# Sensitivity Test for Intermediate Break Loss of Coolant of LSTF No.2 using SPACE

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## 1. Introduction

As a part of the Project related to development of safety analysis methodology for an intermediate break loss of coolant accident (IBLOCA), we are newly developing a PIRT for an IBLOCA. In addition, various benchmark calculations are conducted using SPACE code. In this work, preliminary calculations of LSTF tests for IBLOCA are conducted. And sensitivity test for major input parameters is carried out.

## 2. Calculation of LSTF tests

### *2.1 LSTF Test*

The JAEA started OECD/NEA ROSA-2 Project in 2009, following ROSA Project, to resolve issues in thermal-hydraulic analyses relevant to LWR safety by using the LSTF of ROSA Program in JAEA. IBLOCA is selected as one of important safety issues to study in the ROSA-2 project[1]. Fig.1 shows schematics of LSTF facilities[2]. The LSTF simulates a typical 3423 MW four-loop Westinghouse-type PWR with a two-loop system model by full height and 1/48 in volume. The inner diameter of hot and cold legs in the primary is 207mm to conserve the volumetric scale (2/48) and the ratio of length to square root of diameter to simulate flow regime transitions in horizontal pipes. In the ROSA project, test no.1, 2 and 7 are related to IBLOCA scenario. In this study, test no. 2, in which the break location is a cold-leg and break size is larger, is selected for benchmark cases. Table I shows summary of each test conditions. A break unit is installed at the same break location for each tests. The break unit was upwardly mounted with the entrance flush with the cold leg inner surface. The nozzle areas and ECCS conditions are different for each test as shown in Table I.

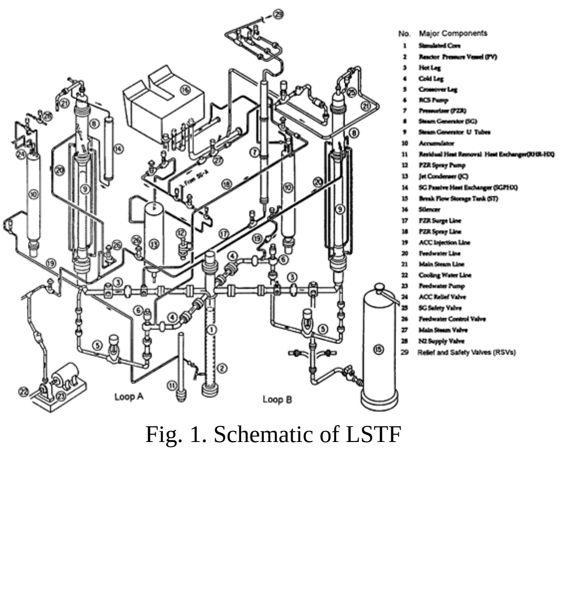


Fig. 1. Schematic of LSTF

Table I Experimental Conditions for LSTF Test No.2

| Experimental conditions | Test No.2 |
|---|---|
| Break size | 17% (ECCS piping) |
| ECCS | HPI, ACC, LPI in the loop with PZR only |
| Single failure | Diesel generator for HPI and LPI |
| Aux-feed | Total failure |

### *2.2 Modeling of LSTF*

All related components are appropriately modeled with nodalization as shown in Fig. 2. The break is modeled as boundary condition with critical flow model of Henry-Fauske. discharge coefficient($C_d$) of 1.0 are applied for all phase conditions. The fuel assemblies in the core are modeled with averaged single channels with 9 axial nodes. The HPI and LPI systems are modeled as boundary conditions with tables of primary pressure and injection flow rate as reported [1, 3]. The accumulator is modeled with SIT component in SPACE code. The main steam safety valves (MSSVs) are adjusted to match secondary pressure transient with set pressures. The steady-state results are well agreed with experimental results. However, the steam flow rate and water level in the steam generator are shows some differences of 2.3% and 3.8%. It will be revised in near future with more design information.

### *2.3 Preliminary Results*

Table II shows comparison result for the major events during the test no. 2. The times of sequential events are very similar due to well prediction of the primary pressure, which is the major parameter to control system, such as SCRAM, pumps, SI, etc. ACC and LPI are initiated earlier than the experiment due to faster depressurization during a lower pressure region as shown in Table II.

