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Analysis of the Downcomer Wall Cooling Effect using MARS Code on Electrical 4 Trains during LBLOCA

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1. Introduction

A thermal-hydraulic integral effect test facility, ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation)[1], has been constructed at the Korea Atomic Energy Research Institute (KAERI). Several integral effect tests for the reflood phase of a large break loss of coolant accident (LBLOCA)[2,3] have been performed with the ATLAS. Those LBLOCA tests were performed to investigate the thermal-hydraulic characteristics during the reflood period and to provide reliable data to help validate the LBLOCA analysis methodology for the APR1400.

By the scaling analysis, the heat transfer area of the downcomer wall of ATLAS is eight times larger than that of the ideal case. To compensate this scaling distortion, the downcomer wall temperature was setting to 205 ^{o}C for the initial condition of the LBLOCA test. During the test, the outer wall temperature of the lower downcomer was kept with the setting value. However, the upper downcomer wall temperature was 60 ^{o}C higher than the initial setting value. To cool-down the upper down comer wall before reflood phase, the change of the depressurization process which uses the DVI lines has been proposed. In this study, the cooling effect of the depressurization process using DVI lines were confirmed using MARS code.

2. MARS Code Modeling

2.1 Nodalization

The overall nodalization scheme of the ATLAS facility is similar to the previous APR1400 nodalization schemed. The nodalization scheme includes all the reactor coolant systems such as the reactor vessel, downcomer, primary piping, steam generators, main steam lines, and the safety injection system. The feedwater and main steam systems are treated with boundary conditions, and they are modeled by time-dependent volume components. The safety injection system has four mechanically separated hydraulic trains which are composed of a high pressure safety injection (HPSI) pump and a safety injection tank, and are connected to a DVI nozzle.

2.2 Modeling of the Depressurization through the DVI line

For the first case, the mass flow rate of the drain was controlled only by the pressure difference between the primary side (8MPa) and the DVI drain line. Thus, the drain area was considered as the whole cross sectional are of the DVI line pipe.

As the second case, the mass flow rate of the drain was controlled by the junction area and the k-factor(loss coefficient) to control the depressurization process time to ensure the enough cooling time. In this study, the drain area was set to 1.5x10^{-4}m^{2} (16.42% of the total pipe area).

In addition, one of the four DVI lines was used first and, as the sensitivity study, all of the 4 DVI lines were also simulated to check the symmetry of the downcomer wall cooling effect.

3. Analysis Results

3.1 Cooling effect

The analysis results of that the drain was controlled by the junction area and the k-factor(loss coefficient) were shown from the Fig. 1-3. The mass flow rate through the DVI line was about 8.5 kg/s from the opening of the drain valve and depressurization process was kept more than 500 sec. The collapsed water levels of the reactor core and the downcomer were decreased gradually. The inner and outer wall temperatures of the downcomer were cooled down to the 135 ^{o}C, and 167 ^{o}C respectively during the depressurization process.

