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Thermal Hydraulic Aspect during a DVI Line Break Simulation with the ATLAS

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1. Introduction

An integral effect test for simulating a guillotine break of a DVI line of the APR1400 was carried out to understand the thermal hydraulic phenomena using the ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation). Though some previous works on the DVI line break were reported [1,2,3], the present data is the first integral effect test data of its kind for simulating a DVI line break accident. A post-test calculation was performed with the best estimate safety analysis code MARS3.1 based on the obtained data. The present integral effect test data will be used to validate the current safety analysis methodology for the DVI line break accident.

2. Scaling for major components

Major components of which their performance can influence a transient behavior were appropriately scaled down to simulate the transient behavior of the APR1400 as closely as possible.

It was concluded from the comparison of stored energy scaling that the case of the no-delay power trip, where the core power starts to follow the scaled decay power curve after it maintains a constant value until it intersects with the scaled decay power, resulted in the least distorted results from the viewpoint of scaling. The core power was continuously controlled to follow 120% of the ANS73 decay curve throughout the test.

A choking is expected to occur during the entire test period of the DVI line break. The inner diameter of the break nozzle was determined to be 15.13mm which corresponds to 1/203.6 of an 8.5 inch break diameter of the APR1400. For the break nozzle, the scaling ratio of the friction loss coefficient between the vessel and the break point was preserved by controlling the roughness of a nozzle.

The required SI flow rate as a function of the primary pressure was obtained from the pre-test calculation of the APR1400. Then, the required rotation speed of the SI pump as a function of the primary downcomer pressure was obtained empirically. This relationship was programmed into the control system of the ATLAS to simulate the scaled safety injection flow rate by the SI pump.

The nitrogen gas volume of a SIT, the discharged high flow rate before the FD is activated and the discharged low flow rate when the FD is working are preserved. Initial water level and the FD-activated water level of the SIT were determined by volume scaling ratio. The flow resistance before and after the activation of the FD were implemented by an orifice and a control valve, respectively.

Two kinds of bypass flow paths in the reactor vessel were implemented into the ATLAS. One is the bypass flow path from the downcomer to the hot leg and the other is from the downcomer to the upper head of the core. The flow resistances of the bypass flow paths need to be preserved to have the same bypass flow characteristics in the ATLAS as the APR1400.

3. Major test results

3.1 Initial conditions

Initial target values for the present test were determined by a pre-test calculation of the ATLAS system by the MARS 3.1 code. The initial measured values for the major parameters were very consistent with the target values.

3.2 Major sequence of events

The major sequence of events of the present test is shown in Table 1. The transient started at 198 seconds. The primary pressure reached a low pressurizer pressure trip set point (LPP) at 217 seconds when the pressurizer pressure decreased to 10.7MPa. The main steam and feedwater lines were isolated after the LPP with a specified time delay. The SIP started after the LPP with a time delay of 28 seconds. Turndown to the low flow mode of the SIT occurred at around 1200 seconds. The test was ended at 8011 seconds when there was no significant variation of the major parameters.

Table 1 Major sequence of events for the present test

Event	Time (sec)	Remarks
Break open	198	
LPP	217	
Main steam isolation	218	
Main feed isolation	225	
Decay power start	228	
SIP	245	
Max. PCT	288	350^{o}C
Loop seal clearing	~300	
SIT on	431	
SIT low flow	1055/1238/1263	SIT3/SIT2/SIT1
SIT off	5145/6249/6504	SIT3/SIT2/SIT1
Stop	8011	

3.3 Major thermal hydraulic aspects

A PCT of 350 °C was observed at around 300 seconds, while the MARS code predicted 293 °C at around 400 seconds as shown in Fig.1. The MARS code also predicted a delayed heat-up than the present data by more than 150 seconds. The discharge coefficient of C_d=0.75 at the break nozzle resulted in the best agreement with the primary pressure trend as shown in Fig.2.

