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# Analysis on Small Break LOCA with HPSI-Failure for Shin-Kori units 1, 2

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## 1. Introduction

After the Fukushima accident, the possibility of unforeseen beyond design basis accidents has been a regulatory concern for nuclear safety. A Small Break Loss of Coolant Accident (SBLOCA) with total failure of the High Pressure Safety Injection (HPSI) System is one of multiple failure accident which is derived from Design Extension Condition (DEC) that is not considered design basis accident.

In the SBLOCA with HPSI failure, the break size is relatively small that the primary system does not depressurize to entry condition for the long-term cooling before core uncovering. Therefore it is necessary to operate secondary cool down as accident management to prevent core heat up. In order to evaluate if the accident management is appropriate, it must be analyzed in accordance with nuclear safety regulations.

In this study, the SBLOCA with HPSI failure was analyzed with an Accident Management Program (AMP). Also the spectrum analysis for the break sizes and break locations was conducted to find the most limiting case on the accident. To analyze the transient, RELAP5/MOD3.3 which is best-estimated thermal-hydraulic analysis code was used. The target plant is Shin-Kori units 1 and 2 which are conventional 2 loop Pressurized Water Reactor (PWR) plants.

## 2. Calculation Model

In order to simulate the postulated accident, a nodalization diagram of the power plant has been constructed as shown in Fig. 1. For steady-state calculation, the normal operational state of the reactor is obtained at 100% full power. Table I shows the steady-state calculation results for the main variables and good agreement with design values. The control systems and assumptions for operator actions are modeled as follows.

1) Pressurizer Pressure Control System (PPCS) which includes proportional and backup heater, spray line and Pressure Operated Relief Valve (PORV). Pressurizer heaters are manually turned off by operator at 30 min after accident occurs
2) Pressurizer Level Control System (PLCS) which includes Chemical and Volume Control System (CVCS) charging and letdown lines. When the Low Pressurizer Pressure (LPP) signal is generated, CVCS letdown valves automatically close.
3) Steam Bypass Control System (SBCS) which includes turbine bypass valve. The turbine bypass valves (TBV) automatically open at the turbine trip. The steam generated in the steam generator (SG) discharges through TBVs before main steam isolation valves are isolated due to the high steam generator level or low steam generator pressure signals.
4) Feed Water Control System (FWCS) which includes main and aux feed water line. The system injects main and aux feed water during the accidents.
5) Reactor Coolant Pump (RCP) trip: it’s assumed 10 minute for operator to trip all RCPs.
6) All Safety Injection Tanks (SIT) and Low Pressure Safety Injection (LPSI) System in each loop are available while HPSI is not available

The sequence of SBLOCA with HPSI failure accident is as follows.

Following the break occurrence in the break locations, the pressure in the primary system starts decreasing until the Reactor Coolant System (RCS) pressure reaches the set point of LPP signal. As the LPP signal is generated, the reactor and turbine will be tripped and the core thermal power falls rapidly to the decay heat level. Secondary system pressure is maintained at a constant value and produced steam is released through the turbine bypass valve.

The RCS depressurize continuously until they reach the safety injection set point. HPSI injection is not available in the simulation, so loss of primary inventory is continued. It is important whether the primary pressure reduce below SIT and LPSI actuation pressures before core uncovering.

