Thermal Evaluation Based on Spent Fuel Transport Velocity

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1. Introduction

Due to the saturation of storage capacity for spent fuel domestically, various alternatives are being explored. In this paper, a thermal evaluation is conducted on the installation of additional high-density storage racks as one of the alternatives to expand storage capacity.

High-density storage racks are new ones that can store and accommodate spent fuel more than the existing ones. Similar to conventional storage racks, when new racks are installed, it is essential to manage the temperature of the storage pool below 60°C during wet storage of spent fuel, even as the number of spent fuel assemblies increases due to the installation of new racks. Particularly, under normal operating conditions, only about one-third of the core fuel is loaded into the pool. However, during refueling or abnormal conditions, all of the core fuel is loaded, making it crucial to maintain the temperature below 60°C and secure additional margin.

For conservative decay heat evaluations, loading all fuel assemblies at once (in a single moment) is common practice. However, due to the significant temperature increase that would occur all at once, this is not practically executed. Therefore, this study aims to evaluate the temperature impact based on fuel transfer velocity to establish a foundation for determining a safe transfer velocity that ensures sufficient margin.

2. Methods and Results

The decay heat calculations were performed using the equation described in Branch Technical Position ASB 9-2. The equation used for temperature calculations is as equation (1).

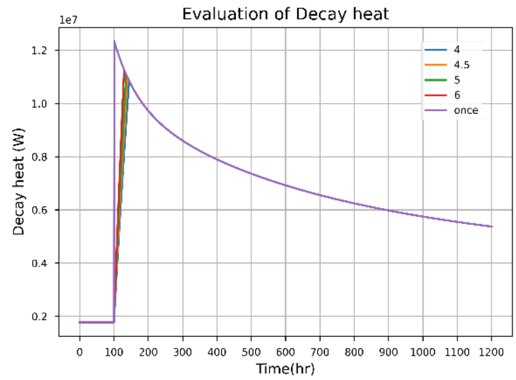
$$(1)\ \mathrm{T_{pool}}(t+dt) = \frac{Q_{gen}-Q_{hx}}{C_{pool}}dt + T_{pool}(t)$$

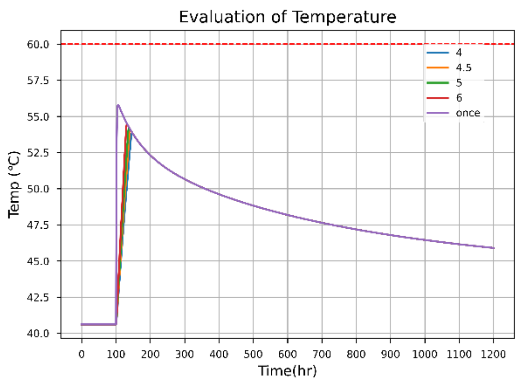
When using this differential equation, the chattering phenomenon occurred when the time interval was increased significantly. To resolve this, the RK4 method, commonly used for modeling time-dependent systems, was employed.

Runge-Kutta 4 equation :

$$(2)\ X_{i+1} = X_i + \frac{dt}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$
$$k_1 = f(t, X_i)$$
$$k_2 = f\left(t + \frac{1}{2}dt, X_i + \frac{k_1}{2}dt\right)$$
$$k_3 = f(t + \frac{1}{2}dt, X_i + \frac{k_2}{2}dt)$$
$$k_4 = f(t + dt, X_i + k_3 dt)$$

The reactor type utilized for this evaluation was OPR1000. For the evaluation of temperature based on spent fuel transport velocity, the number of spent fuel assemblies transported per hour was considered to be 4, 4.5, 5, and 6, as well as the case where all assemblies are loaded at once. Typically, evaluations are conducted for Normal, Refueling, and Abnormal operation scenarios. However, in this paper, only the Refueling scenario, which demonstrates significant temperature differences based on transport velocity, is discussed. The calculation results are as follows.





The deviation rates from the maximum temperature values for each transport velocity, compared to the design requirement temperature of 60°C, were calculated. The results are presented in the table below.

Table I: Calculation Result

SF_tranport (FA/hr)	Max Temperature	Deviation Rates
4	53.85	10%
4.5	54.04	10%
5	54.20	10%
6	54.45	9%
3600	55.80	7%

3. Conclusions

Utilizing the RK4 method allowed for accurate and rapid computation of results even with increased time intervals. Additionally, it is anticipated that conducting thermal evaluations of high-density storage racks using the fuel transport velocity specified in the Final Safety Analysis Report (FSAR), which is 6FA/hr, instead of the conservative evaluation method typically employed, will secure a comfortable operational margin. This approach is deemed beneficial for determining the appropriate transport velocity in the future.

REFERENCES

[1] NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants”, Section 9.2.5 Ultimate Heat Sink. Rev. 2.
[2] Regulatory Guide 1.13, “Spent Fuel Storage Facility and Design Basis”.