# Experimental Study on SBLOCA using Full-Height CPRSS Validation Test Facility

Jin-Hwa Yang*, Hong-Hyun Son, Hwang Bae, and Hyun-Sik Park
*Korea Atomic Energy Research Institute*
*989-111 Daedeokdaero, Yuseong-gu, Daejeon, 305-353, Korea*
**Corresponding author: f1yjh@kaeri.re.kr*

## 1. Introduction

An integral type reactor, system-integrated modular advanced reactor (SMART) [1] adopted a new passive safety system, which is called containment pressure and radioactivity suppression system (CPRSS) [2]. There were several types of separated effect tests (SETs) to validate the design concept of CPRSS using 1/10 height test facility, SMART IRWST separate effect test apparatus (SISTA) [3-7]. It is called as SISTA1. Recently, Korea Atomic Energy Research Institute (KAERI) constructed a full-height validation test facility to validate CPRSS in a view of integral effect among main components. It is SMART CPRSS Integral System Test Apparutus2 (SISTA2). It will be used to conduct validation tests for development of SMART CPRSS. In this study, we introduced design features of the SISTA2 and test results of SBLOCA. It will be compared with preliminary analysis results using the MARS-KS code [8].

## 2. Experimental Facility

The SISTA2 was constructed following SMART CPRSS design values reduced to 1/750 volumes containing all of main components and pipes as presented in Fig. 1.

### *2.1 Scaling of SISTA2*

Table 1 shows scaling ratios of SISTA2. The SISTA2 was scaled down following the Ishii's scaling method [9]. It was designed and constructed as a full-height test facility because the reduced height of test facility is able to distort characteristics of natural circulation and hydraulic pressure difference. Most part of SISTA2 was scaled down following standard ratios as shown in Table 1.

**Table 1. Scaling ratios of SISTA2.**

| Parameters | Scale Ratio | Value |
|---|---|---|
| Height, $h_{0R}$ | $h_{0R}$ | 1/1 |
| Diameter, $d_{0R}$ | $d_{0R}$ | $1/5\sqrt{30}$ |
| Area, $A_{0R}$ | $d_{0R}^2$ | 1/750 |
| Volume, $V_{0R}$ | $d_{0R}^2 h_{0R}$ | 1/750 |
| Time | $h_{0R}^{1/2}$ | 1/1 |
| Flowrate | $A_{0R} h_{0R}^{1/2}$ | 1/750 |
| Hydraulic pressure | $h_{0R}$ | 1/1 |

### *2.2 Main components*

Figure 1 presents a schematic diagram of SISTA2. The lower containment area (LCA) is divided into four sections in the SISTA2; LCA reactor vessel (LCA_RV), LCA lid cover (LCA_Lid), LCA core makeup tank (LCA_CMT), and LCA safety injection tank (LCA_SIT). The three connections between four sections are open doors in the proto-type, i.e., SMART CPRSS. Since it is not possible to measure the physical variables in these doors and the connection areas are narrow, it was simulated using pipes in the SISTA2. LCA_RV is a room for a reactor pressure vessel to which superheated steam is discharged when SBLOCA or MSLB is simulated. Since it simulates free volume, the RPV is not in the LCA_RV. LCA_Lid is a room for region of lid cover, which is linked with LCA_RV. LCA_CMT and LCA_SIT are rooms where CMT and SIT occupies in LCA. It was designed following free volumes of CMT and SIT rooms in the CPRSS.

Emergency cool-down tank (ECT) and CPRSS heat exchanger (CHX) are significant components of CHRS that play a role in reducing pressure and temperature of LCA. The CHX is composed of a heat exchanger tube bundle and it is immersed inside ECT which is a water pool for heat sink. If a single failure of CHRS is assumed, three trains of CHRS can be activated. The CHX of SISTA2 was scaled down following numbers of three trains of CHX in the proto-type to maintain thermal hydraulic characteristics, i.e., condensation in vertical tube.

