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Integral Effect Tests on the Reflood Period of a LBLOCA for APR1400 using the ATLAS

Hyun-Sik Park, Ki-Yong Choi, Seok Cho, Kyoung-Ho Kang, Nam-Hyun Choi,
Chul-Hwa Song, Moon-Ki Chung, Won-Pil Baek and Yeon-Sik Kim
Thermal Hydraulics Safety Research Division, Korea Atomic Energy Research Institute
1045 Daedeokdaero, Yuseong, Daejeon, 305-600, Korea
**Corresponding author: hspark@kaeri.re.kr*

1. Introduction

KAERI (Korea Atomic Energy Research Institute) had started the operation of the ATLAS (Advanced Thermal-Hydraulic Test Loop for Accident Simulation) [1] which is a thermal-hydraulic integral effect test facility for evolutionary pressurized water reactors of APR1400 and OPR1000. Recently integral tests for the reflood phase of a large-break loss of coolant accident (LBLOCA) have been performed with the ATLAS after an extensive series of commissioning tests. [2] The reflood tests include both Phase-I and Phase-II tests. Phase-I tests are parametric effect tests for a reactor vessel downcomer boiling during the LBLOCA late reflood period [3] and Phase-II tests are integral effect tests for the thermal-hydraulic phenomena in the downcomer and the core during the LBLOCA reflood period to provide the peak cladding temperature data for an evaluation of the safety analysis code and the corresponding licensing methodology. In the present paper the ATLAS Test Nos. 9, 11, and 14, which are Phase-II tests, are compared each other to understand the thermal-hydraulic characteristics during an entire reflood period.

2. Overview of the Major Phase-II Tests

The ATLAS Test No. 9 is a typical test for a conservative condition, and the ATLAS Test No. 11 is for a best-estimate condition. The ATLAS Test No. 14 is also for a best-estimate condition but it includes the effects of a radial power distribution and a varying system pressure, which are expected during the APR1400 LBLOCA scenario. Table 1 summarizes the test conditions for the major Phase-II tests.

Table 1 Summary of the test conditions for the major Phase-II tests

Test ID	No. 9	No. 11	No. 14
Decay curve	1.2*ANS73	1.02*ANS79	1.02*ANS79
CS pres.	0.1 MPa	0.2 MPa	Varying
Bypass valves	Fully open	Adjusted for APR1400	Adjusted for APR1400
Power	Uniform	Radial distribution	Radial distribution

3. Results and Discussion

The overall thermal-hydraulic trends such as level variation and core quench phenomena in the RPV. However, the specific values of the maximum rod surface temperature and rewetting time is quite different between three Phase-II tests.

3.1 Some characteristic thermal-hydraulic phenomena

Figure 1 shows the wide-range water level variations for the reactor pressure vessel both in the core and downcomer regions for the ATLAS Test No. 14. On initiating the reflood, the water levels both in the core and downcomer regions increased rapidly. However, they decreased with a decreased ECC flow and a spillover of the water inventory until 284 seconds after the reflood start time. Then the water levels were decreased by the entrainment or off-take of the droplets, possibly generated by a downcomer boiling in the downcomber region until 294 seconds after the reflood start time. After this, the water levels steadily increased due to the lowered wall temperature in the downcomer and a sufficient cooling capacity of the ECC water injected by the HPSI pump. The collapsed level in the downcomer is always higher than in the core to supply the ECC water into the core.

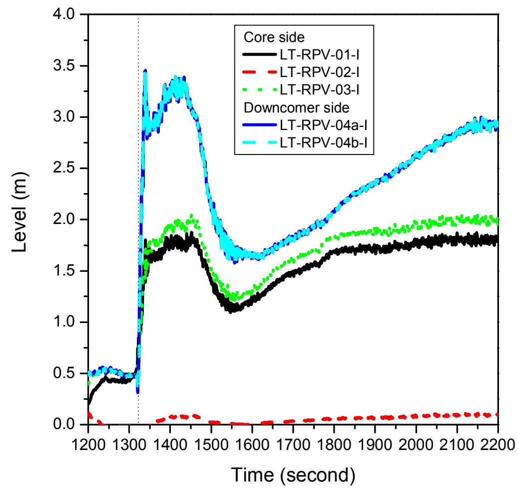

Figure 1 Wide range water level variation of the reactor pressure vessel during the ATLAS Test No. 14

Figure 2 shows the axial surface temperature distributions of core heater group 1, which is located in the center region, for the ATLAS Test No. 14. It was also shown that a top quenching phenomena was observed. The top quenching phenomena occurred more widely in the center region (group 1) than in the outer region (group 3).

