Commissioning Test for the FINCLS Facility

Eunkoo Yun [a], Byong-Guk Jeon[a], Jin-Hwa Yang[a], Yoon-Gon Bang[a], Chan-Jong Seo[a], Ji-Hwan Park[b], Ki-Suk Han[b], Hyun-Sik Park [a*]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeokdaero, Yuseong, Daejeon, 305-353, Korea*
[b]*University of Science and Technology, 217 Gajeong-ro, Yuseong, Daejeon, 34113, Korea*
[*]*Corresponding author: hspark@kaeri.re.kr*

1. Introduction

The main purpose of the FINCLS (Facility to Investigate Natural CirLulation in SMART) is to perform a parametric study on the Natural Circulation (NC) phenomena in SMART design [1] over a wide operating range with more accurate measurement compared with the SMART-ITL [2]. The configurations and features of this facility are derived from those of SMART with a simplification, as shown in Fig. 1. The flow area and fluid volume of FINCLS was scaled down to 1/64 against the reference system (SMART-ITL) for reducing experimental time and resource consumption while the height was conserved for avoiding the hydrostatic distortion.

Recently, the commissioning tests for the FINCLS facility have been performed to ensure the system tightness, as well as to identify the reliability in the measurement. The results obtained from the present tests will be provided as the validation data for both theoretical analysis and MARS-KS simulation [3].

2. Results of commissioning tests

The present tests include the loop circulation test under ambient temperature condition. Additionally, one single-phase NC test has been conducted as the preliminary test under a low temperature condition of less than 100 ℃.

2.1 Loop Circulation Test

Active operation in FINCLS is utilized not only to achieve boundary conditions before NC tests, but also to protect the core heater during heat-up and to enable stable operation. The main purposes of the loop circulation test are to check the controllability of pumps and valves, as well as to verify the reliability of measuring devices such as flow meters and differential pressure transmitters (DPs).

As shown in Fig. 2, the pressure losses for all DP sections are obtained as a function of flow rate. The measured pressure losses are less than 4 kPa, and the repeatability for DP measurement was identified. The pressure loss through the helical coil tube in the SG could be characterized as a function of mass flow rate as shown in Fig. 3. The higher pressure loss is clearly observed in secondary loop compared to that in primary loop, and it is expected to be strongly affected by excessive length of fluid path along the helical tube.

Further, the experimental results of pressure losses depending on the flow rate can be used as the validation data for the MARS-KS simulation.

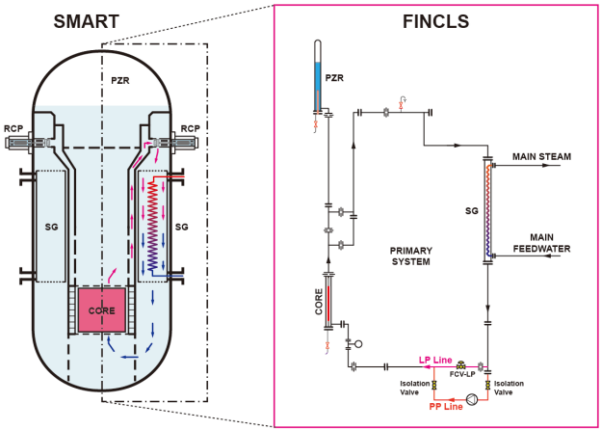

Fig. 1. Schematic diagrams of SMART and FINCLS.

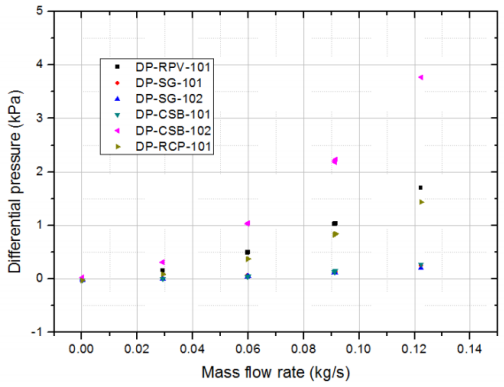

Fig. 2. Pressure losses for the primary loop.

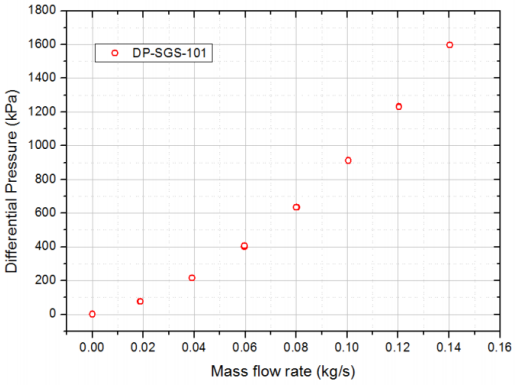

Fig. 3. Pressure losses for the secondary loop.

