Steady-State Calculation of the ATLAS Test Facility Using the SPACE Code

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1. Introduction

The Korean nuclear industry is developing a thermal-hydraulic analysis code for safety analysis of pressurized water reactors (PWRs). The new code is called the Safety and Performance Analysis Code for Nuclear Power Plants (SPACE) [1]. Several research and industrial organizations including KAERI (Korea Atomic Energy Research Institute) are participating in the collaboration for the development of the SPACE code. One of the main tasks of KAERI is to carry out separate effect tests (SET) and integral effect tests (IET) for code verification and validation (V&V). The IET has been performed with ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation) [2] based on the design features of the APR1400 (Advanced Power Reactor of 1400MWe).

In the present work the SPACE code input-deck for ATLAS is developed and used for simulation of the steady-state conditions of ATLAS as a preliminary work for IET V&V of the SPACE code.

2. SPACE Code Input-deck for ATLAS

2.1 ATLAS Nodalization

Previously the MARS 3.1 code input-deck [3] for the ATLAS test facility was developed and the present SPACE input-deck is based on this MARS input-deck.

Figure 1 shows a nodalization diagram for the SPACE code. The same nodalization scheme was used both for the MARS and the SPACE input models. Total 253 volumes and 340 junctions are used for the SPACE nodalization except for the ECCS systems of the ATLAS.

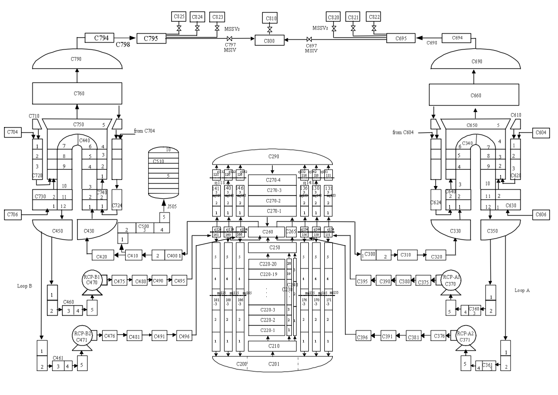


Fig. 1. Nodalization diagram of the ATLAS for SPACE code.

2.2 Steady-State Conditions of ATLAS

The ATLAS has a maximum power capacity of 8% of the scaled full power. An initial primary condition for the present data was obtained by applying 8% of the scaled power and by reducing the primary coolant flow rate by 8%.

3. Steady-State Calculations

Prior to the steady-state calculation of the whole test loop, the SPACE code input-decks for major components such as reactor vessel, steam generator, and primary coolant pump are separately tested to obtain the steady-state conditions in each component.

3.1 Reator Vessel

The inlet coolant flow rate and the pressure in the cold leg are given as flow boundary conditions. These boundary conditions are determined from the steady-state conditions predicted by the MARS code. The SPACE prediction of the core outlet temperature is compared with the experimental data and the MARS result as shown in Fig. 2. The SPACE result approaches the steady value, which is in good agreement with the MARS result. Both of SPACE and MARS results under-predict the test results by 1℃.

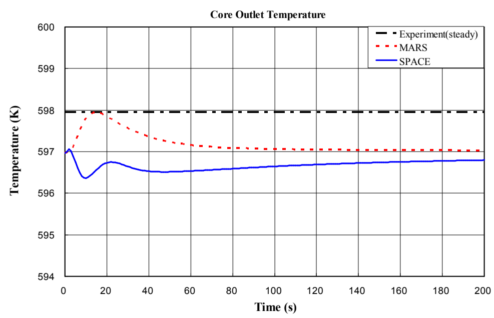
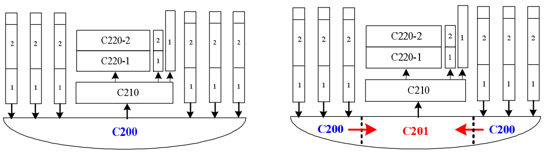


Fig. 2. Core outlet temperatures of the reactor vessel model.

The lower plenum for MARS code is modeled by the single branch component (single volume model in Fig. 3) and shows good convergence in the steady-state calculation as shown in Fig. 4. However, the calculation result by SPACE code with this single volume model cannot reach the steady-state condition, since the single volume for the lower plenum has the opposite junctions connecting one face of the volume with the downcomer and the lower core region simultaneously. Therefore, the volume of lower plenum is divided to two equal volumes connected each other with cross flow junctions as shown in Fig. 3-(b). The SPACE code result with this new nodalization scheme applied to the lower plenum shows the same steady-state result as the MARS code.



