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Evaluation of ATLAS 100% DVI Line Break Using TRACE Code

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1. Introduction

ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation) is an integral effect test facility in KAERI. It had installed completely to simulate the accident for the OPR1000 and the APR1400 in 2005. After then, several tests for LBLOCA, DVI line break have been performed successfully to resolve the safety issues of the APR1400 [1]. Especially, a DVI line break is considered as another spectrum among the SBLOCAs in APR1400 because the DVI line is directly connected to the reactor vessel and the thermal hydraulic behaviors are expected to be different from those for the cold leg injection. However, there are not enough experimental data for the DVI line break. Therefore, integral effect data for the DVI line break of ATLAS is very useful and available for an improvement and validation of safety codes.

For the DVI line break in ATLAS, several analyses using MARS and RELAP codes were performed in the ATLAS DSP (Domestic Standard Problem) meetings [1]. However, TRACE code has still not used to simulate a DVI line break. TRACE code has developed as the unified code for the reactor thermal hydraulic analyses in USNRC [2]. In this study, the 100% DVI line break in ATLAS was evaluated by TRACE code. The objectives of this study are to identify the prediction capability of TRACE code for the major thermal hydraulic phenomena of a DVI line break in ATLAS.

2. Modeling of ATLAS

The reactor vessel of ATLAS is modeled as a VESSEL component of TRACE with 3 radial, 6 azimuthal and 28 axial volumes [3]. The core, lower & upper plenums are modeled in an inner two radial parts and an outer radial part is downcomer. The core is divided as 12 volumes and two heaters (1 average rod, 1 hot rod) are modeled in each volume. The core bypass and CEA guide tube bypass are modeled as 4 channels respectively. The two reactor coolant loops are modeled with two cold leg, one hot leg and one steam generator respectively. The pressurizer is connected to the one hot leg. The APR1400 has four mechanically separated hydraulic trains and two electrically separated divisions. Therefore, if the break is occurred simultaneously with the worst single failure for a loss of a diesel generator, the safety water is injected only through a nozzle opposite to the broken nozzle. In this study, the DVI-4 nozzle is broken and the DVI-2 nozzle is the intact safety injection loop. Also, three SITs except the SIT connected to the broken DVI-4 nozzle are considered as the available safety injection flow and the low flow region for the fluid device in each SIT is modeled by adjusting the flow area when the SIT water level is less than a specific set point. The break line is modeled as a single junction and a FILL component to simulate the initiation the DVI line break to the containment.

3. Analysis Results

The initial conditions were obtained from the steady state calculation of TRACE. The calculated initial conditions show a good agreement to the measured values for the major parameter such as a core power, pressurizer pressure and hot & cold leg flow rates.

The DVI line break was started by the opening trip in the FILL component at 199 s. After then, the pressurizer pressure decreased and reached to a low PZR set pressure (~ 10.7 MPa) at ~228 s. The LPP time of TRACE is ~ 9 s later than that of ATLAS. This may result from the characteristic of the choke model in TRACE code. It will be improved from the sensitivity study for the choke model. The decay of heater power is modeled to start at same time (~ 223 s) with the experiment. The major sequence of events is listed in Table I.

Table I. Evaluation Conditions for Sensitivity Analysis

Events	Time (sec)	
	ATLAS	TRACE
Steady state condition	< 199.0	< 199.0
Break open	199.0	199.0
Low pressurizer pressure(LPP)	219.0	228.8
Main steam isolation	219.0	229.7
Reactor trip by LPP	-	229.2
RCP trip	-	229.2
Decay power start	223.0	223.0
Main feedwater isolation	226.0	237.0
SIP injection signal	246.0	257.1
SIT injection start	431.0	426.0

