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Simulation of IBLOCA (Intermediate-break Loss of a Coolant Accident) scenario of PKL i2.2 test

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1. Introduction

As a part of a "LOCA (Loss of a Coolant Accident) reclassification and development of IBLOCA (Intermediate-break LOCA) safety analysis methodology" project which supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea, we are investigating to establish the new DBA (Design Basis Accident) including IBLOCA, which has a relatively small break size by excluding LBLOCA (Large-break LOCA) assuming a double-ended guillotine break accident belonging the existing DBA. In this regard, it is essential to develop the PIRT for IBLOCA to achieve the goal of this project.

This paper includes the SPACE [1] analysis of PKL i2.2 Run3 test [2], which of one of IBLOCA scenarios, to understand the current predictability of the SPACE code for the thermal-hydraulic phenomena in a transient IBLOCA scenario and support the PIRT development for IBLOCA.

2. SPACE analysis on PKL i2.2 Run3 test

2.1 PKL i2.2 test

As a result of the OECD-PKL4 experimental program, the PKL i2.2 run3 test [2] is an IBLOCA scenario postulating a 17% cold-leg break, 1 HPSI (High-pressure Safety Injection), 2 ACCs (Accumulator) and 1 LPSI (Low-pressure Safety Injection), no secondary-side cool down, which was conducted at the PKL test facility. The large-scale PKL test facility replicates the NSSS of a 1300 MWe PWR of SIEMENCE KWU-design.

The scenario of this test is originally postulated with a counterpart test of ROSA/LSTF [3] IBLOCA cases. The PKL i2.2 Run3 test considered additional failures of HPSI and LPSI more than the original scenario to understand the effect of the PCT excursion on the availability of safety injection systems.

The main sequence of events for PKL i2.2 Run3 test is shown in Table I.

The transient test starts with the opening of the break. The cut-off of secondary side system started before 10 sec after the start of test (SoT). After the secondary-side isolation, the secondary pressure increased slightly. The coast-down of the RCPs was started approximately 30 sec after SoT. When primary pressure reached to the set value of HPSI, ACC and LPSI.

HPSI and LPSI is only one train activated and connected to loop 3. Two of ACCs are utilized in this scenario with connecting to loop 2&3, respectively.

Table I: Sequence of events for PKL i2.2 Run3

Time	Measure/action	Condition
0	Break open Begin of core power decrease	SoT
8	Shut off of feed water system	
29	Begin of coast-down for all RCPs	
161	Start of HPSI in loop 3	P_{prim} < 31.7 bar
252	Shut down of all RCPs	
265	Closure of butterfly valves	
290	ACCs injection in loop 2&3	P_{prim} < 16.8 bar
1473	Start of LPSI in loop 3	P_{prim} < 6.7 bar
2750	End of test	

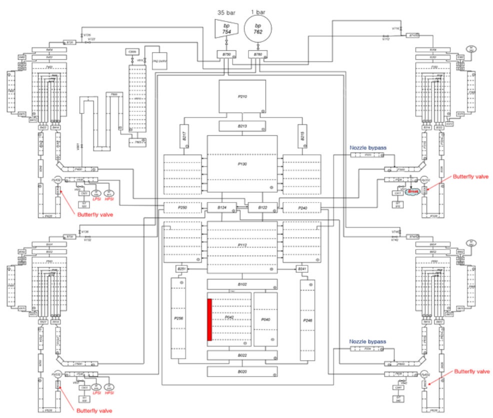

Fig. 1. SPACE modeling for PKL facility

2.2 SPACE modeling

The SPACE modeling for the PKL facility was presented in Fig. 1. It has 4 identical reactor coolant loops including SG, cold-leg, RCP, and hot-leg arranged symmetrically around the reactor pressure vessel.

The PKL i2.2 Run3 test is comprised of a conditioning phase and an afterSoT phase. The conditioning phase includes the set-up of the initial test condition with a constant core power.