After opening of the break valve, break flow rate is well predicted. And primary pressure is suddenly decreased. The scram signal is activated at the primary pressure of 12.97 MPa. Then, turbine trip occurred by closure of SG main steam stop valve. Thus, the SG secondary pressure increased rapidly up to about 8 MPa. The SGs no longer served as the heat sink at 59 s when the primary pressure became lower than the SG

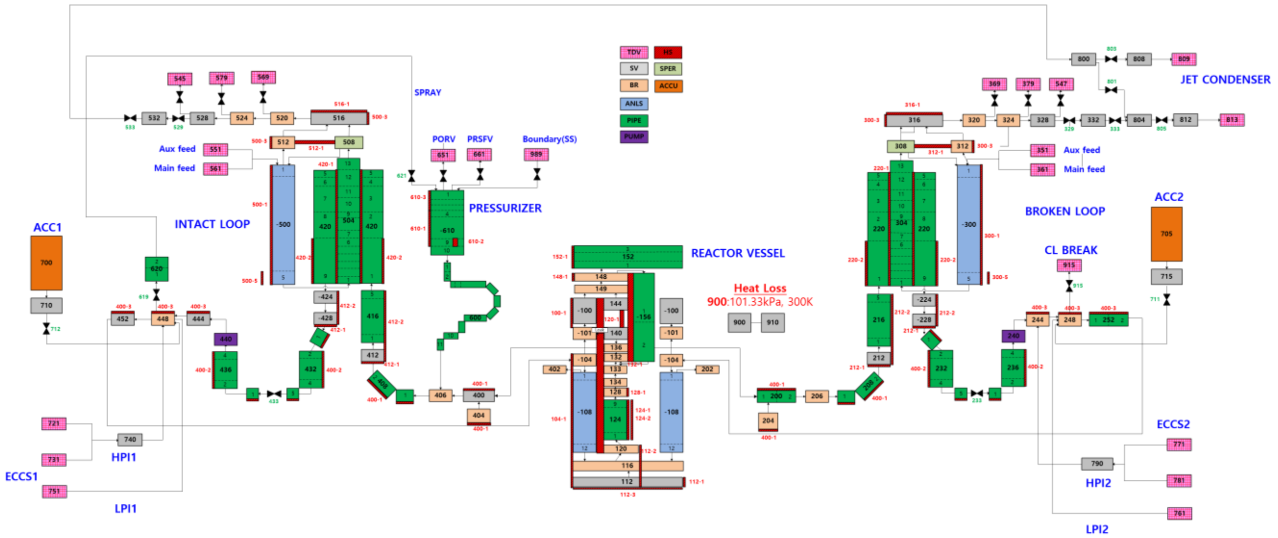



Fig. 2 Nodalization of LSTF for SPACE code

Table II Sequence of LSTF Test No.2

| Event | Time (s) | |
|---|---|---|
| | EXP | SPACE |
| Break valve open<br>Initiation of primary coolant pumps rotation speed increase | 0.0 | 0.0 |
| Scram signal | 7.0 | 5.1 |
| Closure of SG main steam stop valve | 8.0 | 6.1 |
| SI signal | 9.0 | 8.8 |
| Closure of SG MSIVs | 10.0 | 8.1 |
| Initiation of decrease in liquid level in SG U=tube | 10.0 | 0.0 |
| Initiation of coast-down of primary coolant pump | 11.0 | 21.0 |
| Termination of SG main feedwater | 13.0 | 13.0 |
| Initiation of decrease in liquid level in crossover leg downflow-side | 25.0 | 25.0 |
| Open of SG relief valves | 27-57 | 26-57 |
| Initiation of core power decay | 29.0 | 29.0 |
| Initiation of HPI system in intact loop only | 35.0 | 34.8 |
| Loop seal clearing (LSC) | 40.0 | 48.0 |
| Primary pressure became lower than SG secondary-side pressure | 55.0 | 59.0 |
| Initiation of ACC system in intact loop only | 110.0 | 102.9 |
| Core power decrease by LSFT core protection system when peak cladding temperature reached 958 K | 140.0 | 140.0 |
| PCT of about 978 K at position 7 and 6 in high-power bundle | 150.0 | - |
| Whole core quench | 180.0 | 200.0 |
| Primary coolant pumps stop | 260.0 | 270.0 |
| Termination of ACC system in intact loop only | 280.0 | 395.0 |
| Initiation of LPI system in intact loop only | 290.0 | 220.0 |
| Break valve closure | 1212.0 | 1000.0 |

secondary pressure. The core water level due to flashing of fluid due to primary depressurization just after the break. The initial core water level was under-estimated. So, the clad temperature shows the early peak, which is not observed in the experiment. The core dryout took place due to rapid water level drop in the core before the loop seal clearing (LSC). And the core level decreased greatly in cold leg after the LSC. At this time, the break flow turned from single phase water to two-phase and single-phase vapor, in turn.

