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Small Break LOCA Analysis for Kori 1 in Operation Mode 3 and 4

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1. Introduction

In general, the Emergency Core Cooling System (ECCS) is designed to sufficiently mitigate the consequence of postulated Loss Of Coolant Accident (LOCA) without any operator actions in power operation. And the ECCS design has to meet the requirement of MOST Notice 2001-39. In shutdown mode the accumulator is isolated and/or the Residual Heat Removal System (RHRS) is operated. Even more the Safety Injection (SI) signal is locked, and the ECCS have to be operated by operator's manual initiation.

After USNRC's Generic Letter 88-17 'Loss of Decay Heat Removal' and Information Notice 95-03 'Loss of Reactor Coolant Inventory and Potential Loss of Emergency Mitigation Functions while in a Shutdown Condition', LOCA in shutdown mode has been an important safety issue [1, 2].

For the large break LOCA (LBLOCA), probabilistic approach has been used and the risk for the LBLOCA of most of all nuclear power plants has been evaluated to be very low. For small break LOCA (SBLOCA), safety analyses have been carried out roughly according to Appendix K.

This study focuses on the SBLOCA of Kori Nuclear Power Plant Unit 1 (Kori 1) in operation mode 3 and 4. For the profound understanding of shutdown SBLOCA, we present following results of analyses;

(1) Phenomena analyses of SBLOCA without any operator actions (section 3)
(2) Safety analyses for SBLOCA in mode 3 and 4 (section 4)
(3) Best-estimated analyses considering operator actions as bases of Abnormal Response Guide (ARG) background analyses (section 5)

2. RELAP5 Modeling, Initial Conditions and Boundary Conditions

2.1 RELAP5 Modeling

RELAP5/Mod3.3 was used in order to analyze the shutdown LOCA [3]. According to analysis purpose, the RELAP5 modeling is different. For the best-estimate analysis most of the components are modeled, and the imposed conditions including initial and boundary conditions are more realistic. Whereas in safety analysis conservative conditions are taken, and only safety related components are modeled. Figure 1 shows RELAP5 nodalization for Kori 1 best-estimate analysis. For safety analysis some components in Figure 1 are omitted.

2.2 Initial Conditions

The initial conditions in this study are operation mode 3 and 4. In order to derive most limiting initial conditions, Kori 1 procedure was utilized [4]. For the definition of operation mode, FSAR Chap. 16 was also referred to [5]. From intensive review of the procedure we derived the most limiting point in the process of reactor shutdown from full power to cold shutdown.

The most limiting initial condition for mode 3 is right after the accumulator is isolated. And that for mode 4 is just before the RHR operates (Table 1).

2.3 Boundary Conditions

Boundary condition is different according to whether the assessment is safety analysis or best-estimate analysis. For example, more conservative SI flow is assumed in safety analysis and more realistic SI flow is in best-estimate analysis

3. Preliminary Analysis

This case is run in order to show the raw phenomena when no operator action is taken. Typical result of pressurizer pressure in mode 3, 1 inch cold leg break is given in Figure 2.

More detailed results will be presented in conference.

4. Safety Analysis

10 min operator action time is assumed. Through the series of analyses the most limiting case was turned out to be 6 inch cold leg break in mode 3. Typical result for core water level is shown in Figure 3.

More detailed results will be presented in conference.

5. Best-estimate Analysis

In this case all the control system except the locked system for example SI are used for the recovery of reactor coolant system inventory. And 10 min operator action time is assumed. Representative result for 6 inch cold leg break in mode 3 is shown in Figure 4.

More detailed results will be presented in conference.

6. Concluding Remarks

Through the systematic analyses, the shutdown SBLOCA was understood and the safety analysis shows that 10 min operator action is sufficient for the mitigation of the accident.

Best-estimate analysis shows the realistic behaviors of shutdown SBLOCA, and it also can play a role of bases of development of Kori 1 specific ARG.

REFERENCES

[1] USNRC, Generic Letter 88-17, Loss of Decay Heat Removal, 1988.

[2] USNRC, Information Notice 95-03, Loss of Reactor Coolant Inventory and Potential Loss of Emergency Mitigation Functions while in a Shutdown Condition, 1995.

[3] Information System Laboratories Inc.., RELAP5/MOD3.3 Code Manual, USNRC Report, NUREG/CR-5535, 2001.

[4] Kori 1 plant, Operation from Full Power to Cold shutdown, Procedure 1-2-004 (Rev. 19).

