of the methodology to the Korean fuel cycle scenario which includes both the PWR and CANDU reactors are also presented.

2. Heat Load Calculation Methodology

The heat load factors are calculated by the following equation:

$$HL = M_{t1} \cdot HLF$$

where HL = Heat load [W-yr],
M_{t1} = Isotope inventory at specific time t1 [g],
HLF = integrated heat load factor [W-yr/g].

The HLF can be calculated by

$$HLF = DH_i \cdot DHF_i + DH_{id} \cdot DHF_{id}$$

where DH_i = decay heat of isotope i [W/g],
DHF_i = decay heat factor of isotope i [yr],
DH_{id} = decay heat of daughter of a isotope i [W/g],
DHF_{id} = decay heat factor of a daughter of isotope i [yr]

The DHF_i and DHF_{id} can be calculated by

$$DHF_i = \frac{1}{\lambda_i}\left[e^{-\frac{t_1}{\lambda_i}} - e^{-\frac{t_2}{\lambda_i}} \right]$$

$$DHF_{id} = \frac{\lambda_d}{\lambda_d - \lambda_i}[DHF_i - DHF_d]$$

where λ_i = decay constant of isotope i [1/yr],
λ_d = decay constant of a daughter of isotope i [1/yr],
t_1 = starting time of integration [yr],
t_2 = termination time of integration [yr].

Once the heat load factor for each tracked isotope is calculated, the factor is then used as a multiplier for the isotope inventory tracked by the system dynamics code, to calculate the contribution of the isotope to the long-term repository heat load. The total long-term repository heat-load indicator is calculated as the sum of contributions from different isotopes.

3. Application to Korean Nuclear Fuel Cycle

The fuel cycle model considers both the PWR and CANDU reactor, which are currently operating in Korea. Based on the nuclear power plant construction plan, in which the nuclear power is expected to grow from 13.716 GWe in 2000 to

27.32 GWe in 2015. From 2016 to 2100, the growth rate was assumed to be 0%. As given in Table I, the spent fuel (SF) inventory increases with time and the total PWR SF will be ~54 kt in the year 2100. Beyond 2049, the CANDU SF remains constant at ~17 kt, since the CANDU reactor is not constructed after 2040.

Table I Accumulation of spent fuel with time in the Korean fuel cycle scenario

Year	PWR (kt)	CANDU (kt)
2000	2.65	2.31
2020	8.08	6.92
2040	18.68	14.01
2060	30.16	17.10
2080	42.14	17.10
2100	54.37	17.10

The heat loads were calculated for the cooling times of 5, 10 and 20 yrs. It was assumed that the SF is disposed of in the repository after the cooling period and there is no active cooling of the repository beyond that period.

The long term heat loads were calculated for the annual SF production from 2000 to 2100. It is known that the actinides mainly dominate the heat load. Figure 1 compares the PWR SF long-term heat load for different cooling times. For the cooling times of 5, 10 and 20 yrs, the total heat loads are ~9600, ~9000 and ~8300 MW-yrs, respectively.

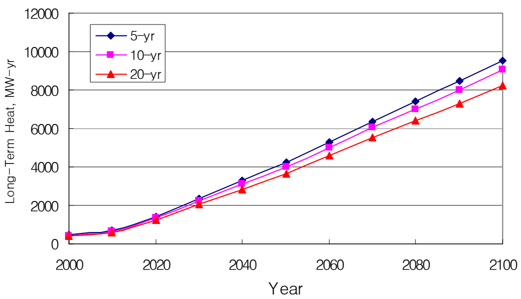

Fig. 1 Comparison of total heat load for different cooling times of the PWR SF

Like the case of the PWR SF, the actinides mainly dominate the heat load for the long term decay of the CANDU SF. As compared in Figure 2, the total heat loads for cooling times of 5, 10 and 20 yrs are ~690, ~650 and ~600 MW-yrs, respectively, which are much smaller when compared with those of the PWR SF.

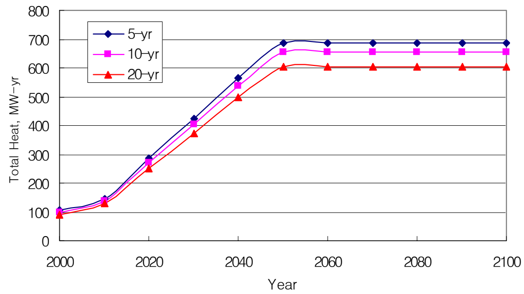

Fig. 2 Comparison of total heat load for different cooling times of the CANDU SF

4. Summary

From the results, it can be summarized as follows:

- The actinides dominate the long-term heat load, especially the Pu and Am isotopes.
- For the PWR SF in the Korean fuel cycle scenario, the long-term heat of a 5-yr cooling time is 9600 MW-yr. The long-term heats of the 10-yr and 20-yr cooling times are reduced by ~6% and ~14%, respectively, when compared with the 5-yr cooling case.
- For the CANDU SF, the total long-term heats for the 5-yr, 10-yr and 20-yr cooling times are 690 MW-yr, 650 MW-yr and 600 MW-yr, respectively.

ACKNOWLEDGEMENTS

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