Sensitivity Analysis of the Break Size in the Small Break LOCA with Safety Injection Failure for Shin Hanul 1,2 NPP

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1. Introduction

Accident Management Plan (AMP) should be properly prepared to assure the capability of accident mitigation strategies for Nuclear Power Plant (NPP) during multiple failure accident[1].

Small Break Loss Of Coolant Accident (SBLOCA) with Safety Injection (SI) failure which is one of multiple failure accidents shall be evaluated to mitigate the NPP transient condition and to prevent severe accident. During the accident, break that the pressure of Reactor Coolant System(RCS) decreased below the pressure setpoint of SI due to continuous leakage of RCS coolant after reactor shutdown, but the RCS inventory continues to decrease due to failure of safety injection.

1. Introduction

In the event of SBLOCA with SI failure, aggressive secondary cooldown is required to supply the emergency core cooling system using the safety injection tank or the injection mode of shutdown cooling system.

Fuel cladding temperature is referred to demonstrate the sensitivity result of break size during SBLOCA with SI failure. Decay heat would be stably and continuously removed for preventing the fuel failure by this evaluation

2. Analysis Methodology

2.1 Plant Modeling and Initial Conditions

The RELAP5/Mod3.3 code is used to analyze thermal hydraulic behavior of multiple failure accident. The nominal design values of reactor power, pressurizer pressure, pressurizer water level and SG water level are assumed as the initial condition shown in Table 1.

Pressurized water reactor Shin Hanul 1,2 Nuclear Power Plant has 2-loop reactor coolant system which circulates the primary side coolant in closed loop and transfer heat from the core and internal structure to secondary side systems.

2. Analysis Methodology

The two primary coolant loops were explicitly represented as loop 1 and loop 2. Each loop consisted of a hot leg (HL), a steam generator (SG), and two cold legs with two RCPs, respectively. The pressurizer (PZR) was attached to loop 1.

In addition, to perform the realistic analysis, the control systems, such as Pressurizer Pressure Control System (PPCS), Pressurizer Level Control System (PLCS), Feedwater Control System(FWCS) and Steam Bypass Control System (SBCS) are modeled.

2. Analysis Methodology

Table 1. Initial Conditions

Parameter	Design Value	Analysis Value
Core power, MWt	3983.0	3983.0
PZR pressure, MPa(a)	15.51	15.524
PZR level, %	50.0	49.9
RCS flow rate, kg/s	10,495	10,340
Secondary pressure, MPa(a)	6.89	7.04
Secondary steam flow rate, kg/s	1131.2	1126.3
Steam Generator level, % NR	77.0	76.8

2. Analysis Methodology

2.2 Assumptions

In AMP, 2-inch cold leg break is analyzed as a basic assumption, but break size sensitivity analysis from 1 inch to 5 inches cold leg break is performed to check break size effect. Additionally, the Henry-Fauske critical flow model is taken into account for the break flow Operator actions are considered to trip the RCPs and to operate the SG aggressive cooldown by opening each Atmospheric Dump Valve(ADV). All RCPs are stopped at 10 minutes after reactor trip. The operator actions for aggressive cooldown using SG start at 30 minutes after initiation of the accident in order to delay the core cooling for conservatism.

3. Analysis Results

Table 2 shows the sequences of events for the analysis depending on the break sizes. As shown in the table 2, the primary-side pressure boundary is depressurized more rapidly and the reactor-trip becomes earlier, as the break sizes get larger.

Table 2. Sequences of Event for Sensitivity Study

Sequences (time,sec)	Cases (break size)				
	1 inch	2 inch	3 inch	4 inch	5 inch
Event Start	0	0	0	0	0
Reactor Trip	323.0	62.4	27.3	13.7	10.5
Safety Injection Actuation Signal-Fail	332.4	70.4	33.7	19.9	15.5
RCP Trip	923.0	662.4	627.3	613.7	610.5
ADV open	1800.0	1800.0	1800.0	1800.0	1800.0
Reaches the SCS entry condition	9405.0	2971.0	2745.0	2580.0	2465.0

3. Analysis Results

Figure 1 shows the pressurizer pressure according to break sizes. As the pressure decreases, RCS temperature reaches hot leg saturation trip setpoint. When the reactor trip occurs, the core power decreases rapidly, and accordingly, pressurizer pressure decreases rapidly. As the pressure decreases, void generated in the RCS and the pressure is kept constant. If the break size is larger than 3-inch break, high energy void and large discharge flow are released through the break point, it reaches shutdown cooling system entry condition. If the break size is smaller than 2-inch, the RCS pressure remains above the SIT injection pressure, at 30 minutes, an aggressive cooldown was initiated by opening ADV on each SG to reach shutdown cooling system entry condition.