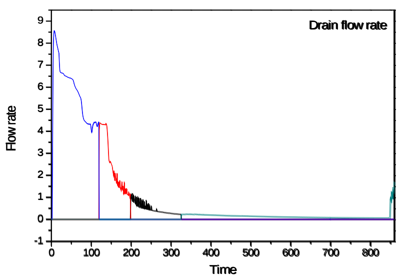


Fig. 1. Mass flow rate of the DVI line

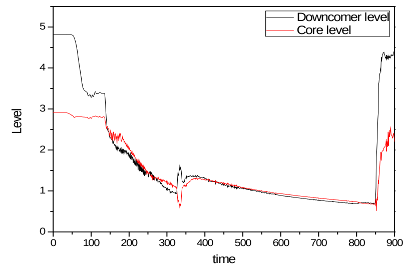


Fig. 2. Collasped water level

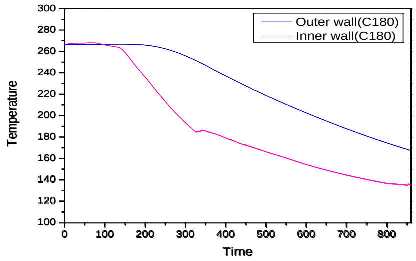
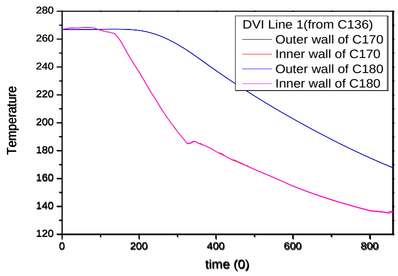


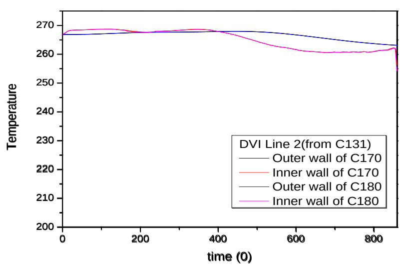
Fig. 3. Downcomer wall temperature

3.2 Symmetry effect

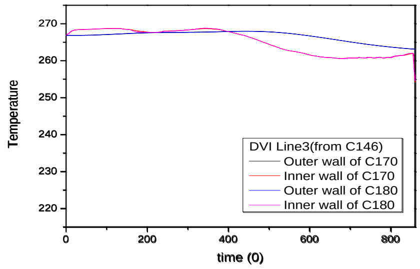
The results shown in the section 3.1 were used only one DVI line of the four. To check the symmetry characteristics of the wall cooling effect in accordance with each DVI line, all four DVI lines were tested with the same flow condition in the previous section. As the results show in Fig. 4, the inner and outer wall temperatures of the same downcomer position were different as the used DVI line changed. From these results, it is recommended that all four DVI lines should be used for the symmetry temperature distribution (uniform cooling effect) of the downcomer wall.



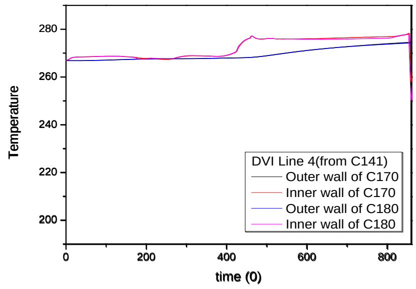
(a) DVI Line 1



(b) DVI Line



(c) DVI Line 3



(d) DVI line 4

Fig. 4. Downcomer wall temperature distribution

4. Conclusions

To cool-down the upper down comer wall before the reflood phase during LBLOCA test, the change of the depressurization process which uses the DVI line was simulated using MARS code.

From the analysis results, it was confirmed that the depressurization method using DVI lines has significant cooling effect of the downcomer wall and it is recommended that all four DVI lines should be used for the symmetry temperature distribution (uniform cooling effect). Thus, for the next LBLOCA experiment of ATLAS, this changed method will be applied for the depressurization process.

REFERENCES

[1] W.P. Baek, C.H. Song, B.J. Yun, *et al*. "KAERI Integral Effect Test Program and the ATLAS Design," *Nuclear Technology*, 152, 183-195 (2005).

[2] Hyun-Sik Park, Ki-Yong Choi, Seok Cho, *et al*., "Major Findings from LBLOCA Reflood Tests Using the ATLAS Facility," *Nuclear Engineering and Design*, Vol.240, No.12, pp. 3920-3929 (2010). (NTHAS6 special issue)

[3] Hyun-Sik Park, Jae-Hoon Jeong, Ki-Yong Choi, *et al*., " A Separate Effect Test on the Cooling Behavior in a Pressurized Water Reactor Core under a Low Reflooding Rate Condition by using ATLAS and RELAP5/MOD3.3 Code Assessment," *Annals of Nuclear Energy*, Vol.38, pp. 1053-1064 (2011).