Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Flow Characteristics in the Steam Generators of the ATLAS Facility

Nam-Hyun Choi, Kyeon-Ho Min, Bok-Deuk Kim, Sung-Jae Lee, and Yeon-Sik Kim
Korea Atomic Energy Research Institute, Thermal Hydraulic Safety Research Division, P.O.Box 105, Yuseong, Daejeon, 305-600, Korea, nhchoi@kaeri.re.kr

1. Introduction

A thermal-hydraulic integral effect test facility, ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation), was constructed at the Korea Atomic Energy Research Institute (KAERI) in 2006. It is a 1/2 reduced height and 1/288 volume scaled test facility based on the design features of the APR1400, an evolutionary pressurized water reactor developed by the Korean industry [1]. Preliminary tests were being carried out in order to characterize the basic thermal hydraulic characteristics such as a pressure drop distribution, a temperature distribution along the primary loop and natural circulation characteristics[2].

Recently, many tests were carried to simulate the reflood scenarios including the parametric effect tests for the downcomer boiling phenomena in late reflood period. For each test, major systems, e.g. reactor coolant system and secondary system etc., should be on the initial steady state for the test. To achieve a steady-state condition, the heat balance between the primary and secondary systems must be maintained. In the reference design, the economizer is included to increase thermal efficiency the steam generator. To simulate the reference steam generator, the ATLAS steam generator adopted two separate pipes for cold-side and hot-side downcomers. This paper is focused on the findings of the operation characteristics in the shell-side, i.e. secondary side, of the steam generator in the ATLAS facility

2. Summary of the ATLAS Steam Generator

The steam generator(SG) is an important component that delivers the primary heat to the secondary system. A summary data of the ATLAS steam generator is given in Table 1[3]. There is a tube bundle in the shell side, which provides a pressure boundary between the reactor coolant system and the secondary system. The design condition of the tube bundle follows that of the primary system. Figure 1 shows the schematic design of the steam generator and two steam generators in the ATLAS. As shown in Fig.1, there are two pipes to simulate the cold- and hot-side annulus downcomer of the reference plant, e.g. longer one for hot-side, shorter one, cold-side. Actually, a flow divider is equipped at the center region of the annulus downcomer in the reference steam generator, which minimizes a flow interaction between two regions. As depicted in Fig.1, the ATLAS steam generator is a typical recirculation type with external downcomers.

Table 1 Summary of the ATLAS steam generator

- Desgin P[MPa]/T[^{o}C]	10/310
- No. of SGs	2
- No. of U-tubes per SG	175
- U-tube ID/OD [mm]	11.8/14.2
- Average tube length [m]	9.46
- Total H/T area per SG [m^2]	44.8
- Downcomer type	External

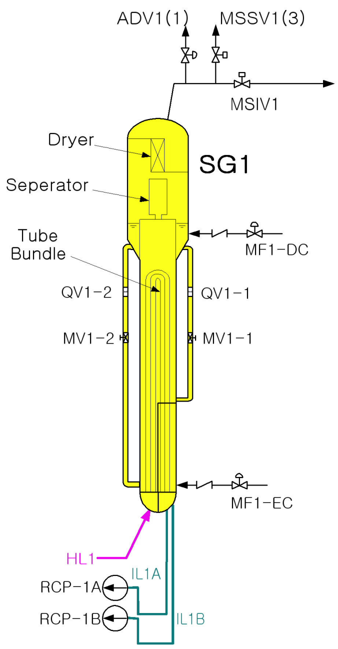

Fig.1 Schematics of the ATLAS steam generator

3. Flow Charateristics in the SG Shell-Side

Before starting a specific test, a quasi-steady state condition was confirmed by checking the operational parameters, e.g. pressures and temperatures etc., achieved in the primary and secondary systems. To confirm the the operational characteristics of the steam generator during the quasi-steady state, the secondary parameters, e.g. feed flow rate and recirculation ratio etc., should be evaluated for the quasi-steady state. Figs. 2 and 3 show the trends of the shell-side parameters for each steam generator. In this case, the core power is about 1.2MW and the steam pressure, is 6.53MPa, respectively. The water level of each steam generator is about 50% in a narrow range. As shown in these figures, all the flowrates of the downcomers have some oscillatory patterns, which mean a kind of flow instabilities. The magnitude of the flowrate oscillation is larger in the cold-side downcomers. And while the flowrates of hot-side downcomers maintain a relatively constant value, e.g. around 3 kg/s, those of the cold-side downcomers vary from around 2kg/s to around zero.