2.2 Preliminary Test for Single-Phase NC

As the preliminary test of FINCLS, a case of single-phase NC test has been performed at low temperature level below 100 ℃. The present test is intended to check the reliability of control and measurement systems, as well as to assess the responsibility to various control parameters. In terms of system protection, the purpose of this test could include identification of controllability against an unexpected transient.

Fig. 4 shows the thermal hydraulic measurements during the transient when the operating mode is switched from active circulation to NC. As shown in the figures, FINCLS was operated at a steady-state condition at the core power of 10 kW, and the subcooling margin at the core outlet was about 30 ℃. During the steady-state, the opening rate of FCV-LP (flow control valve on the LP Line) was about 70 %. It is noted that the fluid in the LP Line flows in reverse direction during the steady-state since the higher pressure at the pump discharge reverses the pressure gradient of the LP Line.

In the process of switching the operating mode form active to NC, the PP (Primary Pump) was tripped and simultaneously the FCV-LP was completely opened.

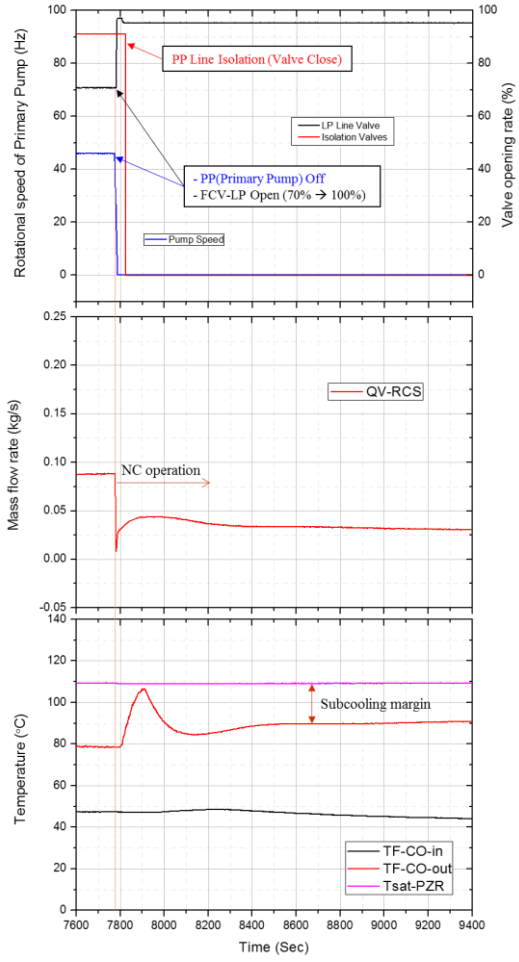

Fig. 4. Transient behavior during a switch from active circulation to NC.

Then, the mass flow rate of primary system showed a sharp under-shooting tendency, and then was gradually recovered. After the operating mode was switched to NC mode, the temperature at core outlet was rapidly increased due to the sudden drop in the mass flow rate of primary system.

During this transient, the flow in LP Line might be switched to the reverse direction because the pressure gradient is reformed along the flow path. Then, the PP Line was sequentially isolated after the NC flow rate was steadily recovered.

In this test, the core power was reduced from 10 kW to 5 kW when the excessive increase in temperature at core outlet was detected. The controllability to avoid a subcooled boiling in transient condition was confirmed. In addition, the experimental results revealed that the sufficient subcooling margin should be ensured for more stable single-phase NC test.

3. Conclusions

FINCLS was constructed as a new test facility for a comprehensive understanding of thermal-hydraulic phenomena in SMART. The main purpose of the FINCLS is to perform a parametric study on NC phenomena, as well as to provide the validation data for both theoretical analysis and MARS-KS simulation.

Two types of commissioning tests were carried out to confirm the characteristics of the FINCLS facility. Firstly, the loop circulation tests for both primary and secondary loops have been performed to assess the tightness and repeatability in measurements including the flow rate and the DP. As a result, the characteristics in pressure losses for all DP sections were obtained as a function of the flow rate.

One single-phase NC test at low temperature level below 100 ℃ was conducted as the preliminary study. The transition from active to NC operation after switching the operating mode was clearly identified. The sufficient controllability to maintain the steady-state operation as well as to avoid a subcooled boiling during a transient condition was verified.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (No. 2016M2C6A1004894)

REFERENCES

[1] K. K. Kim et al., SMART: The First Licensed Advanced Integral Reactor, Journal of Energy and Power Engineering, 8, pp.94-102, 2014.
[2] H. S. Park, et al., "SMR accident simulation in experimental test loop." Nuclear Engineering International, pp.12-15, November, 2013.
[3] KAERI. "MARS Code Manual Volume I: Code Structure, System Models and Solution Methods," KAERI/TR-2812, 2009.