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Sensitivity Test of RIA in 5MW Research Reactor during Startup

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1. Introduction

Sensitivity test of reactivity induced accidents (RIAs) are performed to demonstrate the safety of research reactor during startup. Inadvertent withdrawal of a control rod during startup operation is a RIA initiated by an operator error or a failure of control rod drive mechanism. During startup operation, control absorber rods are not located in the equal critical position since they can be manually controlled by an operator without position limitation. Therefore, the power peaking factor in this control mode becomes larger due to the skewed power shape, making the accident consequence worse. In research reactor, the reactor protection system (RPS) has linear power trip and power lograte trip for a safe shutdown of reactor in the accident, and the occurrence of those trips depend both on the initial reactor power and the reactivity insertion rate. Therefore, with a series of sensitive analyses, we identified the most severe combination of initial conditions among the various initial reactor powers and reactivity insertion rates.

The model reactor in this analysis is a 5MW pool-type research reactor having two different operation modes; a power operation and a training operation. Since the accident occurs during startup of the reactor, the training mode without a forced convection results in more severe consequences in a view of fuel integrity. Therefore, the inadvertent withdrawal of a control rod during a startup of training operation is analyzed as a limiting case of the accident.

2. Test Matrix for Sensitivity Test

Table I. Test Matrix

		Initial reactor power [%FP]				
		1E-5	1E-4	1E-3	1E-2	1E-1
Reactivity insertion rate [mk/s]	8.4E-1	P1R1	P2R1	P3R1	P4R1	P5R1
	R2	P1R2	P2R2	P3R2	P4R2	P5R2
	R3	P1R3	P2R3	P3R3	P4R3	P5R3
	R4	P1R4	P2R4	P3R4	P4R4	P5R4
	R5	P1R5	P2R5	P3R5	P4R5	P5R5

The test matrix is composed considering both the initial reactor power and the reactivity insertion rate since they are the key parameters influencing the accident consequence. The initial reactor power varies from 1E-5%FP to 1E-1%FP. The reactivity insertion rate varies up to 8.4E-1mk/s, which is the maximum value to be credible in this event during startup operation. The reactivity insertion rates vary from R2 to R5 depending on the initial reactor power and are shown in figure 1 and figure 2. When trip signals occur simultaneously by both reactor linear power and reactor power lograte, more limiting results is predicted due to the increasing of overshooting power. Therefore, this particular point for each initial power is different with each other.

The reactivity feedbacks by fuel and coolant temperature are neglected since they mitigate the accident consequence due to the initial temperature rises. The test matrix used in this study is tabulated in Table I. These events are simulated using the RELAP5/MOD3.3 code. And this system code cannot describe the change of power peaking factor during transient, maximum power peaking factor with freely moving control absorber rods is considered.

3. Results and Discussions

3.1 Comparison factors

Critical heat flux ratios (CHFR) and maximum fuel temperatures are calculated and compared for each case to find out the case that shows the most severe results. The case that shows minimum CHFR and maximum fuel temperature is selected as the most severe case for RIA during startup in training operation.

3.2 Results of Sensitivity Test

Figure 1 and figure 2 show the minimum CHFR and maximum fuel temperature comparison for various initial powers, respectively. Table 2 and table 3 show the summary of the minimum CHFR and the maximum fuel temperature for all cases.

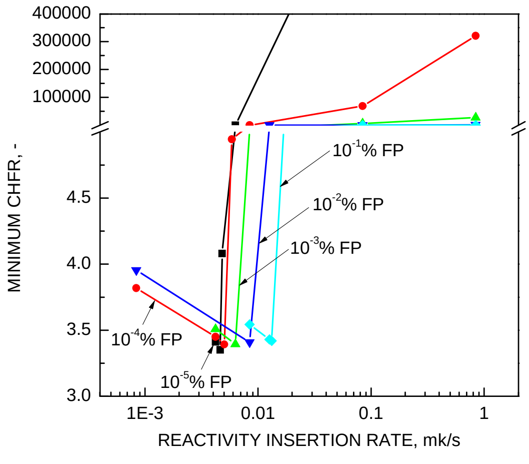

Fig. 1. Comparison of CHFRs

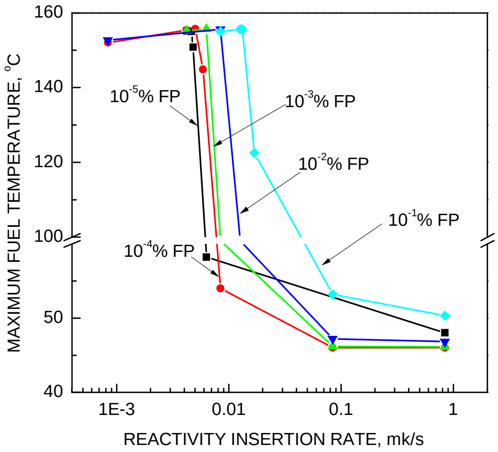

Fig. 2. Comparison of maximum fuel temperatures

In every initial reactor power cases, the minimum CHFR and the maximum fuel temperature do not increase or decrease simply as the reactivity insertion rate decreases. In other words, certain combination of the initial reactor power and the reactivity insertion rate result in the minimum CHFR and the maximum fuel temperature. However, the minimum CHFR and the maximum fuel temperature values are almost constant regardless of the initial power.

As all possible initial powers during startup are much smaller than the reactor linear power trip set point, the higher reactivity insertion rate leads the power lograte set point faster than the reactor linear power trip set point. At a certain reactivity insertion rate, reactor linear power and reactor power lograte reach the trip setpoint simultaneously, the power overshoot becomes the maximum. Under this circumstance, the most severe result is shown. However, if reactor linear power reaches trip set point faster than the reactor power lograte at the smaller reactivity insertion rate, the power overshoot decreases, therefore minimum CHFR increases and maximum fuel temperature decreases.

Table II. Comparison of CHFRs (unit: -)

		Initial reactor power [%FP]				
		1E-5	1E-4	1E-3	1E-2	1E-1
Reactivity insertion rate [mk/s]	5.6E-1	1.4E4	3.2E5	2E4	1E3	1E2
	R2	9.53	48.10	6E3	7E2	63.35
	R3	3.39	3.39	9.94	12.35	3.41
	R4	3.52	3.44	3.39	3.40	3.42
	R5	3.89	3.81	3.50	3.95	3.54

Table III. Comparison of fuel temperatures (unit: °C)

		Initial reactor power [%FP]				
		1E-5	1E-4	1E-3	1E-2	1E-1
Reactivity insertion rate [mk/s]	5.6E-1	48.1	46.0	46.1	46.8	50.3
	R2	97.8	54.0	46.2	47.2	53.2
	R3	155.3	155.8	94.4	85.7	155.6
	R4	154.6	155.4	155.7	155.6	155.6
	R5	152.8	152.1	155.2	152.7	155.1

4. Conclusion

Sensitivity tests with combinations of different initial reactor powers and reactivity insertion rates are performed for an inadvertent CAR withdrawal during startup of the training operation. Although the combination resulting in the minimum CHFR and the maximum fuel temperature are different in all the initial powers, the values of minimum CHFR and maximum fuel temperature are almost constant because they appear when the reactor linear power and power lograte exceed the trip set points simultaneously.

REFERENCES

[1] IAEA Safety Standards, Safety requirement No. NS-R-4, 2005