The SPACE calculation for the conditioning phase was conducted with the SPACE modeling and Table II shows the comparison of major parameters between test and the SPACE simulation for the conditioning phase of PKL i2.2 Run3 test. The SPACE calculation results predict the test values well for most of selected parameters. After obtaining a good agreement between the code calculation and the test results, this modeling was used as initial conditions for the transient calculations.

Table II: Comparison of SPACE calculation with the PKL i2.2 Run3 test results for conditioning phase

Parameter	Test	SPACE	diff(-)
Normal Power (kW_{th})	1971.2	1971.2	-
Pressurizer (bar)	45.02	45.2	+0.18
Upper Plenum (bar)	45.90	45.91	+0.01
Pressurizer level (m)	7.8	7.83	+0.03
Core inlet temperature (°C)	245.6	245.7	+0.1
Core exit temperature (°C)	250.1	248.3	-1.8
SG inlet/outlet (°C)	~247/~244	~248/~246	-
Loop flows (kg/s)	37.77/38.77/ 38.56/38.91	39.64/39.06/ 39.03/38.89	-
SG (bar/°C)	~35/~240	~35/~242	-

2.3 SPACE analysis results

It is important to determine the inventory loss through a break in a LOCA transient simulation like as the PKL i2.2 Run3 test. In this calculation, Henry-Fauske critical flow model was used in the SPACE calculations. By conducting of sensitivity studies on discharge coefficient at a break location, finally the coefficients are determined and the calculated results are as shown in Fig. 2.

Based on this modeling, SPACE calculation for PKL i2.2 Run3 test was conducted and Fig. 3~7 shows the comparisons of major parameters between PKL test results and the SPACE calculations.

Fig. 3 shows the primary pressure behavior. When a cold-leg break occurs, the pressure sharply decreases and reached to a pressure plateau due to the energy balance of the system. However, the pressure drops rapidly again as a coolant with a vapor phase discharged through a break. At this point, a HPSI pump, provided with the table on the injection flow rate according to the pressure, starts operating when the setup pressure is reached. Two of ACCs are also injected after reaching the set pressure. Finally, a LPSI is also activated and injected into the loop 3 (in Fig. 4).

The collapsed water level in the core are presented in the Fig. 5. When a break occurs, the level was sharply decreased but a sudden increase of level is occurred due to the loop seal clearing in all the loops. After that water level kept a certain level due to the stable safety injections of ACCs, LPSI and HPSI. A collapse water level in a downcomer are well predicted as shown in Fig. 6.

Most of the SPACE results are well-matched with the test values. However, it has a different behavior of the peak cladding temperature (PCT) excursion even though collapsed water level of a core and a downcomer is well-predicted. The initial PCT excursion in the test is an instantaneous phenomenon, and it is thought that it is because the distribution of a coolant in the system cannot be accurately simulated in the SPACE code. It is expected that more accurate prediction can be made if additional study is conducted on the CCFL model and pressure drop model inside RPV.

3. Conclusions

The SPACE analysis of an IBLOCA scenario was conducted using the PKL i2.2 Run3 test postulating a 17% cold-leg break concurrent with partially failure of safety injection to understand the transient phenomena of IBLOCA scenario.

The SPACE code properly predicts the overall thermal-hydraulic behaviors such as the primary pressure, water level in the reactor core and the downcomer, safety injection behaviors. However, the PCT excursion behavior cannot be accurately predicted. It thought that it is because the coolant distribution in the reactor vessel cannot be accurately simulated in the SPACE code. It is expected that the simulation results can be improved by additional sensitivity studies on the CCFL model and pressure drop model as a further works.