The SI signal is actuated about 8.8 s and the HPI was initiated in the loop with PZR only at 34.8 s. However, it was not effective on the core cooling due to smaller injection flow rate than the break flow rate. The ACC is initiated when the primary pressure reduced to 4.51 MPa. The predicted ACC flow rate is smaller and injection time is longer than the experiment. In the SPACE results, the second fuel temperature rise is stared around 80 s due to continuous boil-off. And after injection of the ACC, the clad temperature reached peak temperature then reduced by core water level recovery. However, the water level is under-estimated by the lower injection rate of the ACC.

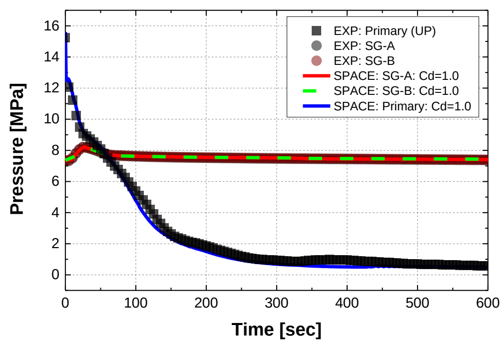



Fig. 3 Primary and secondary pressure for LSTF No.2

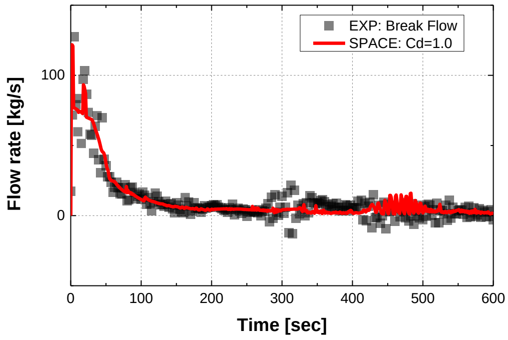



Fig. 4 Break flow for LSTF No.2

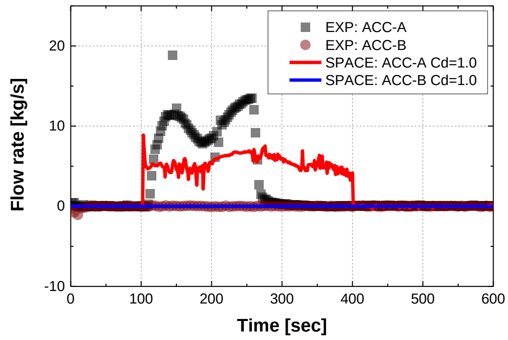



Fig. 5 Accumulator flow rate for LSTF No.2

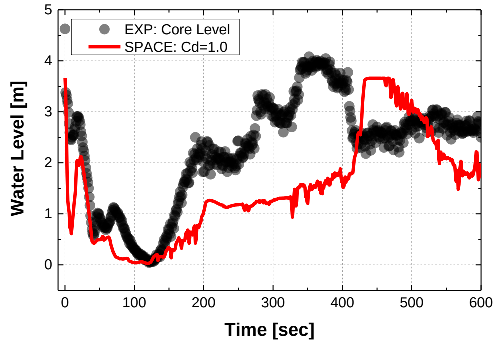


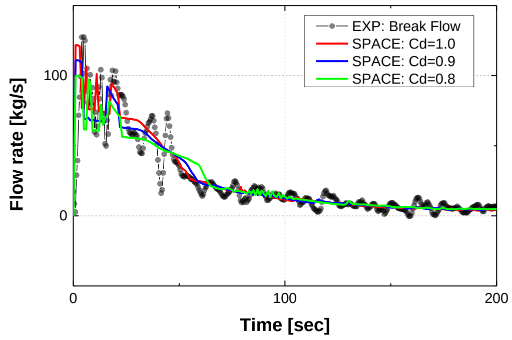

Fig. 6 Core water level for LSTF No.2

## 3. Sensitivity Test

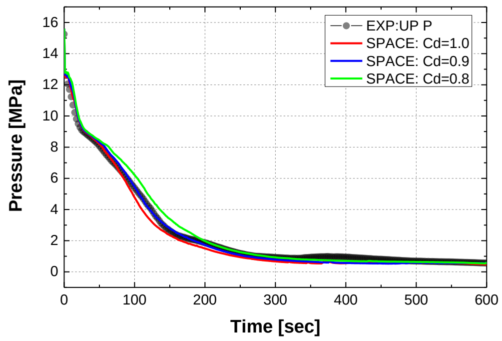
In order to investigate the major phenomena during IBLOCA, sensitivity test for various parameters is conducted. Freixa et al. reported modeling guidelines for LSTF tests [4]. They considered CCFL at various locations, breaking modeling, CRGT modeling. In our study, detailed breaking model has no effects for major transient behavior. And CCFL effect is still testing. Abe et al. reported multi-dimensional flow effect for LSTF tests [5]. They modeled core with three channels of different power levels. In their results show the multi-dimensional model gives a better prediction. When the same core modeling is applied, our results has no dramatic differences. In this study, sensitivity results of some major influential parameters will be discussed.

