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Evaluating the break flow for the 100% DVI line break accident of ATLAS using the RELAP5/MOD3.3 code

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1. Introduction

An integral effect test database for major design basis accidents using the Advanced Test Loop for Accident Simulation (ATLAS) facility has been compiled by the Korea Atomic Energy Research Institute (KAERI) [1]. In order to effectively utilize the database, the Domestic Standard Problem (DSP) exercise was proposed and launched in 2009. As the first DSP exercise, scenario involving a 100% break of the DVI nozzle was determined by considering its technical importance including such phenomena as the break flow, loop seal clearing [2].

The first DSP exercise was performed in an open calculation environment. Thus, integral effect test data were opened to the participants prior to code calculations. Ten domestic organizations including members of nuclear industry, a research institute, and universities participated in the DSP exercise using various best-estimate safety analysis codes and finally presented their code prediction results, comparing them to the experimental data.

This paper presents the analysis results performed by NETEC as one of the first DSP exercise participants. This analysis focuses on the break flow phenomena and modeling.

2. Analysis modeling for ATLAS DSP-01

The overall noding diagram of the ATLAS is similar to the APR1400 noding diagram except for the detailed minor design data which it used. The nodalization scheme includes all the reactor coolant systems such as the vessel and the downcomer, the primary piping, the steam generators, the steam lines, and the safety injection system. The feedwater and main steam systems are treated as boundary conditions, i.e. they are modeled by time-dependent volume components. 4 cold legs, 2 hot legs and 3 DVI lines except for the break- line are connected from the normal direction to the outer surface of the downcomer. All the heat structures of the ATLAS facility are simulated using the detailed design data. The heater power is given as a function of time, which corresponds to the decay heat power (120%*ANS 73) generated in the APR1400 simulation. For real transient analysis, the decay heat power measured by the experiment is used as an input value.

The break modeling of the faulted DVI pipe line is presented in Figure 1 [3]. The break position corresponding to the experiment is assumed to be the quick opening break valve on a DVI line in order to simulate its break flow to the containment. The containment pressure history is given as a function of time using the experimental data.

This analysis assumes a single. Thus, one of four SIPs and three of four SITs are available during the transient.

The sequence of events (SOE) during the transient is appropriately simulated according to the experimental scenario.

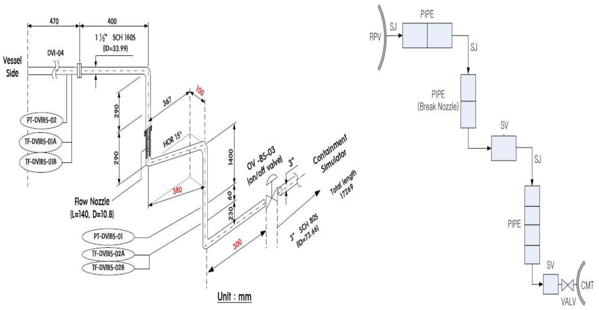

Figure 1. RELAP5 modeling for ATLAS break line

3. Pre-calculation for determining a discharge coefficient

RELAP5/MOD3.3 is used as the reference code for analysis. The Henry-Fauske (HF) model is used as the default critical model of the RELAP5 code. Two parameters, a discharge coefficient (Cd) and a non-equilibrium factor (Neq) should be defined by users in order to use the HF model.

Since we added break line modeling to the ATLAS break simulating system, the effect of Cd at the break nozzle should be evaluated. For Neq, the default value, 0.14 is used for all cases because it does not affect the depressurization rate significantly.

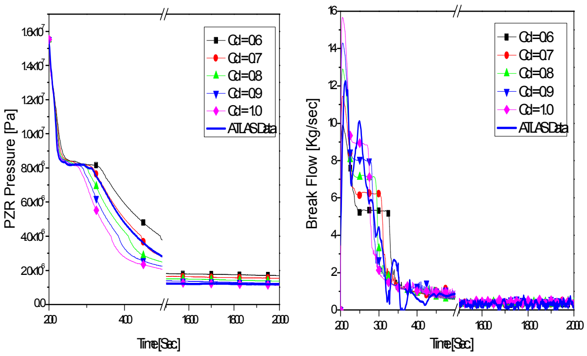

Figure 2. Pressurizer pressure and break flow according to Cd variation

Figure 2 shows the primary pressure and break flow according to variation in Cd. As expected, the break flow and the primary pressure decreasing rate are proportional to the Cd value. Through additional sensitivity analyses, the Cd value is set to 0.72 for the base case analysis of the simulation. In addtition, the other major parameters are much closer to the experimental data.

