Validation of ISAAC Thermal Hydraulic Model Against the RD-14M Experiment B9401

Dong Ha Kim*, Hyung Tae Kim, Soo Yong Park, Sang Baik Kim
Korea Atomic Energy Research Institute, 1045 Daeduck daero, Yusoeong-Gu, Daejeon, Korea
**Corresponding author: dhkim8@kaeri.re.kr*

1. Introduction

As a severe accident progression in CANDU plants will be very different from PWRs due to their unique plant configuration, the ISAAC (*I*ntegrated *S*evere *A*ccident *A*nalysis code for *C*ANDU plants) computer code [1] was developed for the Wolsong unit 2. The MAAP4/PWR computer code was used as a reference. In addition to the Wolsong-specific system modeling, physical phenomena expected during a severe core damage accident like core heatup, horizontal fuel channel failure, relocation of damaged fuel to calandria, debris behavior in the calandria and the calandria failure, are also modeled.

Though the data for the severe accident progression in CANDU plants are very limited, in-house efforts on code validation are going on [2]. Also the thermal hydraulic conditions of the primary system prior to core damage are important since they may affect the severe core damage progression. In this paper, the thermal hydraulic behavior of ISAAC prior to core damage was compared against the RD-14M experiment.

2. Simulation of RD-14M B9401 Experiment

2.1 Overview of B9401 Experiment [3]

RD-14M test B9401 was a 30mm diameter inlet-header break test with a high pressure pumped emergency coolant injection available. The purpose of the test was to investigate the primary loop response to a 30mm break with emergency coolant injection. A summary of the significant events is shown in Table 1.

Table 1 Significant Events in B9401 Test and Comparison of ISAAC Simulation

Significant Events	Time in B9401	Time in ISAAC+
valve opening started	0.*	0.
power ramp started	2.	2.
Initiation of primary pump rundown	2.	2 (start coastdown)
High-pressure ECC started	10.6	15.0
Pressurizer isolated	12.8	12.8
High ECC terminated Low ECC started	106.2	111.7
Primary pumps off	203.2	-
Low ECC terminated	340.7	252.9

* Timings of events were adjusted to start from time 0.
\+ 170% of actual break size is assumed

2.2 ISAAC Input Preparations

As ISAAC was designed to simulate the Wolsong units, it needs to be modified to simulate the B9401 test. In this analysis, mainly the input parameters were modified for the sequence simulation along with the minimum change in the code itself.

2.2.1 Single Loop Simulation

The control logics in the input files were used in order to simulate the single closed loop in the RD-14M experiment. That is, the loop isolation valves were forced to be closed initially by setting the higher value of LOCA pressure without delay. Then the Loop 1 isolation valve is controlled to be stuck open from the beginning by using the event code. Then only one loop is connected to the pressurizer like the experiment. This pressurizer is also separated from the loop using the event code.

2.2.2 Core Channel Power Simulation

Each test section connected to the steam generators via reactor headers has its own power level and the total power is controlled at 8.14MW and 325kW, respectively, before and after the reactor trip at 2 seconds. Fig. 1 shows the power distribution in the test sections simulated from ISAAC.

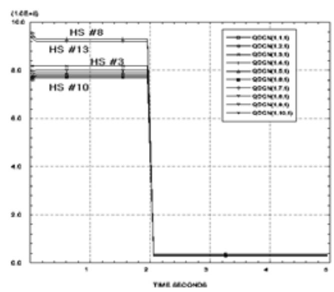

Fig. 1 Test Section Power Input from ISAAC

2.2.3 PHTS/SG/Pressurizer Simulation

The information of the PHTS and the steam generators was applied to the heat sink inputs in ISAAC. Especially the volume data are important to define the initial water inventory in the system. The pressurizer information is also replaced with the RD-14M data. The PHTS pump coast down curves of RD-14M was implemented in the input file.

2.2.4 Heated Section Simulation

The heated section has seven fuel element simulators and each element consists of center core of MgO, inconel-625 heater tube, Boron Nitride and outer S.S. Sheath. Though it has a different configuration from the actual fuels, RD-14M heaters were designed to have a capacity close to that of CANDU reactor fuel [3]. Hence the current ISAAC fuel models were used without modification.