### *3.1 Discharge coefficient of critical flow*

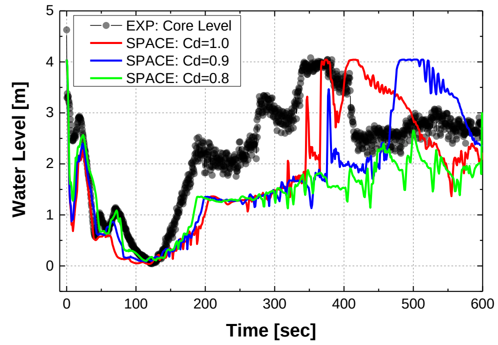
The discharge coefficient($C_d$) in critical flow model is a obviously sensitive parameter. In this study, based on the $C_d$ = 1.0, additional 0.9, and 0.8 values are applied. Fig. 7 shows sensitivity test results for the discharge coefficient in the LSTF test no.2. When the discharge coefficient is decreased, the discharge flow rate is reduced (Fig. 7a). Thus, the depressurization rate reduced (Fig. 7b). After 50 seconds of break, when a discharge flow becomes two-phase regime, pressure variation is distinguishable. And the core water level is relatively increased (Fig. 7c). For the sequence of scenario, the discharge coefficient of 0.9 shows better timing.




(a) Discharge flow rate

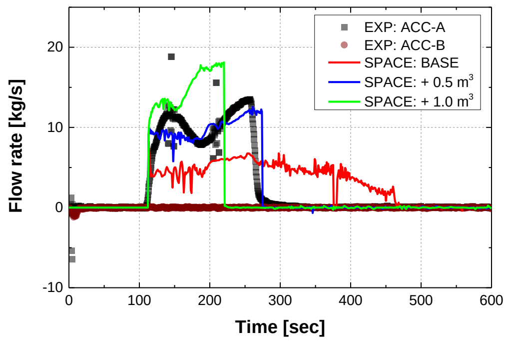



(b) Primary pressure

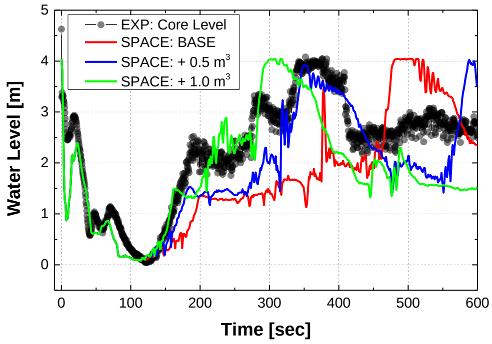



(c) Core water level

Fig. 7 Sensitivity test results for discharge coefficient




(a) Accumulator flow rate




(b) Core water level

### *3.2 Accumulator model parameters*

The preliminary calculation results show very low accumulator injection rate. Thus, various input parameters of SIT component in SPACE code are tested. The dominant parameter is an accumulator volume, which includes tank, stand pipe, and surge-line pipe. Based on the designed tank volume, additional volumes of 0.5 and 1.0 m3 are applied for the sensitivity test. When the accumulator volume increased, the injection Fig. 8 shows sensitivity test results for SIT model parameter (with $C_d$=0.9) flow rate is increased (Fig.8a). Therefore, the core water level recovery has good prediction. When the additional volume of 0.5m3 is added, the accumulator injection rates show similar to measured one (Fig.8b). However, the accumulator initial water level and long-term pressure and temperature show non-physical behavior. So, the improvement of SIT model in SPACE code is necessary for better prediction in accumulator behavior.

## 4. Conclusions

One of intermediate break loss of coolant accident (IBLOCA) integrated effect test, LSTF test no.2 are calculated using SPACE in order to validate SPACE code for the IBLOCA phenomena. The preliminary calculation results show acceptable results for IBLOCA phenomena, except accumulator flow behavior and peak cladding temperatures. In order to understand physical phenomena during IBLOCA and predictability of related models in SPACE code, various sensitivity test for model parameters are conducted. The discharge coefficient of 0.9 shows better behavior of primary pressure. So, the SI injection timing is also improved. The most influential parameter of SIT model is a accumulator total volume. When the accumulator volume is increased with additional 0.5 $m^3$, the injection flow rate and core water level are improved. There can be various important parameters, such as multi-dimensional effect, Counter current flow limit(CCFL), flow distribution of core, downcomer, upper plenum, etc. In the near future, these parameters effects will be intensively investigated. In addition, the rest of IBLOCA tests in the LSTF, No.1 and No.9 will be calculated.

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