Thermal-Hydraulic Integral Effect Test with ATLAS for an Intermediate Break Loss of Coolant Accident at a Pressurizer Surge Line

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1. Introduction

Redefinition of break size for design basis accident (DBA) based on risk information is being extensively investigated due to the potential for safety benefits and unnecessary burden reduction from current LBLOCA (large break loss of coolant accident)-based ECC (Emergency Core Cooling) Acceptance Criteria [1]. As a transition break size (TBS), the rupture of medium-size pipe is considered to be more important than ever in risk-informed regulation (RIR)-relevant safety analysis.

As plants age, are up-rated, and continue to seek improved operating efficiencies, the small break and intermediate break LOCA (IBLOCA) can become a concern. In particular, IBLOCA with DVI (Direct Vessel Injection) features will be addressed to support redefinition of a design-basis LOCA. With an aim of expanding code validation to address small and medium break sizes, development of an evaluation model (EM) for full spectrum LOCA is attracting an extensive attention in the field of nuclear safety analysis. The experimental data for an IBLOCA, however, are quite limited especially on the effect of the ECC water injection methods of DVI. Core uncovery, ECC bypass, and loop seal clearance characteristics during an IBLOCA transient may be different from those during a SBLOCA and a LBLOCA transient.

In order to provide integral effect test data to validate the SPACE code [2] for an IBLOCA, a pressurizer surge line break simulation test was decided to be performed in technical consultation with Korean nuclear industry. In this study, a thermal-hydraulic integral effect test was performed with ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation) to simulate a double-ended guillotine break of a pressurizer surge line of the APR1400 (Advanced Power Reactor 1400 MWe). The main objectives of this test were not only to provide physical insight into the system response of the APR1400 during the pressurizer surge line break accident but also to produce an integral effect test data to validate the SPACE code.

2. Experimental Methodology

2.1 Description of the ATLAS Facility

A thermal-hydraulic integral effect test facility, ATLAS, has the same two-loop features as the reference plant of the APR1400, and is designed according to the well-known scaling method suggested by Ishii and Kataoka to simulate the various accident scenarios as realistically as possible. ATLAS is a 1/2 reduced height and a 1/288 volume scaled integral effect test facility with respect to the APR1400. It has a maximum power capacity of 10% of the scaled nominal core power, and can simulate the full pressure and temperature conditions of the APR1400. Detailed description of ATLAS facility can be found in the open literature [3].

2.2 Experimental Conditions and Procedures

In the present IB-SUR-01R test, a pressurizer surge line break IBLOCA was simulated. The test conditions were determined by a pre-test calculation with a best-estimate thermal-hydraulic safety analysis code, MARS [4]. A single failure assumption for a safety injection system was assumed in the MARS calculation; four safety injection tank (SITs) and two of four safety injection pump (SIPs) were available. The initial and boundary conditions for the present test were obtained by applying the scaling ratios shown to the MARS calculation results for the APR1400. Table 1 compares the steady-state conditions between the APR1400 and the ATLAS for the present test.

Fig. 1 shows a schematic diagram of the break simulation system in the IB-SUR-01R test. The break nozzle was precisely manufactured to have a scaled break flow as realistically as possible. The inner diameter of the break nozzle was determined to be 18 mm which corresponds to 1/203.6 of a 10 inch break area. The break nozzle has a well-rounded entrance and total length is up to 226 mm including the entrance region to comply with the long pipe requirement that the length to diameter ratio should be above 12.

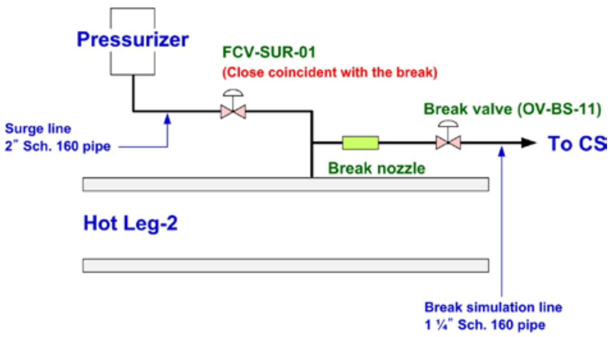

Fig. 1. Schematic diagram of the break simulation system

The decay heat was simulated to be 1.2 times that of the ANS-73 decay curve for the conservative condition. The initial heater power was controlled to be maintained at about 1.645 MW, which was equal to the sum of the scaled-down core power (1.565 MW) and the heat loss rate of the primary system (about 80 kW). The heater power was then controlled to follow the specified decay curve after 12.07 seconds from the reactor trip.