3. Analysis Results

Figure 2 shows the break mass flow rate depending on the break sizes. At the beginning of the accident, the break mass flow shows unstable fluctuation. The liquid fraction of the break junction depends on the liquid fraction at the top of break node and whether it is stratified and it affects the discharge flow through the break.

3. Analysis Results

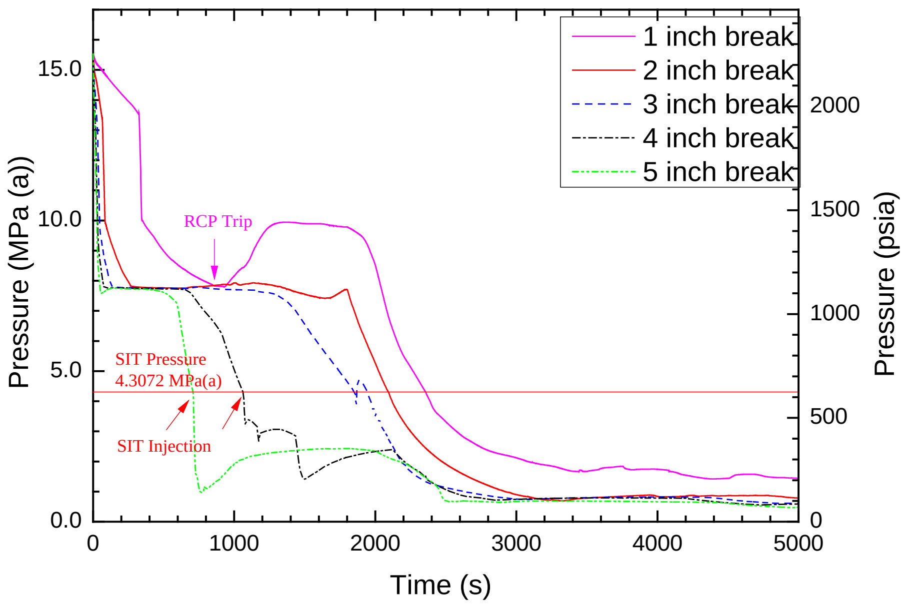

Figure 1. PZR Pressure

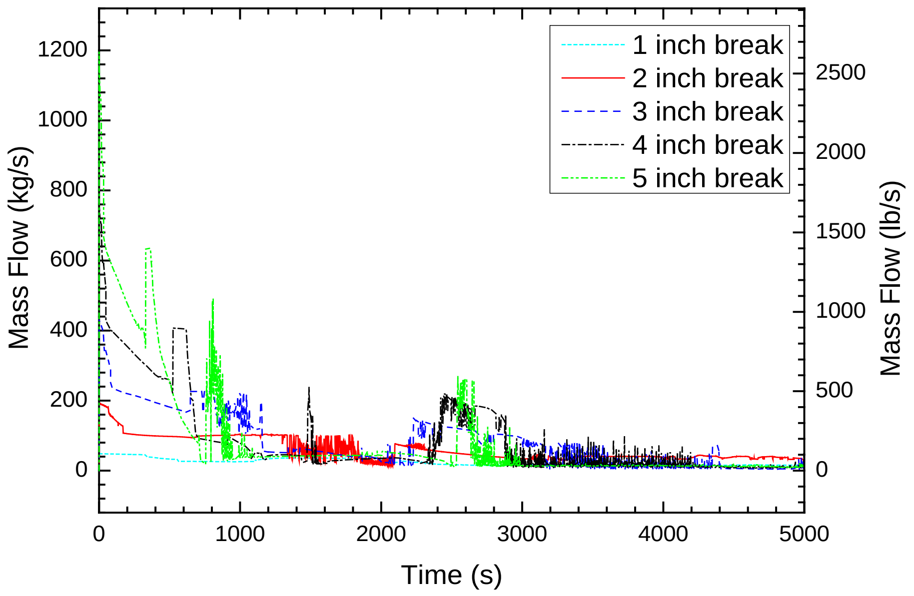

Figure 2. Discharge flow through the break

3. Analysis Results

Figures 3 and 4 show core collapsed level and Safety Injection Tank (SIT) injection flow, respectively. If the break size is larger than 3 inch break size, the collapsed level decreases below or near the bottom of the active core. Collapsed level starts to be recovered when the makeup water from SIT is larger than break flow.