The driving force for the downcomer flow is given by the hydraulic head between the top and the bottom nozzles. A larger one is found in the hot-side downcomer and that's why less oscillatory pattens and more stable flowrates are shown in that region.

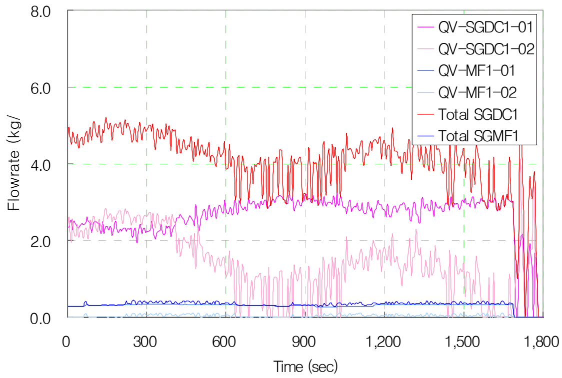

Fig.2 Secondary flowrates in steam generator 1

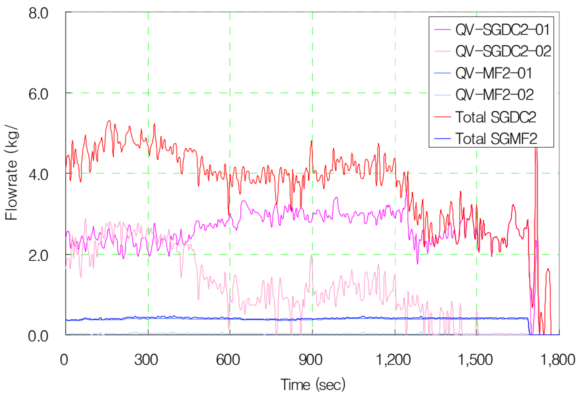

Fig.3 Secondary flowrates in steam generator 2

Using the main feedwater and the downcomer flowrates, the circulation ratio can be calculated as shown in Fig. 4. There are two nozzles for the main feedwater injection, e.g. one for the downcomer and the other for the economizer. For a higher power level, most of the main feedwater is supplied through the economizer nozzle as shown in Figs. 2 and 3.

The circulation ratio for a quasi-steady state under a specific condition as mentioned before ranges from around 15 to around 7. The oscillatory patterns of the circulation ratio are due to those of the downcomer flowrates.

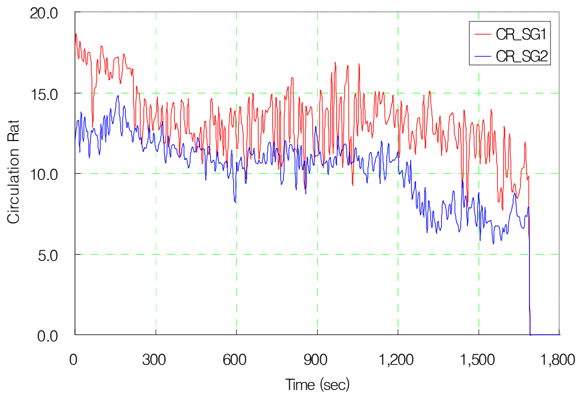

Fig.4 Circulation ratios of the steam generator 1&2

4. Conclusion

In the ATLAS steam generators, all the flowrates of the downcomers show some oscillatory patterns, which mean a kind of flow instability. The magnitude of the flowrate oscillation is larger in the cold-side downcomers, and while the flowrates of the hot-side downcomers maintain a relatively constant value around 3 kg/s, those of cold-side downcomers vary from around 2kg/s to around zero.

Less oscillatory pattens and more stable flowrates are found in the hot-side downcomer, which are the reasons for the larger hydraulic head in that region. The circulation ratio for a quasi-steady state under a specific condition as mentioned before ranges from around 15 to around 7.

Acknowledgement

This work has been performed under the fund of Korea Ministry of Science and Technology as Mid- and Long-Term Nuclear Research and Development Program.

REFERENCES

[1] W.P. Baek, et al. "KAERI Integral Effect Test Program and the ATLAS Design," *Nucl. Technol.*, **152**, 183 (2005).
[2] K.Y. Choi, et al., "Preliminary Tests for an Identification of the System Characteristics of the ATLAS Facility," 2007 KNS Spring Conference (2007).
[3] H.S. Park, et at., "Calculation Sheet for the Basic Design of the ATLAS Fluid System," Technical Report: KAERI/TR-3333/2007.