Comparison of Decay Heat Evaluation Methods for Spent Nuclear Fuel Storage Pool Temperatures Assessment

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1. Introduction

After the operation of a nuclear power plant, the spent nuclear fuel (SNF) generated is stored in the spent fuel pool (SFP) once discharged from the reactor. The storage capacity of the SFP is determined by the configuration of the storage racks and the dimensions of the pool. In addition, to evaluate whether the maximum allowable number of fuel assemblies can be accommodated, it is necessary to assess the cooling capacity of the SFP to ensure adequate removal of decay heat from the stored fuel.

For calculating the decay heat of SNF, the commonly used methods are the BTP ASB 9-2 [1] approach presented in NUREG-0800 and the methodology specified in ANSI/ANS 5.1 [2]. This study aims to compare the temperature evaluation results for different SFP storage scenarios by reflecting both the decay heat calculated from each method and the capacity of the cooling system.

2. Evaluation Method

Decay heat of spent nuclear fuel are consist with fission products, neutron capture, U and Np decay, and actinide in ANSI/ANS 5.1. This method applies to shutdowns times up to 10^{10} seconds and should not be extrapolated over 10^{10} seconds. Otherwise, Decay heat for BTP ASB 9-2 are calculated using fission products and heavy elements. Experimental data used in fission product decay have been considered reliable for decay times of 10^3 to 10^7 seconds. Over this decay time, the decay heat rate can be predicted to within 10% of experimental data.

Total time-varying decay heat generation rate in SFP is calculated from decay heat of previous offloaded fuel and recently offloaded fuel with heat removal from heat exchangers of an SFP. The transient thermal response of an SFP and an SFP cooling system to thermal loads is governed by the following equation:

$$Q_{pool} = Q_{previou} + Q_{recent} - Q_{SFPCS}$$

Heat removal from the SFPCS is a nonlinear function of the bulk temperature and the cooling water temperature with heat exchanger performance.

The ANSI/ANS 5.1 method requires the user to define the isotopic fractions of uranium-235, uranium-238, plutonium-239, and plutonium-241. However, analytical review indicates that the most influential parameter is the plutonium fraction. According to the LLNL [3], the amount of plutonium increases as burnup progresses, as shown in Fig. 1. Therefore, this study adopted the maximum plutonium fraction reported in that reference.

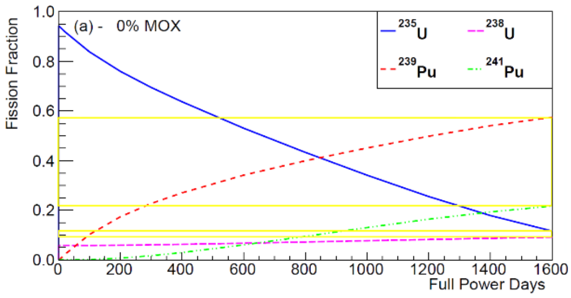

Fig. 1. Fission product ratio for spent nuclear fuel

Fig. 2 shows the temperature evaluation results over time for reloaded scenario. Under the same conditions, the ANSI/ANS 5.1 methodology was evaluated to have a higher temperature than the ASB 9-2 methodology. The results of the ANS 5.1 (with using fission product ratio and uncertainty) and the ASB 9-2 do not differ significantly in terms of trends when compared across the entire time period. However, the period of greatest influence in the calculation of the temperature of SFP is after about 300 hours shown in Fig. 2.

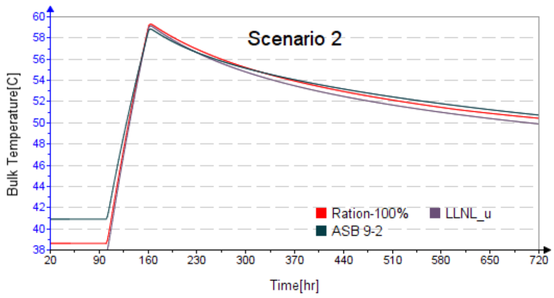

Fig. 2. Calculation Results for reloaded scenario

3. Conclusions

The evaluation results for decay heat and temperature under different SFP storage scenarios showed that the ASB 9-2 methodology yielded the lowest decay heat values. In contrast, the ANSI/ANS 5.1 method produced results that varied depending on whether uncertainties in decay heat were considered. In particular, the ANSI/ANS 5.1 results were found to be highly sensitive to how the isotopic fractions of uranium-235, uranium-238, plutonium-239, and plutonium-241 were applied. When the maximum plutonium fraction suggested in the LLNL report was applied, it was confirmed that the cooling system capacity remained sufficient even when considering the uncertainties in decay heat.

Therefore, it is concluded that when applying the ANSI/ANS 5.1 methodology for SFP decay heat evaluation, referencing the LLNL report allows for sufficiently conservative assessments.

REFERENCES

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