3. Analysis Results

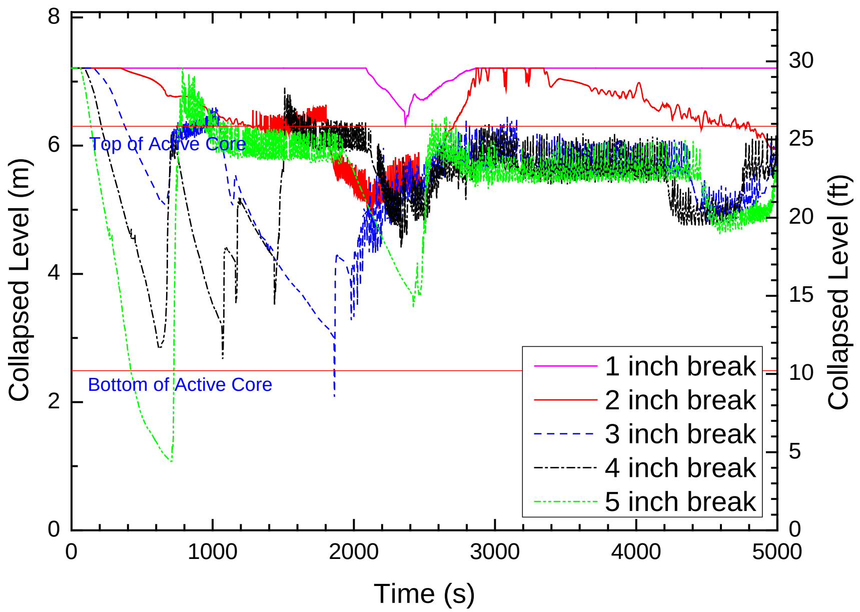

Figure 3. Core collapsed level

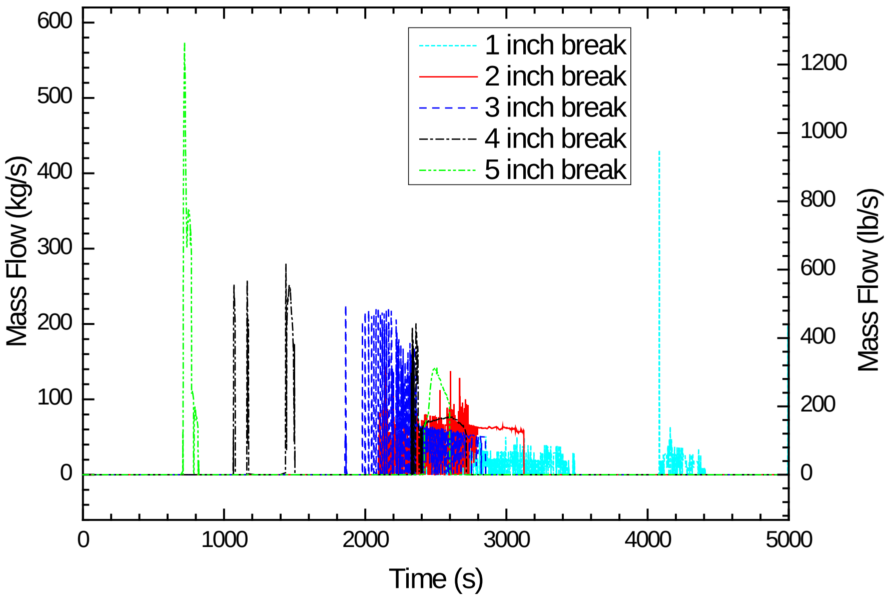

Figure 4. SIT injection flow

3. Analysis Results

Pressure conditions to start the shutdown cooling system are quickly reached, but the hot leg temperature condition reaches it after aggressive secondary cooldown begin as shown in Figure 5.

Figure 6 shows the hot rod peak cladding temperatures. Among these break cases, 3-inch cold leg break case showed the most conservative result due to delayed safety injection.

