Investigation of the Thermal-Hydraulic Phenomena during the Late Reflood Period on the Large-Break LOCA for APR1400 using the ATLAS Facility

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1. Introduction

KAERI has recently started the operation of the ATLAS facility (Advanced Thermal-Hydraulic Test Loop for Accident Simulation) [1] which is a thermal-hydraulic integral effect test facility for the pressurized water reactors of APR1400 and OPR1400. The adoption of the DVI system introduced two important technical issues for the ECC (Emergency Core Cooling) bypass phenomenon and the downcomer boiling phenomenon during the reflood phase of a postulated LBLOCA of the APR1400. Three kinds of separate effect-test programs of DIVA, MIDAS [2], and DOBO [3] were progressed by KAERI to acquire available experimental data to assess the existing safety analysis codes and to develop an appropriate model. A set of tests are under way to simulate the reflood phase of the large-break LOCA for APR1400. The ATLAS facility will provide unique test data for APR1400 which adopts a direct vessel injection (DVI) of ECC water. In this paper the design characteristics of the ATLAS facility will be described in brief and some recent test results on the late reflood period of a large-break LOCA will be discussed.

2. Description of the ATLAS Facility

The ATLAS [1] has the same two-loop features as the APR1400 and is designed according to the well-known scaling method suggested by Ishii and Kataoka to simulate the various test scenarios as realistically as possible. It is a half height and 1/288 volume scaled test facility with respect to the APR1400. The fluid system of the ATLAS facility consists of a primary system, a secondary system, a safety injection system, a break simulating system, a containment simulating system, and auxiliary systems. The number of instruments is up to 1,236 which includes 921, 220, 52, 5, 34, and 4 measurements for the temperature, pressure, flow rate, mass, electric power and pump speed, respectively. For the data acquisition and control system, RPT 2300 Hybrid Control System (HCS) was adopted to enhance the integrated performance of a demanding process control application for acquiring the experimental data. The total number of signals for the data acquisition and the system control of the ATLAS facility is up to about 2010, which are distributed in 16 chasses and installed in 10 cabinets. The raw signals from the field are processed or converted to engineering units (EU) in a system server and the processed or converted signals are monitored and controlled through the HMI system by operators.

3. ATLAS Reflood Test No. 5

3.1 Test Objectives

The present late reflood tests were done to help understanding the thermal-hydraulic phenomena during the late reflood period of a large-break LOCA for APR1400 and resolving the current safety issues for APR1400 licensing on the downcomer boiling phenomenon. The present reflood test No. 5 is one of several late reflood tests investigating the effects of various thermal-hydraulic parameters such as the downcomer wall temperature, the HPSI flow rate, the system pressure and the decay heat on downcomer boiling phenomena to provide reliable data to help in validating the LBLOCA analysis methodology for APR1400.

3.2 Initial and Boundary Conditions

The initial and boundary conditions were obtained by applying the scaling ratios to the MARS calculation results. A single failure of a safety injection system was assumed in the MARS calculation, and thus two of the HPSIs were working. In the ATLAS facility the ECC water was supplied from the RWT and the temperature of 50^{o}C was kept the same as that of APR1400. The containment simulator pressure was fixed at around 0.180 Mpa and the heater power was fixed to the scaled-down power of 700 kW during the test. The initial wall temperatures of downcomer were changed from 120 to 130^{o}C and 285 to 290^{o}C for the inner and outer walls, respectively. From the scaling criteria for the total energy of downcomer heat structure, the initial outer wall temperature was determined to be 220^{o}C.