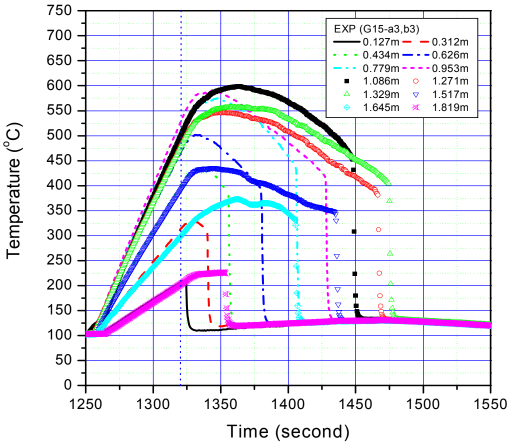

Figure 2 Axial surface temperature distribution of a core heater rod during the ATLAS Test No. 14 (Core heater group 1)

3.2 Comparison of the test results

Three Phase-II reflood tests were compared to show the difference caused by the variation of the test conditions. Table 1 shows the comparison of the test results for the major Phase-II tests. The core heater power is higher and the system pressure is lower during the ATLAS Test No. 9 than No. 11 and thus the maximum heater rod surface temperature is higher and the rewetting time is longer, as shown in Table 1.

Table 1 Comparison of the test results for the major Phase-II tests

Test ID	No. 9	No. 11	No. 14
Init. Power (kW)	1065	830.9	801.4
Avg. DC pres. (MPa)	0.15	0.21	0.21~0.11
Init. rod surface temperature (°C)	465	459	546
Max. rod surface temperature (°C)	722	558	615
Rewetting time (s)	654	218	171
Rewetting velocity (cm/s)	0.30	0.87	1.11

Figure 3 shows the comparison of the maximum heater rod surface temperature between the ATLAS Test Nos. 11 and 14. The temperature trend shows that the core quenching occurs earlier during the ATLAS Test No. 14 than No. 11. The heater rod surface temperature turns around its peak with the temperature increase of 99 and 69°C, respectively, for the ATLAS Test Nos. 11 and 14. It could be concluded that the Test ATLAS Test No. 11 results gives more conservative results than those of the ATLAS Test No. 14, which considers the radial power distribution and the varying containment pressure more realistically.

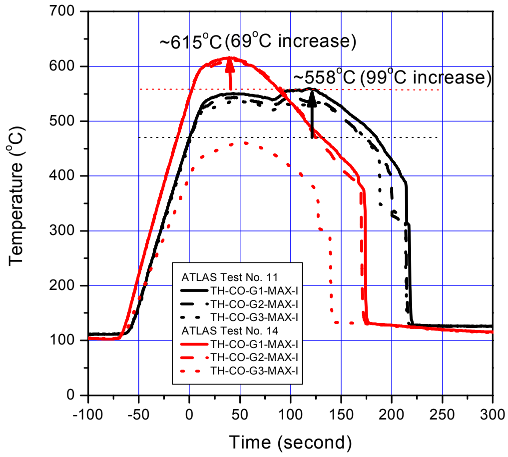

Figure 3 Comparison of the maximum heater rod surface temperature between the ATLAS Test Nos. 11 and 14

4. Conclusion

Integral effect tests for the reflood phase of a large-break LOCA have been performed by using the ATLAS. The experimental results revealed that the typical thermal-hydraulic trends occurred during the reflood phase of a large-break LOCA scenario for the APR1400. The Phase-II tests included both the conservative and best-estimate conditions and the effects of the radial power distribution and a varying system pressure were properly experimented by using the ATLAS.

REFERENCES

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

[2] Kim, Y.S., Choi, K.Y., Park, H.S., et al., "Commissioning of the ATLAS Thermal-Hydraulic Integral Test Facility," (ANS Transactions, Vol. 97, pp.755-756 (2007).

[3] Park, H.S., Choi, K.Y., Cho, S., et al., "Recent ATLAS Test Results on the Late Reflood Period of the Large-Break LOCA for APR1400," IAEA Topical Meeting on Advanced Safety Assessment Methods for Nuclear Reactors, Daejeon, Korea, Oct. 30-Nov.1 (2007).