Fig. 1 shows the calculated PCT with the measured PCT and Fig. 2 shows the calculated and measured downcomer and core collapsed water levels. The measured temperature behavior agrees well to the TRACE prediction except the pecking phenomena at ~290 s. After breaking, the reduction of the downcomer water level resulted in the decrease of the core water level. After initiating of the safety injection, the injected cold safety water contracted the downcomer water level in the experiment. This phenomenon reduced continuously the core water level until ~ 290s and the pecking of cladding temperature occurred at that time. However, in TRACE prediction, the steam generated in the core was moving to a cold leg through a hot leg and a steam generator. The moving steam was blocked by the non-saturated water in the loop seal of each loop and then the pressure of the upper plenum increased until the loop seal clearing occurred (see Fig. 3). Therefore, during the period between the SIP injection and the loop seal clearing, the downcomer water level was not changed because of the interaction between the injected water in the downcomer and the build-up pressure in the core. Consequently, the stagnation of the downcomer water level did not reduce the core water level to the measured value and the peaking of the cladding temperature was not shown in the TRACE prediction.

After a loop seal clearing, the downcomer and core water level were reduced until the SIP injection started. After the water in SIT was injected, the core water level was almost identical to the measured value. However, the downcomer water level showed the low prediction results compared to the measured value. The low downcomer water level in the TRACE prediction might be resulted from the low SIT injected flow and the high water inventory in the intermediate leg.

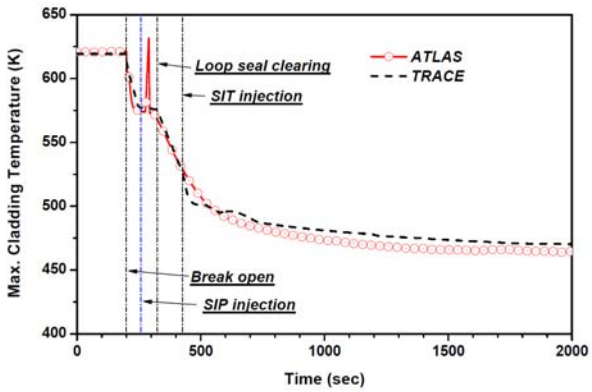

Fig. 1 Max. Cladding Temperature at Hot Rod

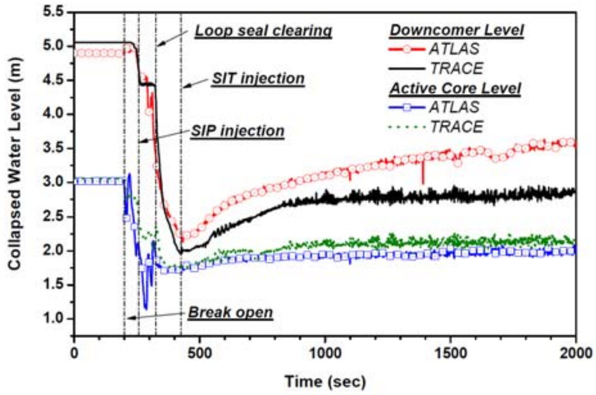

Fig. 2 Core & Downcomer Collapsed Water Level (m)

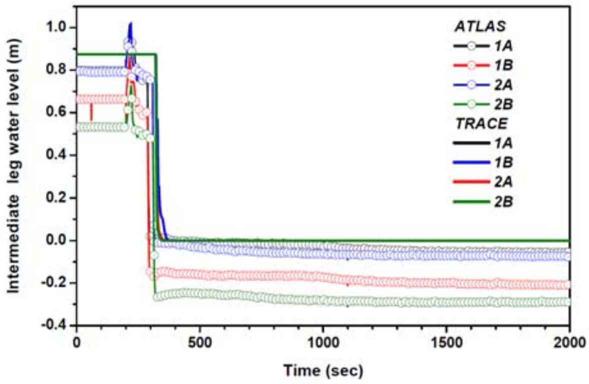

Fig. 3 Intermediate Leg Water Level

4. Conclusion

The calculation for the 100% DVI line break of ATLAS was performed with the TRACE code. The reactor vessel, coolant loops and safety injection systems were modeled on the basis of the design data of ATLAS. For the transient analysis, the initial and boundary conditions were defined well with the measured values. The major behavior of the cladding temperature, the downcomer and core water levels could be predicted well with TRACE code. However, the further study will be needed to resolve the differences of the choke flow, the water inventory, etc.

REFERENCES

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[3] KINS, Development of Input System of TRACE Code for Evaluation of ATLAS Experiments, KINS/RR-710, 2009.