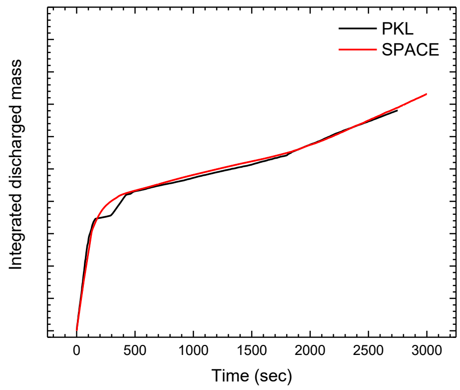

Fig 2. Comparison of integrated discharged mass between PKL test and SPACE calculation

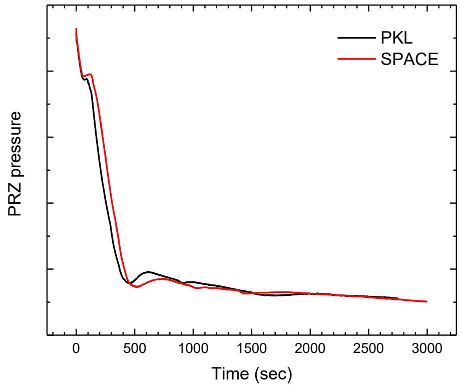

Fig. 3. Comparison of primary pressure behavior between PKL test and SPACE calculation.

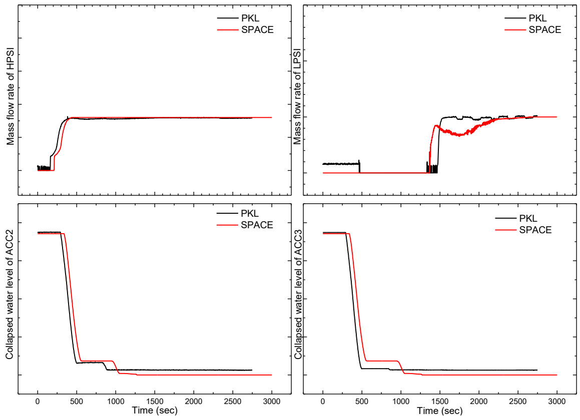

Fig. 4. HPSI, LPSI and ACCs injection behavior of PKL i2.2 Run3 test

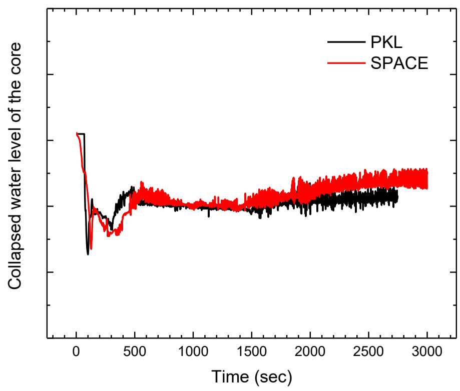

Fig. 5. Comparison of collapsed water level in the core

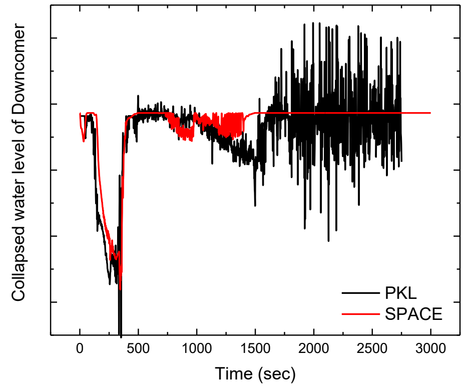

Fig. 6. Comparison of collapsed water level of a downcomer

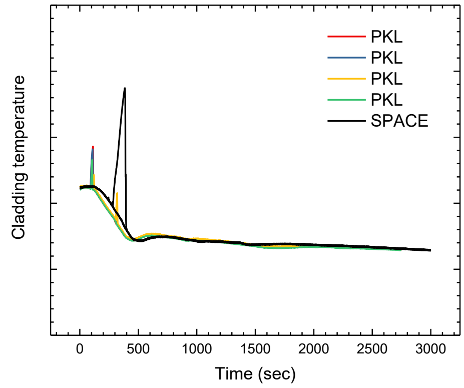

Fig. 7. Comparison of cladding temperature at varied measured locations

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