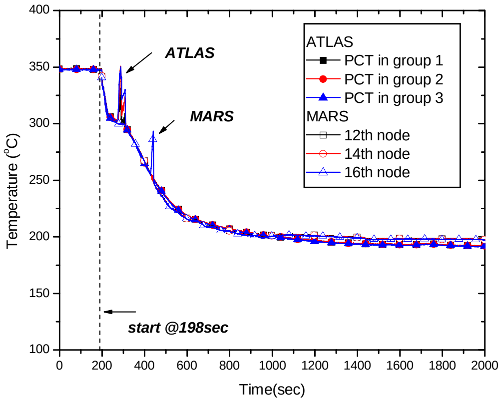

Figure 1 Comparison of the measured PCT behavior

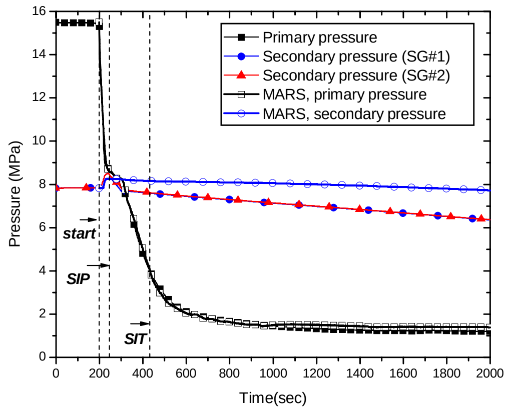

Figure 2 Comparison of the 1st and 2nd pressures

As an alternative method for a load cell-based break flow measuring method, a RCS inventory-based break flow estimation method has been developed to obtain a more accurate break flow rate especially in the initial stage of the transient. The predicted break flow shows a similar trend to a RCS inventory-based break flow as in Fig.3. The measured collapsed water level of the core had no sooner decreased down to about 30% of the active core region than the break had occurred as shown in Fig.4. However, the predicted collapsed water level of the core did not decrease as much as the measured data. Such initial core level decreases are recovered when the loop seals in the intermediate legs are cleared. Subsequently the collapsed water level of the core shows a continuous decrease until the SIT starts to inject additional ECC water into the core.

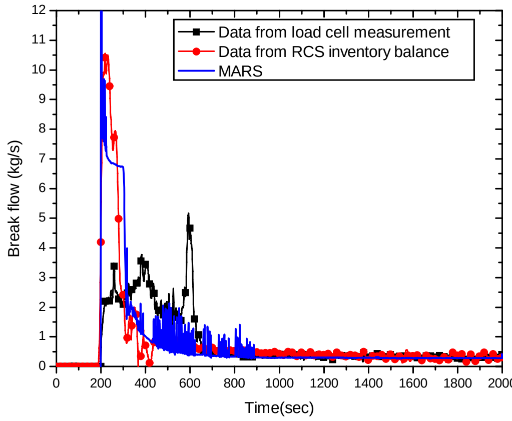

Figure 3 Comparison of the break flow

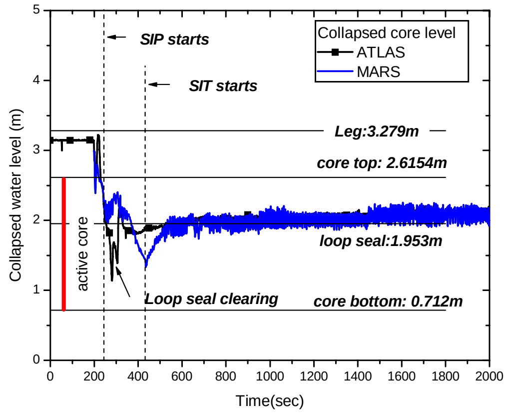

Figure 4 Comparison of the collapsed core water level

4. Conclusions

An entire scenario for a guillotine break of one of the DVI lines of the APR1400 was simulated successfully with the ATLAS. Initial and boundary conditions were determined carefully by a scaling analysis in order to minimize the scaling distortions. The MARS code revealed reasonable prediction results for the present data. However, it predicted a higher core level than the data in the post-trip phase when a loop seal clearing occurs and a delayed increase in the peak cladding temperature. This is considered to be the main cause for a low PCT than the data.

REFERENCES

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