3. Analysis Results

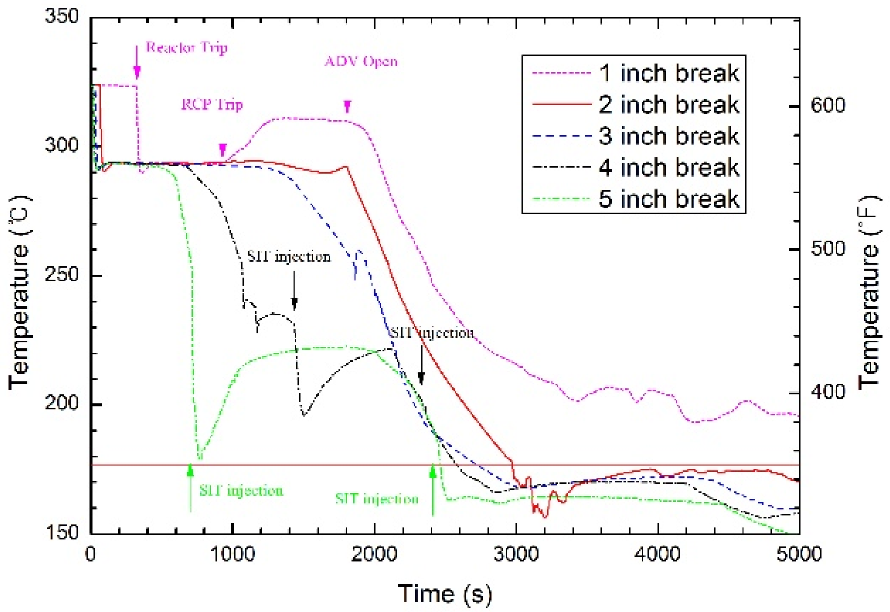

Figure 5. Hot leg temperature

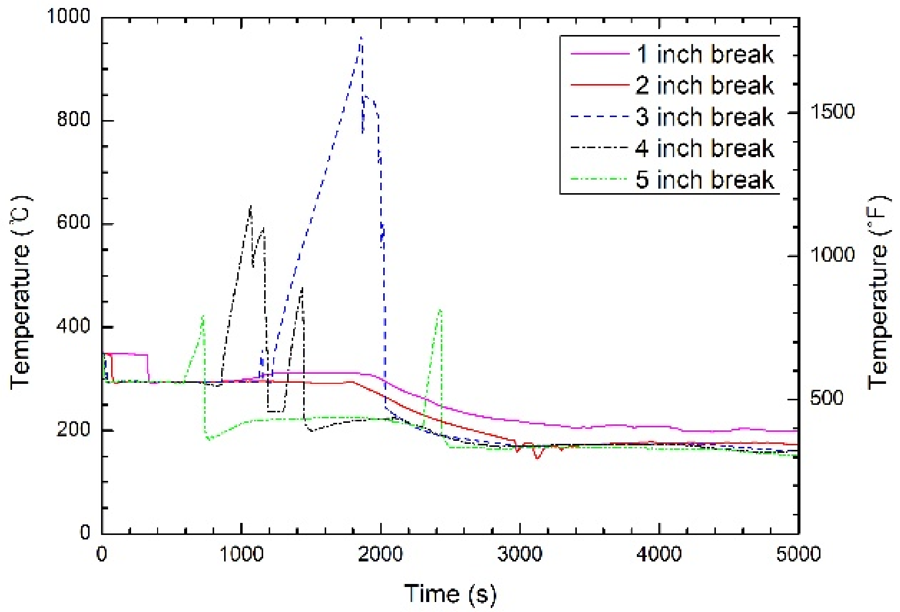

Figure 6. Peak cladding temperature

3. Analysis Results

According to the sensitivity analysis on the break size, if the break size is less than 2- inch break, these cases do not have large discharge flow rate comparing with the other small break size, and it shall not result in the fuel exposure. According to the sensitivity analysis on the break size, if the break size is less than 2- inch break, these cases do not have large discharge flow rate comparing with the other small break size, and it shall not result in the fuel exposure. Thus, it is confirmed that safety injection is properly supplied by the aggressive cooldown with steam generator.

3. Analysis Results

The fuel exposure resulted from heating of the fuel cladding can be founded in the break size which is larger than the 3-inch. And, from the viewpoint of PCT, the 3-inch cold leg break is the most conservative case, because the slow depressurization is tended to delay the actuation of safety injection. But the core is continuously cooled by the safety injection with SG aggressive cooldown and, the RCS could get the entry condition of the shutdown cooling mode at 2745.0s

4. Conclusions

Sensitivity analyses on the break sizes show different discharge flow through the break, SIT injection time, and time to reach Shutdown Cooling System (SCS) entry condition. If the operator open SG`s ADV for the aggressive cooldown within 30 minutes after initiation of SBLOCA with the SI failure event, reactor coolant system could get to the entry condition of the shutdown cooling mode

ACKNOWLEDGEMENTS

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