(a) Single volume model (b) 2-volume model

Fig. 3. Comparison of the nodalization schemes for lower plenum of the reactor vessel.

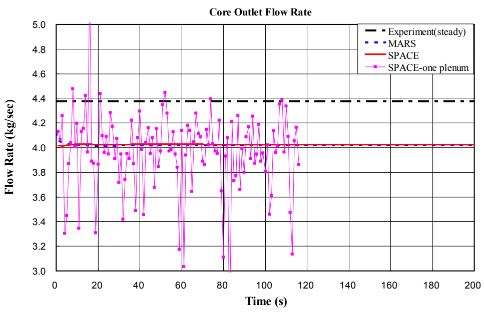


Fig. 4. Comparison of the core outlet flow rates by different nodalization schemes for lower plenum of the reactor vessel.

3.2 Steam Generator

For the steam generator (SG) test, the flow and enthalpy boundary conditions are applied to the inlet and outlet plenums of the SG primary side. The feed water flow rate and the constant pressure at the inlet of turbine are given as boundary conditions in the SG secondary side. Figures 5 shows the results of the SG exit temperatures. The results of SPACE code are similar to those of MARS code and are in good agreement with the test results.

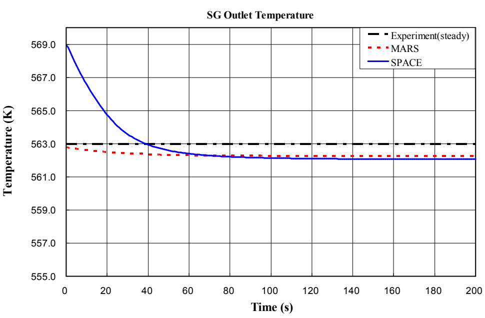


Fig. 5. Steam generator exit temperatures from the SG test.

3.3 Coolant Pump

For the coolant pump test, the pump input parameters for SPACE code are used to obtain 4 kg/sec of coolant flow as a target value of steady-state condition as shown in Fig. 6.

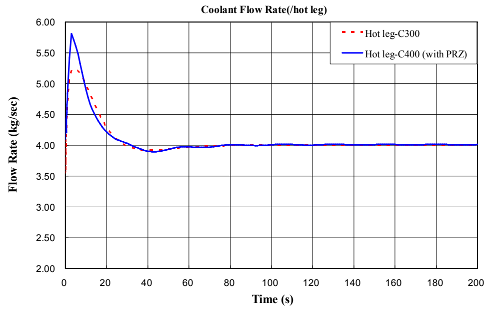


Fig. 6. Coolant flow rates from the pump test.

3.4 Total Loop

Completing the component tests, the overall loop test is performed. The steady-state results for MARS and SPACE codes are listed and compared with experimental data in Table I. The code predictions for main thermal-hydraulic parameter are in good agreement with the test data. The core power used for code simulation is slightly lower than the measurement data, because the heat loss is considered.

Table I: Steady-State Results for ATLAS Test Loop

Parameters	Experiment	MARS	SPACE	Difference
Primary System				
- Core Power (MW)	1.647	1.566	1.566	-0.049/0.004
- PZR Pressure (MPa)	15.49	15.56	15.52	0.005/0.001
- RCS Flow Rate (kg/s)	2.187	2.009	2.024	-0.081/0.012
- Core Inlet Temp. (K)	562.95	562.75	562.28	0.000/-0.003
- Core Exit Temp. (K)	597.95	596.97	596.34	-0.002/-0.002
Secondary System				
- SG Steam Pressure (MPa)	7.83	7.81	7.83	-0.003/0.000
- Steam Temp. (K)	566.15	566.5	566.6	0.001/0.000
- FW Temp. (K)	505.95	505.37	505.37	-0.001/0.000
- FW Flow Rate (kg/s)	0.331	0.444	0.434	0.341/0.311

3. Conclusions

In the present study the SPACE code input-deck for the ATLAS test facility is produced and tested by the component test and then overall loop test. It is shown that the opposite junctions on the same face of the volume should be avoided for the SPACE nodalization to obtain the steady-state result.

Since the present SPACE input-deck succeeded in producing the steady-state target value, the transient simulation of the ATLAS tests will be performed with this input-deck in the future work.

REFERENCES

[1] S. J. Ha, C. E. Park, K. D. Kim, and C. H. Ban, Development of the SPACE Code for Nuclear Power Plants, Nuclear Engineering and Technology, Vol.43 No.1, p. 45, 2011.

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