In-containment refueling water storage tank (IRWST) is utilized to reduce pressure and temperature in LCA mainly in the beginning of transients of SBLOCA or MSLB. Two types of spargers are built-in the IRWST, which induce condensing the steam to a water pool.

The design purpose of radioactive material removal tank (RRT) is to remove radioactive materials coming from IRWST by chemical reaction. However, it is not simulated in the SISTA2, but water is filled in the RRT.

The upper containment area (UCA) was constructed as small sized one. It was reduced a 1/3 sized single tank. Additionally, four sub-tanks were reused to compensate the volume of UCA.

Steam supply tank (SST) plays a role of generating superheated steam pressurized up to 18 MPa and of supplying it to LCA_RV. While SST supplies the superheated steam to LCA_RV, other tank refills high temperature water to SST being exhausted.

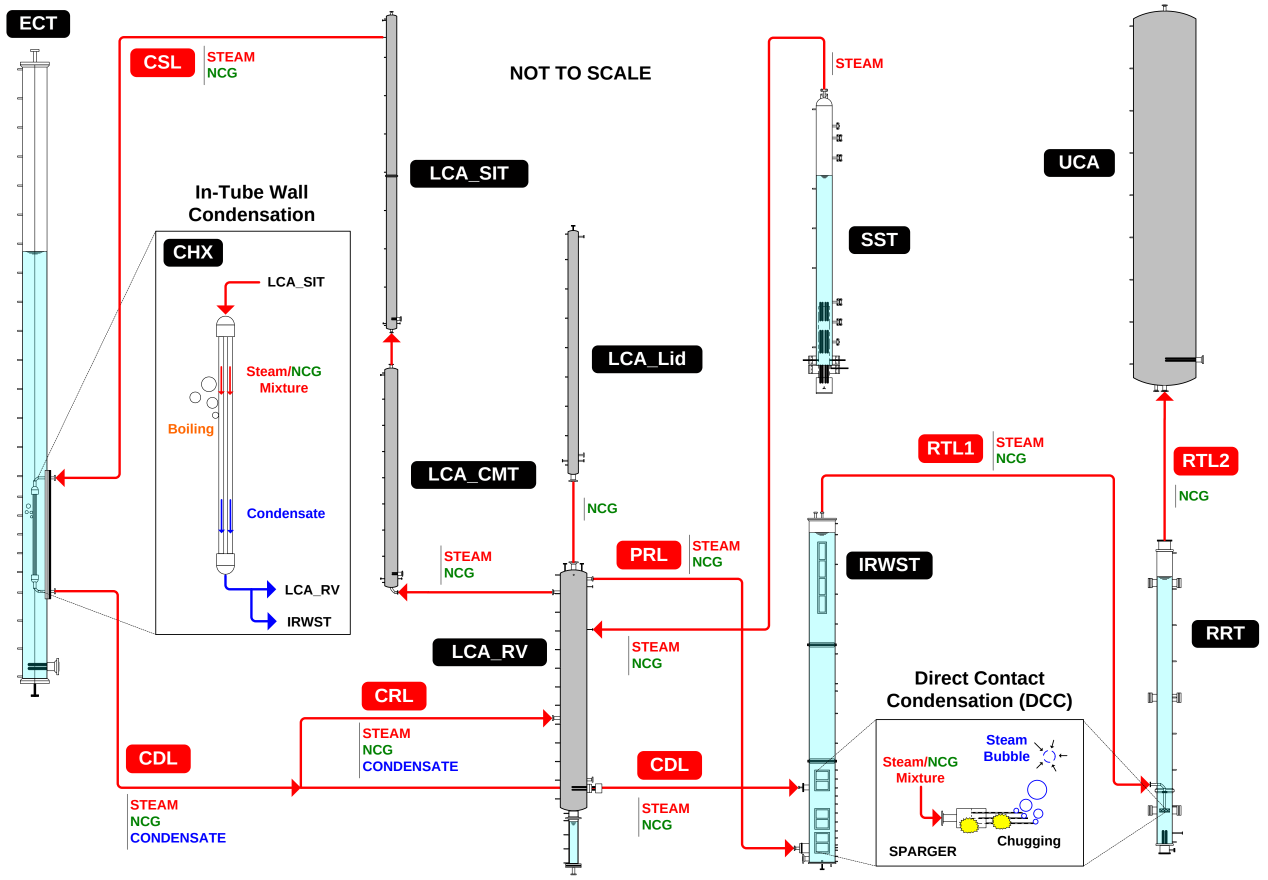


Fig. 1. Schematic diagram of SISTA2

### 3. Experimental Results of SBLOCA

The present test was carried out to simulate the beginning of SBLOCA using SISTA2. The SBLOCA scenario is a representative case among design basis accidents (DBA). It was continued until 10,000 seconds after break simulation. Initial conditions of each component were adjusted to meet design values. The design value was calculated with MARS-KS [8].

#### *3.1 Injected steam mass flow rate*

Figure 2 shows comparison results of SBLOCA break mass flow rate. It was an injected steam mass flow rate from SST in the experiment, because RPV could not be installed in the LCA_RV. Heat loss test was conducted to quantify the minimum steam flow rate to maintain LCA pressure as constant. The sum of the design value and the heat loss compensation value was a target value (Design + heat loss) which is red line in the Fig. 2. The blue line in the Fig. 2 means the measured value in the experiment. The injected steam mass flow rate was measured by a Coriolis mass flow meter. The operator adjusted the valve opening of the SST to meet the target value. Accumulated masses between target value and experimental result during 10,000 seconds have below 5% difference.

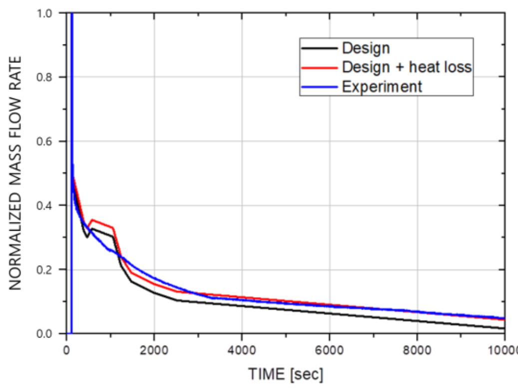


Fig. 2. Simulation of break mass flow rate

#### *3.2 Pressure*

Figure 3 presents pressure distribution in the LCA and UCA. Amount of air moved from the LCA to UCA determined the pressure of UCA. There is a delay of air distribution for about 1,000 seconds after break. It is because there was a pipe line between RRT to UCA. The pressure of LCA went up slightly until 1,500 seconds and it was maintained as constant before 6,000 seconds and fell again in the experiment. There is also a delay of pressure distribution between the calculated value and experimental result. It was confirmed that the injected steam mass flow rate with heat loss compensation resulted in similar to the design value.

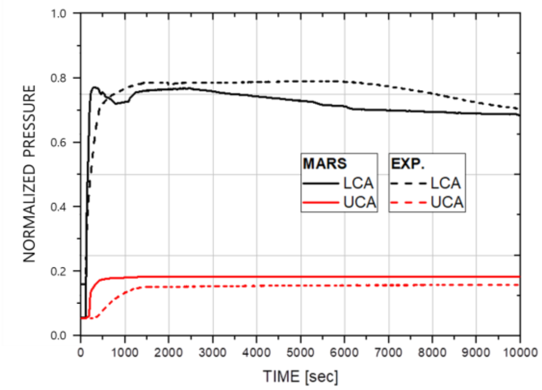


Fig. 3. Pressure distribution in LCA and UCA

## 4. Conclusions

A full-height validation test facility, SISTA2, was constructed to conduct integral effect tests for validation of SMART CPRSS. It is able to maintain thermal hydraulic characteristics of the proto-type system, for examples, natural circulation and hydraulic pressure difference. As a representative test, a SBLOCA test was carried out using SISTA2. It was confirmed that the pressure behaviors of LCA and UCA were similar to design values, if the heat loss was compensated properly as a boundary condition.

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