Performance Assessment of Passive Heat Exchanger with Horizontal Tube using RELAP5

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1. Introduction

In the world nuclear industry to enhance safety and reliability of nuclear power plant, passive safety system design has been introducing. Especially, passive auxiliary feedwater system (PAFS) has been applied to the advanced power reactor plus (APR+) in our domestic industry [1]. According to PAFS design concept, PAFS makes role completely for the existing auxiliary feedwater system. PAFS can remove the residual heat in the core and then prevent the core damage when the feedwater is not available.

The passive heat removal system has essentially heat exchanger with vertical or horizontal tubes. PAFS is a kind of passive heat exchanger with an inclined horizontal U tube bundle. Heat transfer phenomena in horizontal tubes play an important role in passive safety systems for the next generation of nuclear power plants.

To assess the performance of the system, it is required to carry experiment and code analysis. NOKO experiment facility for investigating the emergency condenser effectiveness in SWR1000, is similar to PAFS. So the experiment result can be useful to evaluate the cooling performance of passive system like PAFS. The purpose of this study is to simulate the TH phenomena such as natural circulation and horizontal condensation heat transfer in NOKO experiment using RELAP5, and to compare the results between experimental data and RELAP5 code analysis.

2. Modeling of NOKO Experiment

2.1 NOKO experiment facility

The general design of the NOKO test facility is shown in Fig. 1. The main components of the facility are the pressure vessel, simulating the reactor pressure vessel of the SWR1000, and the laterally connected emergency condenser bundle. In NOKO, a two-phase-flow mixture is produced by an electrical heater with a maximum power of 4 MW. The steam mass flow has a maximum value of 2.5 kg/s [2-4].

The condenser represents the core-flooding pool of the SWR1000. This pool is 6 m long and 2 m in diameter with a 20 m^3 volume. The relief tank is the heat sink of the test facility. The design of the test facility provides the possibility of adjusting the same pressure and temperature conditions as in the SWR1000. To simulate the pressure increase during a loss-of-coolant accident inside the containment, pressures up to 1 MPa can be adjusted in the condenser. All elevations and water levels are the same as in the reactor. The average tube length is 9.8 m, the inner diameter is 38.7 mm, and the wall thickness, 2.9 mm. The inclination is 1.6 deg in the upper leg and 3.2 deg in the lower leg as shown Fig. 1.

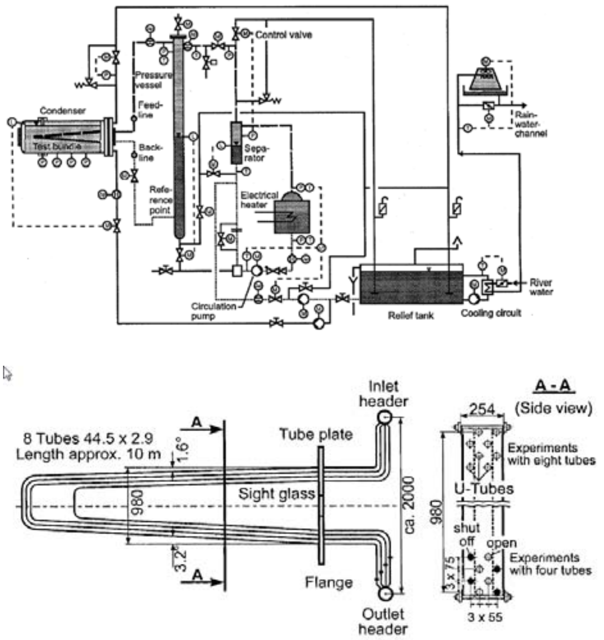


Fig. 1 NOKO Facility

2.2 RELAP5 modeling of NOKO

Fig. 2 shows the nodalization of NOKO facility for RELAP5 input modeling. The model consists of pressure vessel (PV), U tube, condensing tank, valve and connecting pipes.

