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Analysis of the ATLAS Cold Leg Top-Slot Break Experiment Using the MARS Code

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1. Introduction

During a small-break loss of coolant accident (SBLOCA) or intermediate-break loss of coolant accident (IBLOCA) in a PWR, such as the APR1400, the steam volume in the reactor vessel upper plenum may continue to expand until the liquid phase in the horizontal intermediate legs is released, called loop seal clearing (LSC), due to the increase of the pressure in the upper plenum. After the LSC, the liquid injected by the emergency core cooling system (ECCS) or the safety injection tanks (SITs) may refill the intermediate legs and this blocks the steam path; this is called the loop seal reformation (LSR).

A domestic standard problem (DSP) exercise using the ATLAS facility was promoted in order to transfer the database to domestic nuclear industries. For 4^{th} DSP (DSP-04), the ATLAS cold leg top-slot break experiment was postulated. For the DSP-04, main concerns are to predict the LSC and LSR having a significantly effect on the behavior of the system under long term cooling.

In this study, we simulated the ATLAS cold leg top-slot break experiment using the MARS code [1] and the predicted LSC and LSR are compared to experimental results.

2. ATLAS Cold leg Top Slot-Break experiment

2.1 Description of ATLAS Test Facility

The ATLAS experimental facility was designed according to the well-known scaling method suggested by Ishii and Kataoka [2] to simulate various test scenarios as realistically as possible. It is a half-height and 1/288-volume scaled test facility with respect to the APR1400.

2.2 Description of the ATLAS LTC-CL-04R

Among a series of the cold leg top-slot break experiments at the ATLAS facility, the LTC-CL-04R was chosen in this analysis. In the experiment, a 7.12 mm nozzle was installed on upward direction at cold leg 1A of ATLAS to simulate a 4.0 inch top-slot break for the APR1400. To simulate conservative condition, four SIPs with maximum flow and four SITs were activated. The SI fluid temperature was ambient temperature (16 ℃) [3]. This experiment was focused on the loop seal reformation under long term cooling.

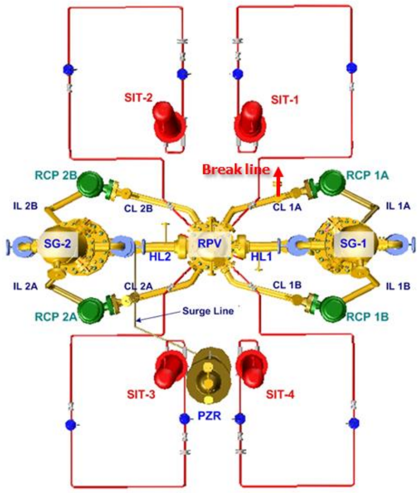

Fig. 1. Schematic diagram of the ATLAS and break position

Major event chronology is as follows:

t=300 s	Opening of the break valve
t=336/340 s	1^{st} Main steam safety valve (MSSV) open (SG-1/SG-2)
t=332 s	Low pressurizer pressure (LPP) signal occurred (PT-PRZ-01 < 12.48 MPa)
t=381 s	Safety injection signal occurred (PT-PRZ-01 < 10.7MPa +28 sec)
t=1066 s	Safety injection tank signal occurred

3. MARS Calculation

3.1 Modeling Information

The nodalization used in present calculations is presented in Fig. 2 [4]. Fine meshes are applied to the pump suction region to predict LSC and LSR, well. The break pipe line in Fig. 3 was additionally modeled to realistically simulate the break flow and, the Trapp-Ransom critical flow model was employed at the break nozzle.

3.2 Steady-State Analysis Results

The steady state was obtained by simulating the null transient of 1800 seconds. The results of the steady-state calculation are presented in Table 1, which shows that the MARS-KS predicts well compared with the experimental results [5].