2.2.5 Horizontal Fuel Channel Simulation

As ISAAC can simulate up to thirty-seven fuel channels per loop, two core passes with five horizontal fuel channels per pass were defined using the input parameters.

2.2.6 High and Low Pressure ECS Simulation

In the test B9401, high pressure ECCS was injected to the core from the TK2 tank using the P14 pump and the low ECCS from the distilled water tank using the pump P8 when the water level in TK2 falls below 10%. As the ISAAC has hard-wired ECCS connections for the high, medium, and low ECCS, minor modifications were done to simulate the B9401 ECCS connections and operations. Though the low pressure ECCS terminated due to the low level of the distilled tank, total mass injected to the core was used instead. The characteristic curves for the P14 and P8 pumps were used in ISAAC.

2.3 Comparison of Main Parameters

Among many parameters, system pressure and ECCS flow behavior were compared here. ISAAC was calculated for three different break sizes (100%, 140%, 170%) which consider the local conditions at the break. It was found that 170% of the actual break size matches the initial peak break discharge flow rate. As shown in Fig. 2 and Fig. 3, the primary system pressure behavior looks similar to each other in general.

Fig. 4 and Fig. 5 show integral of ECCS flow from the experiment and the ISAAC, respectively. As ISAAC calculates the average flow rate compared to the header-wise flow rates in the experiment, the cumulative flow was compared. ISAAC estimated a little higher flow rates for the low pressure ECCS flow, resulting in shorter injection periods (refer to Table 1).

3. Conclusions

A large LOCA in the RD-14M facility was simulated with ISAAC. Among many important parameters, primary system pressure and the integral of ECCS flow rate were compared against the test data. Though ISAAC could not provide the plant response by locations, the overall behavior of the pressure and the ECCS flow rates prior to core damage follows the actual data reasonably. Currently benchmarking severe accident computer codes for heavy water reactor applications is going on under the IAEA CRP program.

REFERENCES

[1] KAERI, "ISAAC Computer Code User's Manual," KAERI/TR-3645/2008.
[2] KAERI, "Validation of ISAAC Thermal Hydraulic Behavior with the CATHENA Results for Large LOCAs," KAERI/TR-3546/2008.
[3] IAEA, "Intercomparison and Validation of computer codes for theramlhydraulic safety analysis of heavy water reactors," IAEA-TECDOC-1395, August 2004.

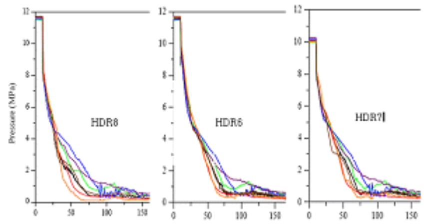

Fig. 2 Header Pressures Measured from RD-14M

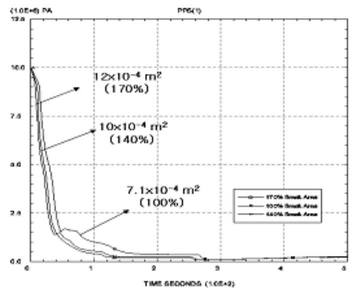

Fig. 3 Primary System Pressure from ISAAC

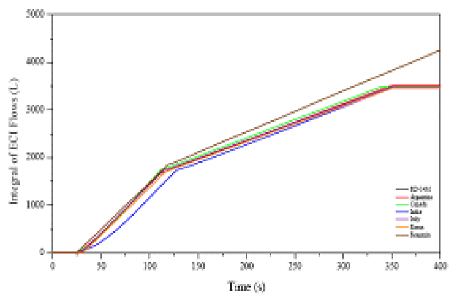

Fig. 4 Integral of ECCS Flows from RD-14M

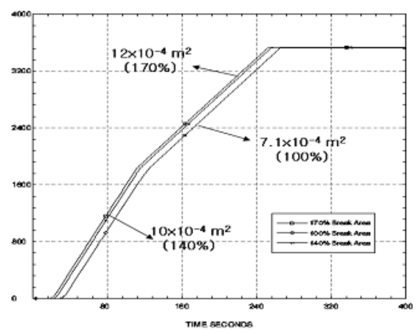

Fig. 5 Integral of ECCS Flows from ISAAC