Development of Test Facility for Evaluating Flow Characteristics for the IHX of Prototype SFR

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1. Introduction

As a sodium-cooled fast reactor (SFR) is being developed in the Korea Atomic Energy Research Institute (KAERI), various computational programs for thermal and hydraulic design and analysis are developed and validated through comparisons with experimental results. As a part of the program development, sodium-to-sodium heat exchanger sizing analyzer (SHXSA) code is developed and used to design the intermediate heat exchangers (IHX) [1]. However, the correlations implemented in the SHXSA code are limited to well-estimate the pressure drop on the IHX shell side due to the geometric complexity and a wide range of required flow rate conditions. Thus, pressure drop correlations should be validated and improved by experimental data. In this study, the flow characteristics test facility of IHX, called iHELP (Intermediate Heat Exchanger Test Loop for PGSFR), was designed and constructed to obtain experimental pressure drop results for a wide range of flow rate conditions. In addition, preliminary experiments were carried out to evaluate the overall performance of the test facility.

2. Description of iHELP

2.1 Design of Test Section

IHX test section was designed by considering geometric and dynamic similarities to simulate the pressure drop characteristics on the shell side of the prototype IHX [2]. The design parameters adapted in the test section are presented in Table 1 and the test section is illustrated in Fig. 1, which consisted of the entrance region, tube bundle region, flow passing region on the grid plate, and exit flow channel.

2.2 Description of Test Facility

As shown in Fig. 2, a test facility was constructed that could simulate the flow characteristics in the prototype IHX, and this was fully instrumented to measure the flow rates, temperatures, and pressure drops while water is flowing through the test section. The test facility mainly consists of an IHX test section, a water storage tank, circulation pumps, a heat exchanger, and cooling tower. Two circulation pumps were installed to supply water to the test section, and the flow rate was adjusted by the motor speed control. The water storage tank had an inbuilt electrical heater to provide water at a constant temperature. The vortex flow meters and RTDs were appropriately placed to measure the flow rates and fluid temperatures, respectively. Absolute pressure transducers were installed to monitor the system's working pressures, and differential pressure transducers were used to measure the pressure drop of water flowing through the test section. A cooling water loop including a heat exchanger, circulation pump, and cooling tower was connected to the main loop to precisely control the fluid temperature by rejecting the heat generated by the pumps.

As shown in Fig. 3, several pressure taps, which were connected to the corresponding differential pressure transducers, were installed in the test section to investigate the pressure drop characteristics. Two different groups of differential pressure transducers were used to accurately measure a wide range of pressure drops led by a broad range of required flow rate conditions.

Table 1 Summary of design parameters

	Prototype IHX	IHX test section
Fluid	Sodium	Water
Temperature, ˚C	467.5	35
Pressure, MPa	0.1	0.1
Density, kg/m^3	849.8	994.0
Viscosity, Ns/m^2	2.53E-4	7.20E-4
Height ratio	1	1
Width ratio	1	1
Volume ratio	1	1/29.6
Hydraulic diameter ratio	1	1
Re ratio	1	1
Flow hole area ratio	1	1

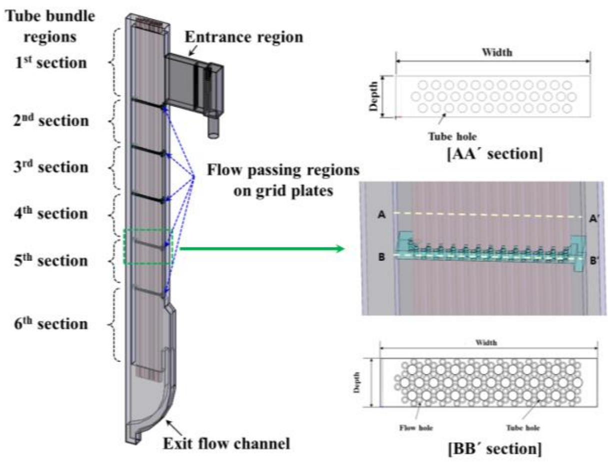
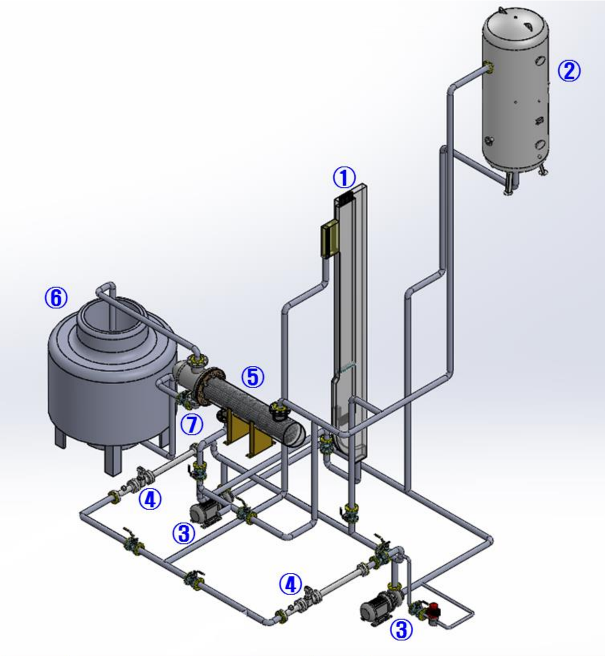


