Simulation of RD-14M Small Break LOCA Experiments by CATHENA Code

Hyoung Tae Kim*, Joo Hwan Park, Sang Baik Kim
Korea Atomic Energy Research Institute, 1045 Daedoek-daero, Yuseong-gu, Daejeon 305-353, Korea
**Corresponding author: kht@kaeri.re.kr*

1. Introduction

KAERI participated with the computer code CATHENA [1], which is used to analyze Pressurized Heavy Water Reactors (PHWRs), in an IAEA International Collaborative Standard problem (ICSP) with the objective to benchmark and validate thermal-hydraulic computer code against qualified data for Small Break Loss of Coolant Accident (SBLOCA) scenario generated on RD-14M Test Facility [2]. Two specific SBLOCA tests selected for this ICSP titled "Comparison of HWR Code Predictions with SBLOCA Experimental Data", are B9006 and B9802. Test B9006 is a 7-mm inlet header break experiment with pressurized accumulator emergency coolant injection and represents most complete SBLOCA test conducted in RD-14M. Test B9802 is a 3-mm inlet header break experiment with full channel power to study boiling in channels and condensation in steam generators in a slowly depressurizing loop rather than a blow down. This paper presents the blind calculation results for these tests.

2. Description of Code and Input Models

2.1 Code version

The qualified PC version of CATHENA MOD-3.5d/Rev2 is used in all the RD-14M experiment simulations. The PC platform uses the Microsoft Windows XP operating system.

2.2 Nodalization

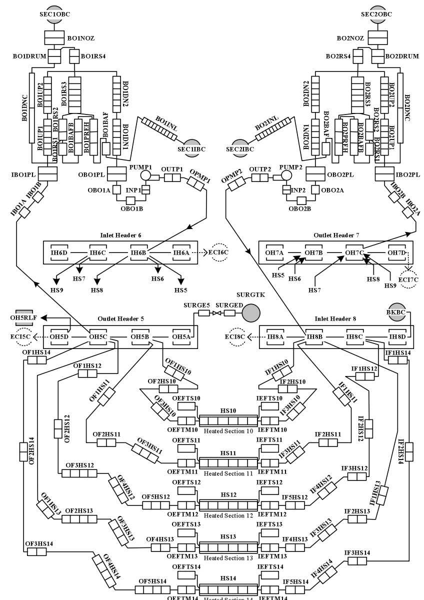
The CATHENA nodalizations of the RD-14M facility with primary and secondary side loops are shown in Figure 1. The nodalization of the ECC system as shown in Fig. 2 is used for modelling the high pressure injection and low pressure injection. The CATHENA nodalization used to simulate B9006 experiment consists of 528 thermal-hydraulic nodes, 543 links and 150 wall heat transfer models. However, in case of B9802, the numbers of thermalhydraulic nodes and links are decreased to 483 and 494, respectively, because the modeling of ECCS is excluded in the B9802 simulation.

2.3 Simulation time steps

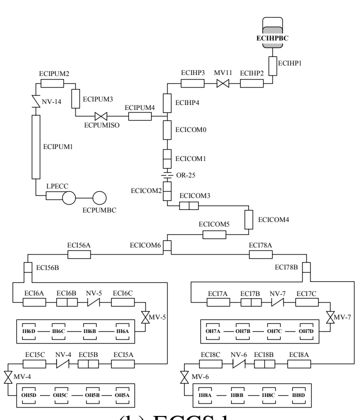
The simulation times for B9006 and B9802 are 2,280 seconds and 1,363 seconds, respectively. Using the CATHENA time step control algorithm, the time steps during the simulation time are calculated within the user specified minimum and maximum time steps. The minimum time step is 10^{-6} second, which is small enough to cover the rapid transient period. The maximum time step is specified as 10^{-1} second.

2.4 Boundary conditions

The heater thermal powers, coolant pump speeds, feedwater temperatures and flow rates, and secondary side steam outlet pressures are given for the blind calculations of B9006 and B9802 tests. Instead of using the pressure history of the ECC tank in B9006 test, the high pressure ECC injection is simulated by the CATHENA accumulator model.



(a) Primary and secondary loop



(b) ECCS loop

Fig. 1 CATHENA Idealization

3. Transient Results for B9006 Test

3.1 Header Pressures (B9006)

Figure 2 shows the header pressures. After break valve opens, the header pressures rapidly decrease due to the break discharge and power rundown. Initially the inlet header pressures are larger than the outlet header pressures, but these four header pressures become similar as the DP (differential pressure) between inlet and outlet headers are reduced to be small. After high pressure accumulator injection starts at 68 seconds, the depressurization rate is decreased. There is a small jump in the header pressure about at 600 seconds, when the primary loop is refilled and ECC injection water starts to be pushed out through the broken header. When the ECI flow switches from the accumulator injection to a low pressure injection at 1140 seconds, the header pressure decreases below 1.0 MPa.