3.3 Test Procedure

When the water level in the core region reached a specified level and the other initial condition of the test stabilized, the test was considered to reach an initial condition of the late reflood test. As the averaged wall temperature of the lower downcomer reached a specified initial temperature, the electrical power was applied to heater rods in the core, which is the initiation of the late reflood test. High pressure safety injection through the DVI line was initiated coincidently with an insertion of the core power. Both the HPSI flow rate and the core power increased linearly from 0 to 0.32 kg/s and from 0 to 700 kW, respectively. The temperature rise of rods, dowmcomer wall temperature and void fractions of core and downcomer regions were monitored during the test. To investigate the parametric effect of HPSI flow rate, the flow rates were decreased stepwise to 0.256 kg/s (80% of the scaled flow rate). Generated steam and entrained water flowed via broken and intact loops into two separating vessels of the containment simulator. The steam was vented to the atmosphere to maintain a constant pressure in the containment simulator and its flow rate was measured with a turbine flowmeter. When the wall temperature in downcomer became low enough, the power supply to the heater rods was turned off and the injected ECC water was stopped. After this, data recording was ended to terminate the entire test.

3.4 Test Results

The experimental results from the present late reflood test No. 5 showed several typical thermal-hydraulic phenomena occurring during the late reflood period of the large-break LOCA scenario. Figure 1 shows the variation of the pressures in the RPV and the temperatures in the downcomer. The overall pressure trend showed the test procedure of a steady state condition, trip, vent, drain, break initiation, and SIT injection. While the pressure in the primary system decreased to the specified pressure of 0.18 MPa, the fluid wall temperature in the downcomer region also decreased. The fluid temperature decreased rapidly after the water inventory began to be drained and the wall temperature decreased rapidly after the ECC water from the SIT was injected into the reactor pressure vessel. After the HPSI flow rate and the core power were introduced, the reflood test started at 760 seconds from the beginning of the DAS and its averaged wall temperature was 207^{o}C. The HPSI flow rate was decreased to 80% at 1008 seconds and its averaged wall temperature was 160^{o}C.

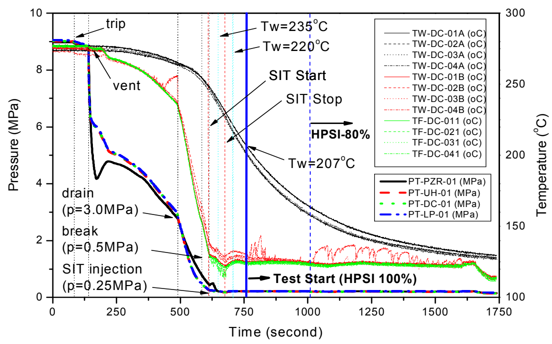

Figure 1 Variation of the pressures in the RPV and temperatures in the downcomer

Figure 2 shows the variation of the sectional water levels in the downcomer and core. When the late reflood test started with the initiation of the core power and HPSI flow rate, the sectional downcomer water levels increased in the lower part of the downcomer as the downcomer wall cooled down. When the HPSI flow rate was decreased to 80% of the rated value, the downcomer level increased a little but the core level varied negligibly.

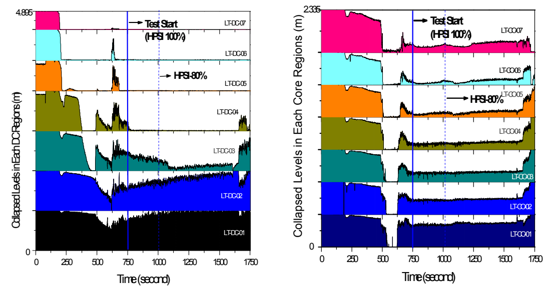

Figure 3 Variation of the sectional water levels in the downcomer and core

4. Conclusion

Experiments on the late reflood period of a large break LOCA are being performed by using the ATLAS facility, which is a thermal-hydraulic integral effect test facility constructed and operated by KAERI. The present reflood test No. 5 is one of several late reflood tests investigating the effects of various thermal-hydraulic parameters. The given ECC water flow rate was 0.32 kg/s, the core heater power simulating decay heat was 700 kW, the system pressure was fixed at around 0.18 MPa, and the initial outer wall temperature was 207^{o}C. The experimental results showed the typical thermal-hydraulic trends expected to occur during the late reflood phase of the large-break LOCA scenario. The ATLAS results showed that there were not any evidence for rod reheating due to a downcomer boiling phenomenon and the core heater rod in the upper core region was reheated up to a temperature of 284^{o}C due to a high void fraction in the upper core region.

REFERENCES

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