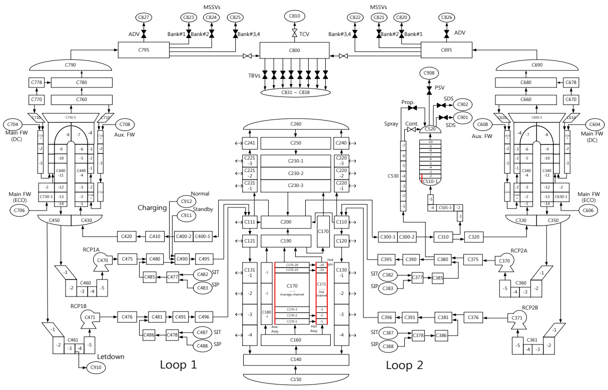


Fig. 1. Nodallization of Shin-Kori units 1, 2

Table I: Steady-state calculation results

| *Item* | | *Design* | *Cal.* |
|---|---|---|---|
| Power | Core Power (MWt) | 2815.0 | 2815.0 |
| Loop | Cold leg Temp (C) | 295.83 | 295.89 |
| | Hot leg Temp (C) | 327.23 | 327.20 |
| | RCS Flow Rate (kg/s) | 15308.0 | 15298.1 |
| PRZ | Pressure (MPa) | 15.513 | 15.5201 |
| | Water Level (%) | 52.6 | 52.5 |
| SG | Steam Pressure (MPa) | 7.5429 | 7.5165 |
| | FW Flow per SG (kg/s) | 802.9 | 798.4 |
| | Wide Range Level (%) | 79 | 79.0 |

## 3. Simulation Results

### *3.1. Analysis of Break Size without AMP*

The SBLOCA has been generally defined to include any break in the PWR pressure boundary which has an equivalent diameter of 2 inch or less. The range of break area encompasses all small lines which penetrate letdown lines, relief valves, drain lines, and various instrumentation lines. It also represents the loss of coolant accident that is small enough for the HPSI to maintain RCS inventory, but not large enough to remove decay heat without additional heat sink to distinguish the middle and large break LOCA.

This definition has been used in many probabilistic safety analysis, but the range of break size and critical size can be different according the plant configuration. The spectrum analysis on 3 different sizes (0.5, 1.0, 2.0 inch) was conducted in the cold leg breaks. Also secondary cool down by opening the Atmospheric Dump Valve (ADV) was not taken into consideration to figure out the necessity of the accident management.

Fig. 2 and 3 show Cladding Temperature and collapsed water level of the core according to break size respectively. The highest maximum PCT was found at the 2 inch break that is close to acceptance limit.

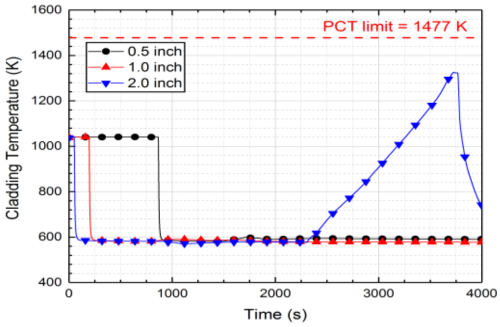


Fig. 2. PCT with respect to the break sizes

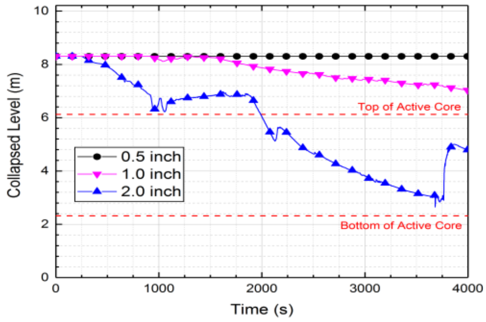


Fig. 3. Core collapsed level with respect to the break sizes

### *3.2. Analysis of break location without AMP*

With HPSI available, the cold-leg break is generally known as most limiting case in a SBLOCA because the Emergency Core Cooling System (ECCS) flow split out the break while all goes through the core in a hot leg break. But considering HPSI failure, it may be different.

Sensitivity analysis with respect to the break locations was performed, as shown in Fig. 4 and 5. The break locations are cold and hot leg with 2 inch break in the loop 2 which includes the pressurizer. Analysis was also conducted the other side loop, but no significant difference was found according to loops with or without pressurizer. Fig. 5 shows that the hot-leg case leads to core damage because the primary pressure did not reach the set pressure of SIT injection.