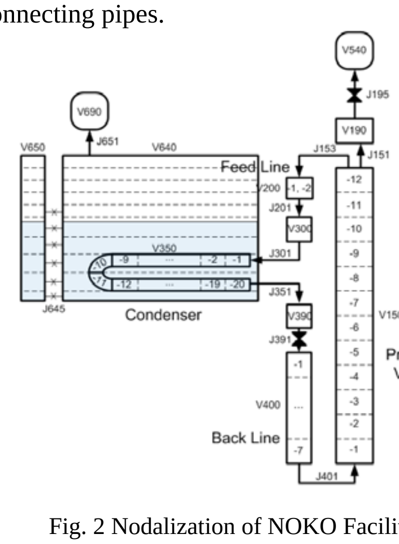


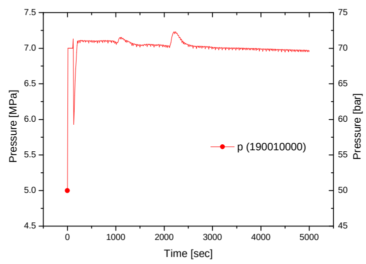
Fig. 2 Nodalization of NOKO Facility

The pressure vessel volume is modeled as a pipe in which the electric heater is located. The top volume is connected to time dependent volume used for initial and boundary conditions. The U tube bundle is located between the feed line and back line.

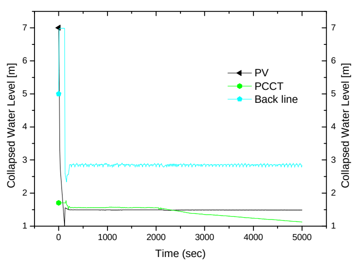
3. Analysis results

The NOKO experimental data of A8 and B8 cases were used to compare the calculation results. The operation conditions were 7 MPa of pressure vessel and 0.1 MPa of condensation tank. The cases showed that the condenser power increases and reaches a maximum of 3.3 MW with decreasing water level.

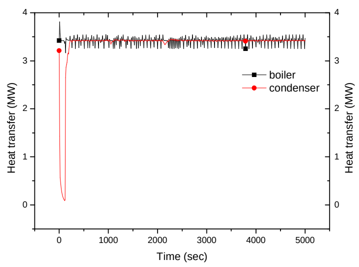
Figure 3 shows the RELAP5 calculation results. For the experimental condition in A7-1 case, the calculation results of natural circulation flow rate and heat removal rate are 1.5 kg/s and 2.49 MW. From the simulation results, it was found that RELAP5 somewhat under-predicts the amount of horizontal condensation heat transfer but RELAP5 could simulate properly the important TH phenomena such as natural circulation and horizontal condensation heat transfer in the NOKO experiment.



(a) PV Pressure



(b) water level



(c) Power

Fig. 3 RELAP5 calculation results

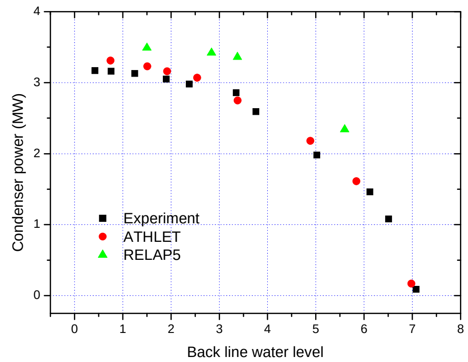


Fig. 4 Comparison of experiments and calculation results

In Fig. 4, the calculation results are compared with the NOKO experiments data. In these calculations, the back line water level was varied from 0 to 7 m. The condenser power of RELAP5 calculation results is higher than that of the NOKO experiments.

4. Conclusions

In this study, the NOKO test facility was modeled with RELAP5 and the calculation results were compared with NOKO experiment results. It is required that the capability of numerical code be assessed for evaluating thermo-hydraulic performance of passive heat removal facility like PAFS. So it could be useful for developing and evaluating the PAFS model with RELAP5.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support from Korean Ministry of Education, Science and Technology (MEST).

REFERENCES

[1] The Feasibility Study Report on Development of The Core Technologies for APR+, NETEC, S07NJ06-K-TR-001, 2008

[2] A. Schaffrath, E.F. Hicken , H. Jaegers, H.-M. Prasser, Experimental And Analytical Investigation Of The Operation Mode Of The Emergency Condenser Of The Swr1000, Nuclear Technology, Vol. 126, May 1999

[3] A. Schaffrath, E.F. Hicken , H. Jaegers, H.-M. Prasser, Operation conditions of the emergency condenser of the SWR1000, Nuclear Engineering and Design Vol. 188, 1999

[4] A. Schaffrath, A.-K. Krussenberg, A. Fjodorow, U. Gocht, W. Lischke, Modeling of condensation in horizontal tubes, Nuclear Engineering and Design Vol. 204 , 2001