

## Evaluation of safety margin sensitivity to initial conditions during reactivity transients in a critical facility

Donghyun Kim \*, Su-ki Park

Research Reactor Design Division, Korea Atomic Energy Research Institute,  
 111, Daedeok-Daero 989 Beon-Gil, Yuseong-Gu, Daejeon, 34057, Korea

\*Corresponding author: dhkim1113@kaeri.re.kr

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### 1. Introduction

A critical facility is a zero-power reactor designed for simplicity and inherent safety [1]. While a previous study[2] analyzed the sensitivity of reactivity insertion accidents (RIA) for the conceptual design, the design of the critical facility has since progressed beyond the conceptual stage. Accordingly, it is now necessary to evaluate safety margins using the updated design data, shifting the focus from intrinsic design variables to initial operating conditions essential for safe operation.

In this study, an evaluation of safety margin sensitivity to initial conditions was conducted based on the design data using MARS-KS[3]. The analysis specifically focuses on the effects of initial power and coolant temperature on the reactor's behavior during reactivity transients. These results are expected to provide a technical basis for establishing the safe operating envelope of the critical facility.

### 2. Methods

Figure 1 shows the calculation model based on the design data of the critical facility. The model is composed of the core, inlet and outlet plenums, grid plate, support plates, and the surrounding pool.

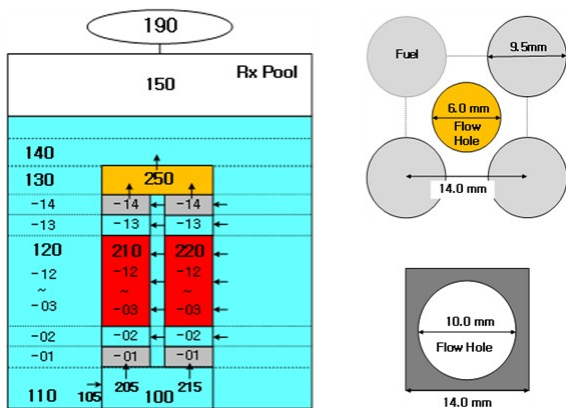


Fig. 1. Calculation model for the design of the critical assembly

Figure 2 presents the normalized axial power distribution used in the analysis. For a conservative

evaluation, an axial peaking factor of 2.0 was applied to this distribution.

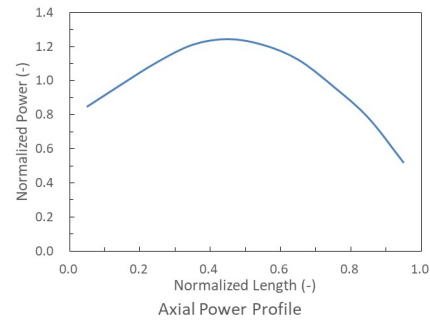


Fig. 2. Normalized axial power distribution

To evaluate the sensitivity of the safety margin, the reactivity insertion accidents (RIA) were simulated under various initial conditions. The initial power level was varied from 1 W to 100 W, and the initial coolant temperature ranged from 20 °C to 60 °C. A step reactivity of 5 mk was assumed to be inserted into the critical facility to initiate the transient.

### 3. Results and Discussion

In this study, the effects of initial power and coolant temperature on reactivity transients were analyzed based on the design data of the critical facility.

#### 3.1 Effect of initial coolant temperature

Table 1 presents the results of varying the initial coolant temperature from 20°C to 60°C with the initial power fixed at 10 W. As the temperature increased, the minimum CHFR significantly decreased from 7.56 to 5.96. Conversely, the maximum fuel temperature notably dropped from 326.7°C to 278.2°C. A higher initial coolant temperature leads to earlier saturation, triggering prompt reactivity feedback that limits the power excursion and reduces the maximum fuel temperature. However, despite the lower peak power, the increased void fraction and associated flow variations are considered the primary factors reducing the minimum CHFR margin. Figure 3 shows the transient behavior of CHFR and temperatures for the 10 W and 60°C condition. The sharp decrease in CHFR

and the subsequent temperature peak demonstrate the prompt feedback and cooling characteristics discussed above.

Table 1. Calculation results for various initial coolant temperatures at a fixed initial power (10 W)

Initial Power (W)	Coolant Temp. (°C)	Max. power (W)	Min. CHF	Max. fuel temp. (°C)
10	20	8.97E+05	7.56	326.7
10	40	8.38E+05	7.42	293.4
10	60	7.91E+05	5.96	278.2

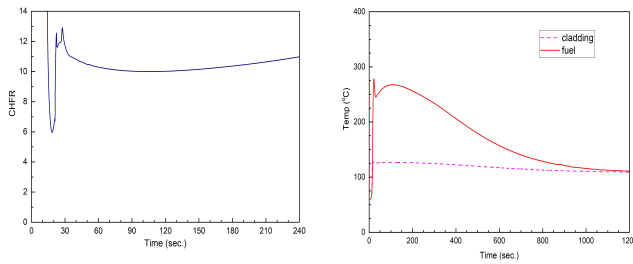


Fig. 3. Transient behavior of CHF (left) and fuel/cladding temperatures (right) during RIA (Initial condition: 10 W, 60°C)

### 3.2 Effect of initial power

Table 2 shows the results of varying the initial power from 1 W to 100 W under two coolant temperature conditions (20°C and 60°C). The minimum CHF exhibited a slight increasing trend as the initial power increased. The maximum fuel temperature showed a minor decrease at higher initial power levels.

Table 2. Analysis results for various initial power levels at specific coolant temperatures (20°C and 60°C)

Initial Power (W)	Coolant Temp. (°C)	Max. power (W)	Min. CHF	Max. fuel temp. (°C)
1	20	8.88E+05	7.55	326.9
10	20	8.97E+05	7.56	326.7
100	20	8.88E+05	7.62	325.5
1	60	7.96E+05	5.93	278.9
10	60	7.91E+05	5.96	278.2
100	60	7.92E+05	5.96	278.4

### 3.3 Summary

Overall, the minimum CHF tends to decrease with lower initial power and higher coolant temperature, while the maximum fuel temperature is highest at lower initial power and lower coolant temperature. The influence of initial power was found to be minor, with the coolant temperature being the dominant factor. In all analyzed cases, both the minimum CHF and the maximum fuel temperature remained well within the

safety limits, confirming the integrity of the critical facility.

## 4. Conclusions

This study analyzed safety margins for a critical facility under various initial conditions. Initial coolant temperature was more influential than power; higher temperatures reduced fuel temperatures via earlier reactivity feedback but decreased MCHF due to void and flow effects. All results remained within safety limits, confirming the inherent safety of the design during reactivity accidents.

## REFERENCES

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