[5] KEPCO, Kori 1 FSAR Chap. 16.

Table 1. Initial Conditions for Operation Mode 3 and 4

Mode	Tavg	Pressure(bar)	Accumulator	SI Pump	Limiting Initial Conditions
Mode 3 (Hot Standby)	≥176.7℃ (≥449.82K) (≥ 350°F)	P>138.9 138.9>P>69.96 P<69.96	2 2 0	2(Auto) 2(Manual) 2(Manual)	Core Power : (note1) Primary Pressure : 69.96 bar Tavg: 241.7+α ℃ (514.92+α K)(note2) Secondary Pressure : 34.5 bar
Mode 4 Hot Shutdown	176.7℃> Tavg>93.3℃ (449.82K> Tavg>366.48K) (350°F> Tavg> 200°F)	P<69.96 27>P>25	0 0	1(Manual) 1(Manual) +RHR	Core Power : (note3) Primary Pressure : 27 bar Tavg : 176.7 ℃ (449.82 K) Secondary Pressure : 9.29-β bar (note4)

Note 1) Cool down rate 27.8℃/hr(50°F/hr) is assumed. Initial temperature is 301.1 ℃(574 °F). Target temperature is 243.11 ℃(469.60 °F, 516.26 K). Thus, the cool down time is (574°F-470°F)/((50°F/hr))=2.08hr. Conservative time 2hr (7200sec) is used for decay heat.

Note 2) Saturation temperature at the secondary pressure 34.5bar plus α is set as Tavg.

Note 3) Cool down rate 27.8℃/hr(50°F/hr)) is assumed. Initial temperature is 301.1 ℃(574 °F)). Target temperature is 176.7 ℃(350 °F, 449.82 K). Thus, the cool down time is (574°F-350°F)/((50°F/hr))=4.48hr. Conservative time 4.45hr (16020sec) is used for decay heat.

Note 4) Saturation pressure at the primary temperature 176.7 ℃ minus β is set as secondary pressure.

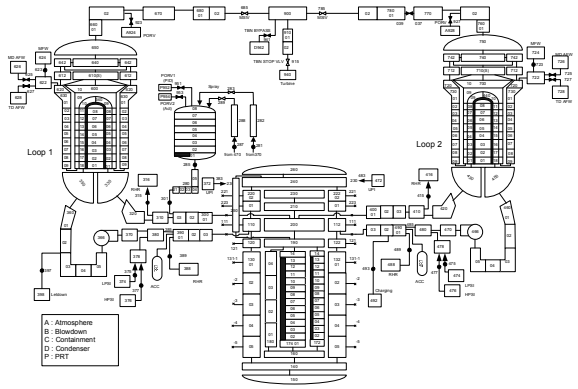

Figure 1. RELAP5 Nodalization for Kori 1

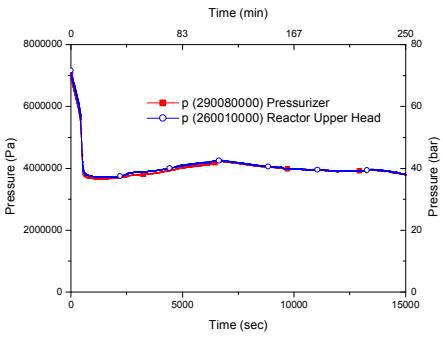

Figure 2 Pressurizer pressure without operator action

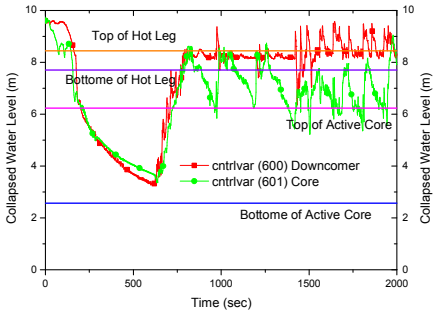

Figure 3 Core water level in safety analysis
6 inch cold leg break6

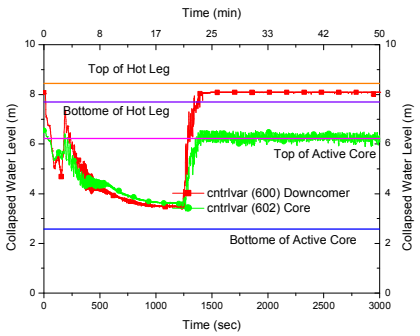

Figure 4 Core water level in best-estimate analysis
6 inch cold leg break