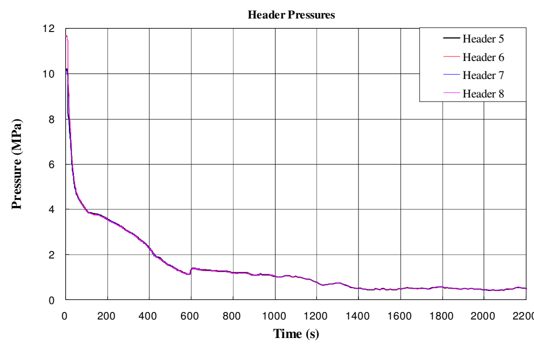


Fig. 2 Header Pressures for B9006 Test

3.2 Sheath temperatures (B9006)

Figure 3 shows the difference of FES temperatures at inlet, middle and outlet of HS13. The FES temperature increases from the inlet to the outlet directions as the coolant is heated along the channel. The FES temperatures of top pin and bottom pin at outlet of HS13 are compared in Fig. 4. The FES temperature of top pin is higher than that of bottom pin, because the local FES surface in the upper pin is temporarily dried out, while that in the lower pin is wet.

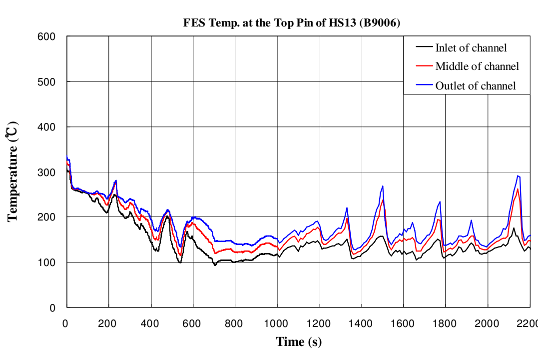


Fig. 3 FES Temperatures at the Top Pin of HS13 for B9006 Test

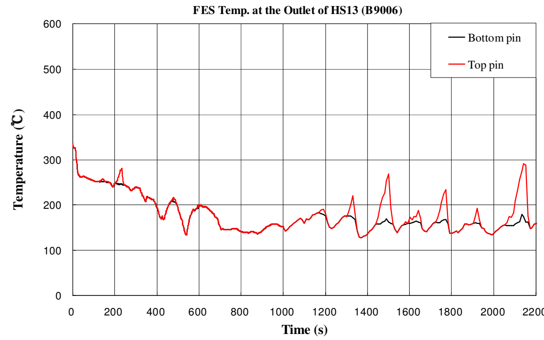


Fig. 4 FES Temperatures at the outlet of HS13 for B9006 Test

4. Transient Results for B9802 Test

4.1 Sheath temperature (B9802)

The FES temperature at top pin, at middle of HS13 increases after 1000 seconds as shown in Fig. 5. The bundle surfaces are under liquid convective or nucleate boiling heat transfer conditions before 1000 seconds and under post-dryout heat transfer conditions after 1000 seconds. Late in the test (around 1200 seconds), the FES temperature rises rapidly and do not cool down until the power supplies are tripped at the end of test.

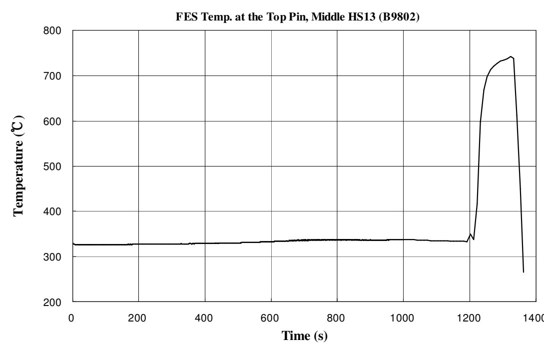


Fig. 5 FES Temperature at the Top Pin, Middle of HS13 for B9006 Test

5. Conclusions

In the simulation of B9006 test, HP ECC injection starts at 68 seconds and LP ECC, at 1140 seconds. Then the heated channels are well cooled by ECC injection.

In the simulation of B9802 test, some predictions of FES temperatures exceed 600 ^{o}C before the FES over temperature trip time at the experiment. Therefore, more validation works are needed for this simulation.

REFERENCES

[1] B.N. Hanna, "CATHENA: A Thermalhydraulic Code for CANDU Analysis", Nuclear Engineering and Design (180), pp. 113-131, 1998.

[2] RD-14M Facility Description and Characterization, AECL Report, COG-00-034-R1