3. Experimental Results and Discussions

The major sequence of events observed during the whole test period is summarized in Table 1.

Table I: Sequence of Events

Event	Time (sec)	Remark
Break open	306	
LPP	311	RPV upper head pressure @ 10.7124 MPa
MSIS	315	LPP + 3.54 s delay
MFIS	319	LPP + 7.07 s delay
MSSV opening	322	Steam generator pressure @ 8.1 MPa
SIP	340	LPP + 28.28 s delay
SIT	525	RPV upper head pressure @ 4.0314 MPa

When the pressurizer surge line break event was initiated by opening the break simulation valve, OV-BS-11, the reactor coolant system (RCS) was rapidly depressurized until the SIPs were actuated as shown in Fig. 2. During the initial blow-down period, the depressurization rate of the RCS was estimated to be 380 kPa/s. Supply of the safety injection water from the SIPs mitigated the RCS depressurization rate by compensating the RCS inventory. Due to the relatively larger break area compared with the small break LOCA tests, however, the plateau of the primary system pressure was not clearly formed and the RCS was depressurized again which resulted in the actuation of the SIT. Following the reactor trip, the secondary pressure increased until the main steam safety valves (MSSVs) were opened to reduce the secondary system .

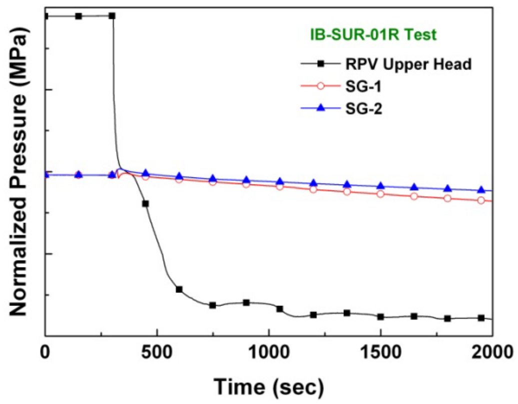

Fig. 2. Variation of the system pressures

Fig. 3 shows the variation of the collapsed water level in the core and the down-comer. The collapsed water level in the core decreased rapidly with the break and the upper region of the active core was uncovered. The collapsed water level in the down-comer maintained until the loop seal clearance occurred. After the loop seal clearance, the collapsed water level in the down-comer decreased rapidly. Despite the core was uncovered, there was no excursion of the cladding temperatures.

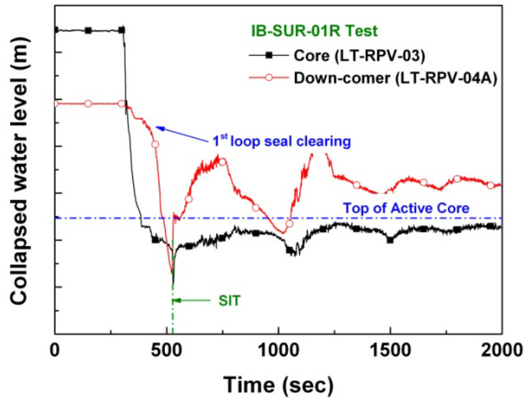

Fig. 3. Variation of the collapsed water levels

4. Conclusions

In order to simulate a double-ended guillotine break of a pressurizer surge line in the APR1400, the IB-SUR-01R test was performed with ATLAS. The major thermal-hydraulic phenomena such as the system pressures, the collapsed water levels, and the break flow rate were presented and discussed. Despite the core was uncovered, no excursion in the cladding temperature was observed. The pressurizer surge line break can be classified as a hot leg break from a break location point of view. Compared with a cold leg break, coolability in the core may be better in case of a hot leg break due to the enhanced flow in the core region.

This integral effect test data will be used to evaluate the prediction capability of existing safety analysis codes of the MARS and the RELAP5 as well as the SPACE code. Furthermore, this data can be utilized to identify any code deficiency for an IBLOCA simulation, especially for DVI-adapted plants.

REFERENCES

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