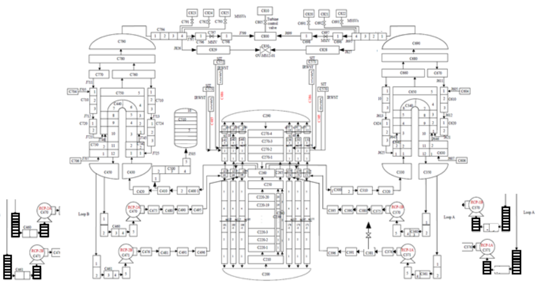

Fig. 2. MARS-KS nodalization for the ATLAS LTC-CL-04R

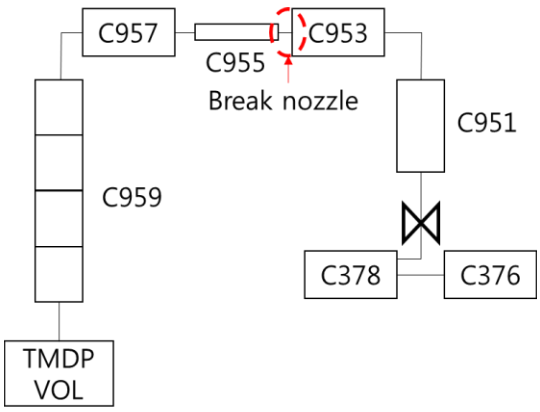

Fig. 3. Break pipe line for the ATLAS LTC-CL-04R

Table 1. Steady state calculation results

Parameter	Exp.	MARS	Difference (%)
Primary system			
Core power(MW)	1.64	1.56*	
Pressurizer pressure (MPa)	15.5	15.53	0.2
Core inlet temp. (K)	564.15	564.47	0.05
Core outlet temp. (K)	599.99	599.99	0.0
Pressurizer level (m)	4.29	4.24	1.2
Cold leg flow rate (kg/s)	1.98	1.83	7.6
Secondary system			
SG dome pressure. (MPa)	7.83 / 7.83	7.87 / 7.87	0.5/0.5
SG steam Temp. (K)	568.75/568.8	567.0/565.1	0.3/0.66
Feed water Temp. (K)	507.05/506.2	506.8/505.7	0.05/0.1
FW flow rate (kg/s)	0.41/0.413	0.43/0.43	4.9/4.1
SG water level (m)	4.99/4.99	5.02/4.95	0.6/0.8

*Considering heat loss

3.3 Transient Analysis Results

The predicted pressurizer pressure agrees well with the experimental data, as shown in Fig. 4. As soon as the break valve opened, the primary pressure decreased rapidly due to the sudden loss of the coolant from the system. The rapid depressurization continued until the blockage of loop-seal occurred. Then, a plateau of the primary pressure was observed until the first LSC occurred. As soon as the loop seal clears, the primary pressure rapidly decreases again until the first LSR occurred. In the MARS, the LSR prematurely occurred compared to that in the experiment. From this point, the primary pressure in the MARS and experiment is slightly different from each other because the timings of the LSC and LSR are different from each other. As shown in Fig. 5, the first LSC in the experiment continues until 3700 s and, then, the LSR and LSC occur intermittently. However, as shown in Fig. 6, the cleared loop seal in the MARS is prematurely blocked after the first LSC compared to experimental results. Then, the LSC and LSR occur intermittently and, all loop seal were continuously blocked after 3400 s unlike experimental data. Meanwhile, the cladding temperature is presented in Fig. 7. In the experiment and the calculation, the core heat up was not observed because a core uncovery did not occur during the whole transient.

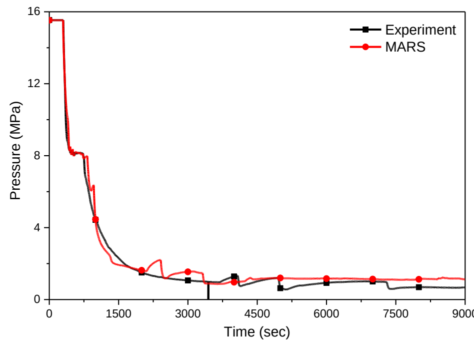

Fig. 4. The pressurizer pressure

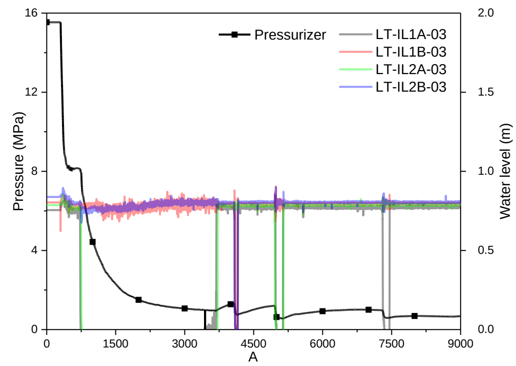

Fig. 5. The pressurizer pressure and water level of the horizontal intermediate legs for the experiment

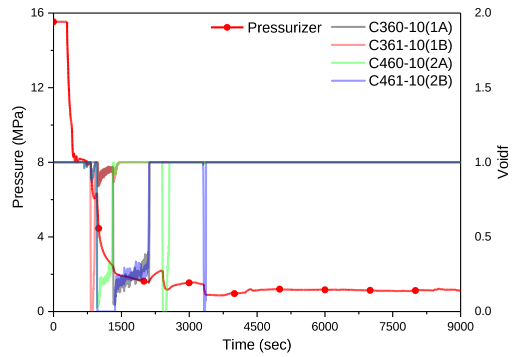

Fig. 6. The pressurizer pressure and liquid fraction of the horizontal intermediate legs for the MARS

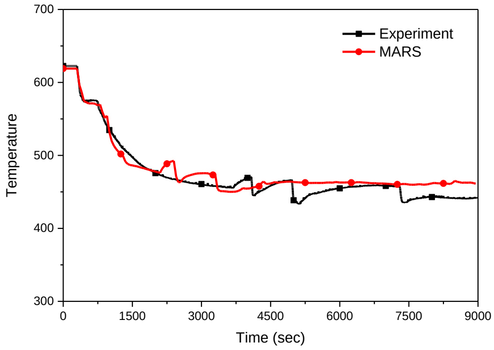

Fig. 7 The cladding temperature

4. Conclusions

The LTC-CL-04R was simulated using the MARS code. Most of the predicted results agree well with the experimental data. However, the timing of LSC and LSR is slightly different from each other and, thus, the behavior of the primary system (e.g. pressure and temperature, etc.) is slightly different. The core heat up was not observed in the experiment and the calculation,

Acknowledgement

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