4. Base case analysis results

The transition analysis is restarted by initiating an SBLOCA at a DVI line from the steady state analysis results. As shown in Figure 3, the primary and secondary pressure behaviors using the Cd value of 0.72 show good agreement with the experimental data. SOE applied to code analysis is based on the results of ATLAS. A low pressurizer pressure (LPP) trip in the analysis occurs at 220 seconds after the break(199 seconds). With this, the reactor and RCP trip (LPP+0.35 seconds), the turbine isolation (LPP+0.07 seconds), the main feedwater isolation (LPP+7.07 seconds) and the starting of the safety injection pumps (LPP+28.28 seconds) are simulated in order [4].

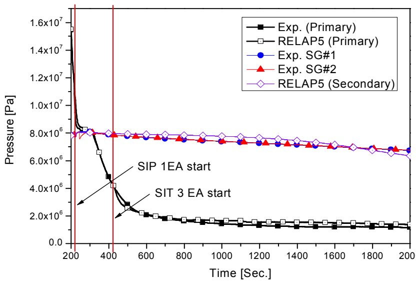

Figure 3. Primary and secondary pressure behaviors

Figure 4 compares the collapsed water levels in the core and intermediate legs. The behavior of the core water level can be analyzed better by dividing it into behavior before and that after the loop seal clearing. The core recovery in the experiment starts at around 300 seconds, which is the loop seal clearing time. The experimental core water level around the loop seal clearing time is considered reasonable because a typical loop seal clearing promotes the venting of steam to the break and results in a rapid decrease of the core level. However, the analysis results do not show such core water level behavior because the code could not predict the loop seal clearing appropriately as shown in Figure 4. In the analysis, the loop seal doesn't completely clear at that time.

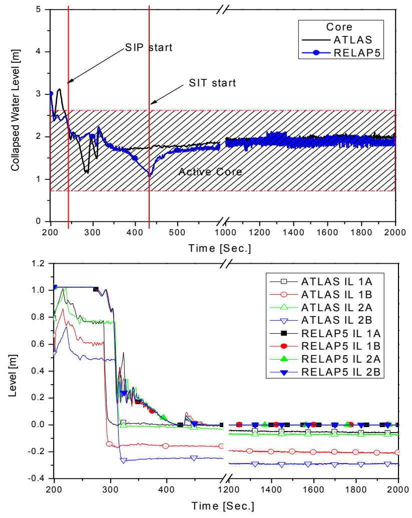

Figure 4. Collapsed water levels in Core and Intermediate legs

Figure 5 compares the measured PCT with the PCT predicted by the RELAP5 code. While a maximum PCT of 603K is observed at around 290 seconds in the experiment, the RELAP5 code predicts that the PCT is not observed at that time because the core water level is not decreased unlike the experiment at SIP injection time. Also, no PCT occurs during the entire period.

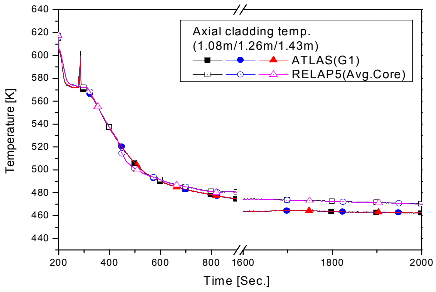

Figure 5. Comparison of axial PCT behaviors

5. Conclusion

The optimal Cd was chosen through a sensitivity study since this follows the experimental data best. We also found that the prediction by the RELAP5 code was generally in reasonable agreement with the experimental data. However, a little disagreement exists in local TH behavior by the differences in loop seal clearing. Also, the base analysis results still include uncertainty for the break flow.

Acknowledgements

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