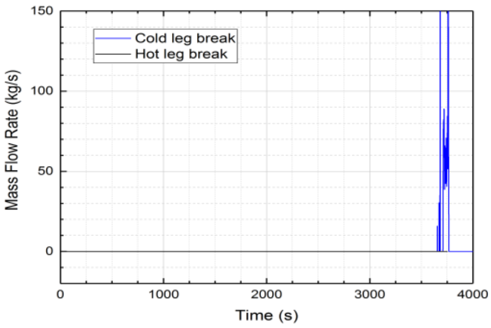


Fig. 4. Mass flow rate of SIT with respect to the break locations on the 2 inch break

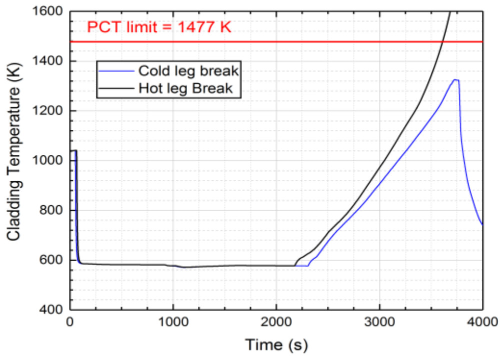


Fig. 5. PCT with respect to the break locations on the 2 inch break

*3.3. Analysis with AMP*

As an AMP, operator will operate secondary cool-down by fully opening the ADV at 30 minutes after event initiation. Fig. 6 shows the PCT with a range of break sizes in the cold leg and 2 inch hot leg break. After AM is conducted, PCT and pressure started to decrease. When the primary pressure reached set pressure of SIT and LPSI injection due to the depressurization of secondary side as shown in Fig. 7, core collapsed level began to increase. The results shown in Fig. 8 present that core uncovering and heat up does not occur throughout all accident cases.

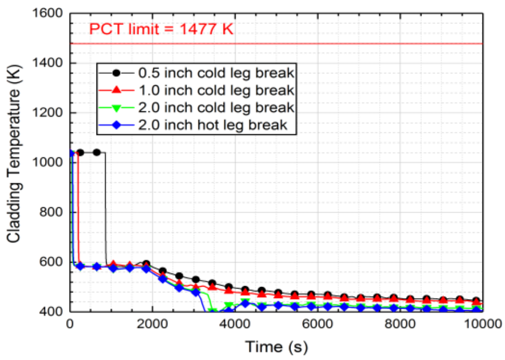


Fig. 6. PCT with AMP

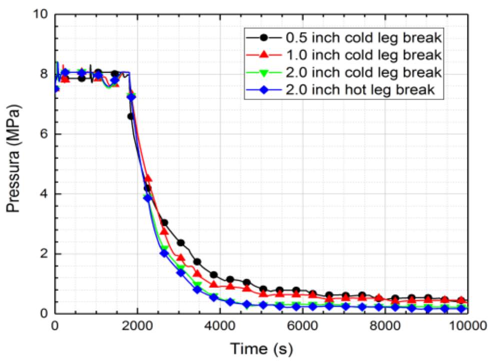


Fig. 7. Steam generator pressure with AMP

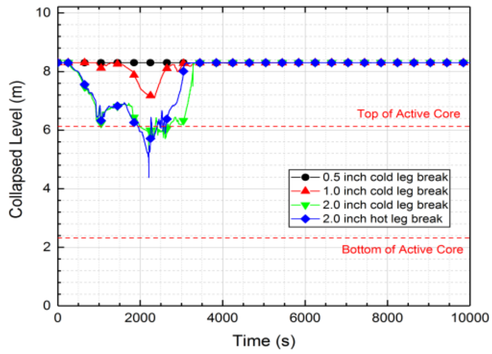


Fig. 8. Core collapsed level with AMP

## 4. Conclusion

In this study, the SBLOCA with HPSI failure accident of Shin-Kori units 1 and 2 were analyzed using RELAP5/MOD3.3. In the terms of the PCT approach, hot leg 2 inch break is considered as a limiting case on the accident from the spectrum analysis. Also, the simulation results showed that the accident management, which is secondary cooldown by fully opening ADV, was effective for all break sizes and locations studied and maintained integrity of nuclear fuel during the postulated accident.

## REFERENCES

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