Fig. 1 IHX test section



No.	Components	No.	Components
①	IHX test section	⑤	Heat exchanger
②	Water storage tank	⑥	Cooling tower
③	Circulation pumps	⑦	Cooling pump
④	Vortex flow meters		

Fig. 2 Schematic of iHELP test facility

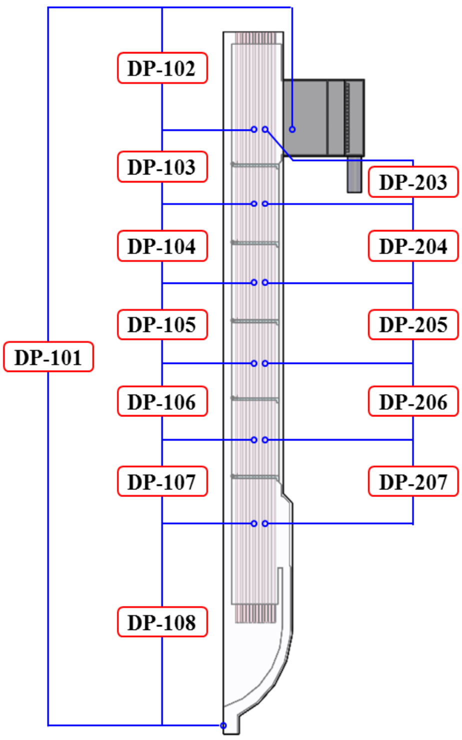


Fig. 3 Experimental setup for pressure drop measurement

3. Preliminary Experiments

Preliminary experiments have been conducted to evaluate the test facility's overall performance. Water was used as the working fluid, and the fluid temperature remained at a constant 35 ˚C during the tests. A rated flow rate of working fluid was 48 kg/s, which was well set by the pump control. All data were recorded using the data acquisition system when physical variables reached a steady state. The pressure drop for water flowing through the grid plates was about 106 kPa and the pressure drop in each grid plate was approximately the same. The value of pressure drop across the grid plates was similar to the numerical results, which can ensure the reliability of the pressure drop measurement in the test facility. Since the test section was built as a slab form, geometric characteristics were not conserved properly in the exit flow channel. Thus, based on the experimental results, analytical analysis should be performed to estimate the pressure drop in the exit flow channel of prototype IHX by considering relations among the pressure drop, loss coefficients, and fluid velocities in both the IHX test section and prototype IHX.

Uncertainty analysis was conducted based on the ASME PTC 19.1-2005 code [3] with 95% confidence to ensure that the experimental results were applicable for data analysis. Experimental uncertainties for the main variables including pressure drop, temperature, and flow rate were calculated by accounting for both systematic and random uncertainties. As shown in Table 2, experimental uncertainties for all variables met their measurement requirements, respectively.

Table 2 Summary of uncertainty analysis results

	Uncertainty	Requirement
Absolute pressure	±0.14%	±3.0% of F.S.
Differential pressure	±0.14%	±3.0% of F.S.
Temperature	±0.58˚C	±1.5˚C of R.S.
Flow rate	±0.76%	±1.1% of R.S.

4. Conclusion

In the study, a test facility (iHELP) was designed and constructed that can simulate the flow characteristics on the shell side of the prototype IHX. The overall performance of the test facility was validated through preliminary experiments, and experimental uncertainties for all measured variables met their respective requirements. In future studies, the experiments will be conducted at various flow rate conditions, and the obtained experimental results will be used to validate and improve the pressure drop correlations used in the SHXSA code.

ACKNOWLEDGEMENT

The authors would like to thank the National Research Foundation of Korea (NRF) grant funded by the Korea Government (MSIP) (No. 2012M2A8A2025638).

REFERENCES

[1] J. H. Eoh, Conceptual Design Report of Prototype SFR Intermediate Heat Exchanger, SFR-FS200-ER-01-2012 Rev.00, KAERI, 2012.
[2] H.J. Chung, W.S. Kim, D.J. Euh, Design Report for Flow Characteristics Test Facility of the SFR IHX, TR-6136/2015, KAERI, 2015.
[3] The American Society of Mechanical Engineers, 2005, "Test Uncertainty," ASME PTC 19.1-2005.