Sensitivity Study on Input Parameters used in the Spent Fuel Pool Cooling Capacity Evaluation

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1. Introduction

The spent fuel pool bulk temperature of the spent fuel pool(SFP) should be maintained below general acceptance criteria by properly removing decay heat generated in the spent fuel assemblies. Such an evaluation of the cooling capability for the spent fuel pool is divided into the decay heat load and the bulk temperature calculation. In this study, the sensitivity analysis of input parameters was performed in evaluating the cooling capability of the spent fuel pool.

2. Methods and Results

2.1 Calculation Method

The decay heat of the spent fuel assemblies is calculated by multiplying the dimensionless decay power and the average fuel assembly operating power. The dimensionless decay power is computed by the equation written in Branch Technical Position ASB 9-2, “Residual decay energy for light reactor for long term cooling”. The SFP decay heat load is determined by considering discharge time after shutdown, fuel transfer rate, batch size, discharge cycle length and the number of SFP rack cell. The governing differential equation for SFP bulk temperature can be expressed by utilizing conservation of energy as:

$$C\times\frac{dT}{d\tau}=P_{cons}+Q(\tau)-Q_{HX}(T)-Q_{EVAP}(T,T_A)-Q_{COND}$$

Where:
C is a thermal capacity of water in the pool
P_{cons} is a heat generation rate from “old” fuel
$Q(\tau)$ is a heat generation rate from recently discharge fuel as a function of time
$Q_{HX}(T)$ is a SFPCS heat removal
$Q_{EVAP}(T, T_A)$ is a evaporative heat loss
Q_{COND} is a heat loss by conduction through pool walls (Conservatively neglected)
T is a bulk pool temperature
T_A is a fuel building ambient temperature

2.2 Selection of Sensitivity Input Parameter

In this study, sensitive input parameters generally close to standard type power plant were selected in order not to be plant-oriented. Plant specific data was excluded in sensitivity input parameter. Table I shows the plant specific data for this study.

Table I: Plant specific data

	Parameter	Data
Decay Heat Load	Cycle length	18 month
	Batch / Core size	68 / 177 FA
	SFP capacity	1000 cell
	Reactor power	3000MWt
Bulk Temperature	SFP volume	$1000m^3$ (from rack top to water surface : $600m^3$)
	Volume of structure in SFP	$100m^3$
	SFPCS heat exchanger design value	- flow rate · shell: 3500gpm · tube: 3000gpm - temperature : · shell: 95°F(in) / 113.6°F (out) · tube: 140°F(in) / 118.3°F (out)
	SFP building ambient temperature	104°F

Table II shows the selected input parameters and the application method for the sensitivity analysis.

Table II: Input parameters and the application method

	Parameter	Application method	
		Conservative(1)	Best-estimate(2)
Decay Heat Load	Cumulative reactor operating time(A)	Based on 3 cycles (1644 day)	Based on Burn-up (1560 day)
	Uncertainty factor “K” (B)	0.1	0.0
	FA Withdrawal history (C)	Based on batch size	Based on (full core FA/ 3 cycles)
	Fuel transfer rate (D)	Instantaneously	Actually (6FAs/hr)
Bulk Temperature	Decay heat load (Ⅰ)	Conservative value (A1B1C1D1)	Best-estimate value (A2B2C2D2)
	Pool water volume (Ⅱ)	Considering from rack top to water surface	Net water volume in SFP
	Pool water density (Ⅲ)	Minimum value (32°F~150°F)	Value at temperature that amount to smallest multiplying lensity and specific heat
	Pool water specific heat (Ⅳ)	Minimum value (32°F~150°F)	

2.3 Method of Sensitivity Analysis

The scenario for this calculation was defined as follows that referred to the maximum heat energy written in SRP 9.1.3.

- Scenario I: A refueling core is transferred to SFP 150 hours after reactor shutdown. The heat load from this freshly discharged batch and background heat load from old fuels discharged previously is removed by one SFP cooling train.
- Scenario II: A full core 150 hours after reactor shutdown and a refueling core 36 days after reactor shutdown are transferred to SFP. The heat load from both a full core and refueling core, and background heat load from old fuels discharged previously is removed by two SFP cooling train.

The sensitivity analysis was performed for the decay heat load and the bulk temperature, respectively. The sensitivity factor for given input parameters was defined as:

$$F_S = \frac{R_C - R_O}{R_C}, \qquad 0 \le F_s \langle 1$$

Where:
R_C is a result of the calculation for the most conservative combination
R_O is a result of the calculation for the optimized combination of only one input parameter

If the sensitivity factor of the input parameter is large, it affects the major effect in SFP cooling capacity evaluation.

2.4 Sensitivity Analysis Results

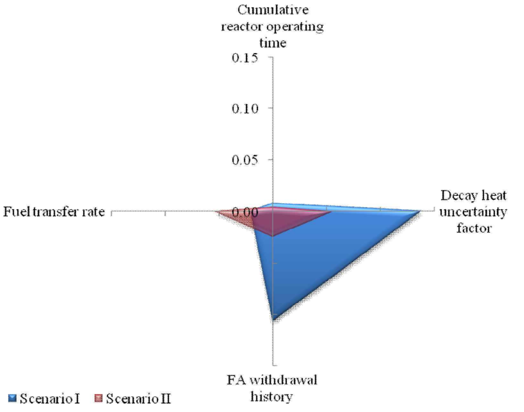

Fig. 1. Sensitivity Analysis results in SFP decay heat load calculation.

Figure 1 shows the result of sensitivity analysis considered input parameters in the SFP decay heat load calculation. The decay heat uncertainty factor, fuel transfer rate, and fuel assembly withdrawal history are major influential parameters, where the cumulative reactor operating time is minor influential parameter as shown in Fig. 1.

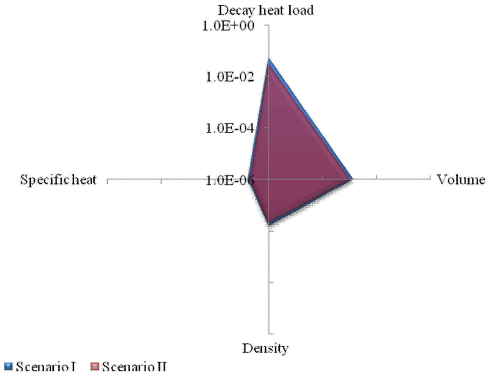

Fig. 2. Sensitivity Analysis results in SFP bulk temperature calculation.

Figure 2 shows the result of sensitivity analysis considered input parameters in the SFP bulk temperature calculation. The pool water volume and decay heat load are major influential parameters but the pool water specific heat and density are minor influential parameters as shown in Fig. 2.

3. Conclusions

The sensitivity study of the input parameters used in the SFP cooling capacity evaluation was performed to evaluate the affection of the decay heat load and the bulk temperature. In order to enhance the accuracy of the calculation, major influential input parameters should be carefully handled in reality. So as to increase the economical efficiency of the evaluation, minor influential input parameters can be managed having conservatism.

REFERENCES

[1] USNRC Branch Technical Position ASB 9-2, "Residual decay energy for light reactor for long term cooling", Rev. 2, 1981.
[2] USNRC SRP 9.1.3, "Spent Fuel Pool Cooling and Cleanup System", Rev. 1, 1981.