Instrumentation and Control Systems for Sodium thermal hydraulic Experiment Loop for Finned-tube sodium-to-Air heat exchanger (SELFA)

Byeong-Yeon Kim*, Hyungmo Kim, Youngil Cho, Jong-Man Kim, Yung Joo Ko, Byeong Su Kang, Min-Hwan Jung, and Ji-Young Jeong
Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, Daejeon, 305-353, Republic of Korea
**Corresponding author: byeongyeon@kaeri.re.kr*

1. Introduction

A forced-draft sodium-to-air heat exchanger (FHX) is a part of decay heat removal system (DHRS) in Prototype Gen-IV Sodium-cooled fast reactor (PGSFR), which is being developed at Korea Atomic Energy Research Institute (KAERI) [1]. Sodium thermal hydraulic Experiment Loop for Finned-tube sodium-to-Air heat exchanger (SELFA) is a test facility for verification and validation of the design code for a forced-draft sodium-to-air heat exchanger (FHX) [2]. In this paper, we have provided design and fabrication features for the instrumentation and control systems of SELFA. In general, the instrumentation systems and control systems are coupled for measurement and control of process variables. Instrumentation systems have been designed for investigating thermal-hydraulic characteristics of FHX and control systems have been designed to control the main components (e.g. electromagnetic pumps, heaters, valves etc.) required for test in SELFA.

2. Design Features

In this section, overview of test facility and configurations of instrumentation and control systems for SELFA are described.

2.1 Overview of Test Facility

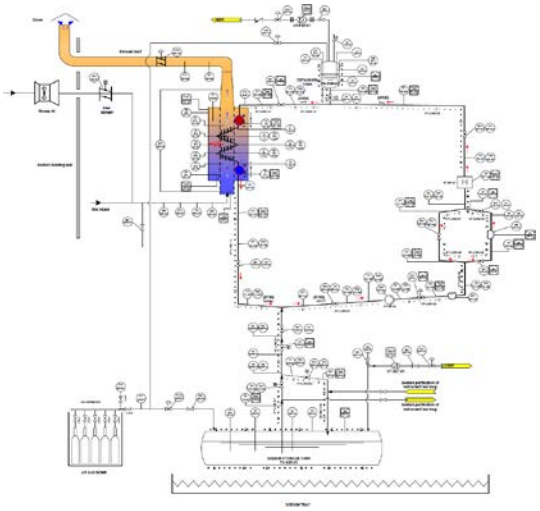

Fig. 1. Piping & Instrumentation Diagram (P&ID) of the SELFA

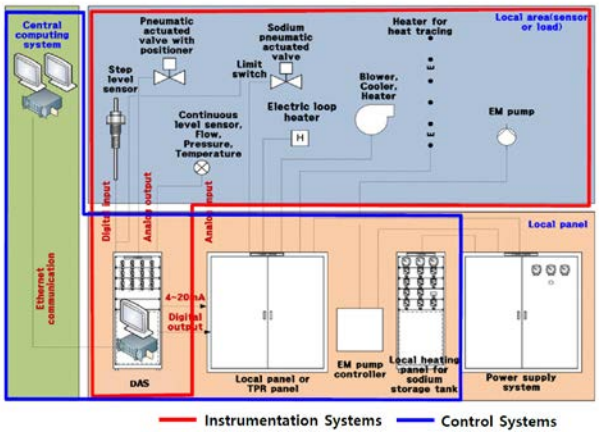

Fig. 2. Configuration of Instrumentation and Control Systems

The SELFA consists of sodium-side components and air-side components as shown in Fig. 1. The sodium-side components include model FHX (M-FHX), electromagnetic pump (EM pump), flowmeters for sodium, pressure transmitters for sodium, electric loop heater, expansion tank, and sodium storage tank. The air-side components include blower, dampers, flowmeter for air, and pressure transmitter for air. Fig. 2 shows configuration of instrumentation and control systems of SELFA. All the signals including analog input (AI) & analog output (AO), digital input (DI) & digital output (DO) from the sensors are collected through Data Acquisition System (DAS). In general, the range of AI & AO signals is from 4mA to 20mA, while DI & DO signals are either 0 or 1. The AI signals comes from the sensors which have continuous measurements of process variables such as flowmeter, pressure transmitter. The DI signals comes from the sensors which have discrete measurements of process variables such as level switch, limit switch. AO signals are for control of the components which have continuous process output such as heater control input, while DO signals are for control of the components which have discrete process output such as on\off valve control.

2.2 Instrumentation Systems for SELFA

Expected operation ranges for sodium side and air side of SELFA are shown in Table I. The instrumentation systems for SELFA are designed based on the expected operation range. First, all the

temperatures of sodium side are measured by K-type thermocouple through thermowell for preventing leakage of sodium. Twenty multipoint thermocouples which can measure five points for each are used for measurement of shell-side air temperature. Second, an electromagnetic flowmeter and a Coriolis flowmeter are installed for measurement of sodium flow rate in the main loop as shown in Fig. 4. The Coriolis flowmeter which have high accuracy is for calibrating the electromagnetic flowmeter and vice versa. A thermal mass flowmeter is installed for measurement of air flow rate through shell side of M-FHX. Third, NaK filled pressure transducers are installed for measurement of pressure at sodium side as shown in Fig. 5 and pressure transmitters are installed for measurement of static pressure and differential pressure at air side. Finally, all the signals from the sensors are collected through data acquisition system (DAS) as shown in Fig. 6.

Table I: Expected Operation Range of SELFA

	Sodium side	Air side
Temperature	~ 500℃	~ 350℃
Flow rate	~ 4.38 kg/s	~ 3.4 kg/s

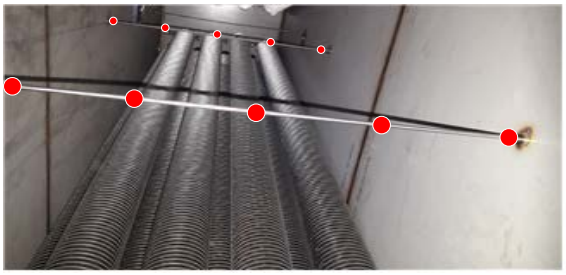

Fig. 3. Multipoint thermocouple installation at shell side of M-FHX

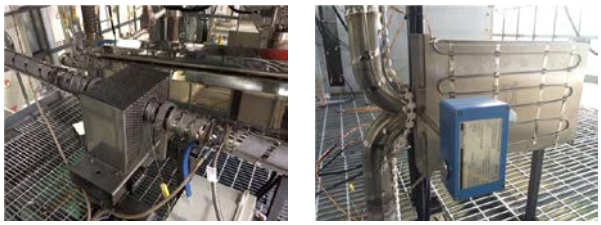

Fig. 4. Electromagnetic flowmeter (left) and Coriolis flowmeter (right) installation at sodium side

Fig. 5. NaK filled pressure transducer (left) at sodium side and pressure transmitters (right) at air side

Fig. 6. Data Acquisition System (DAS) panel of the instrumentation systems

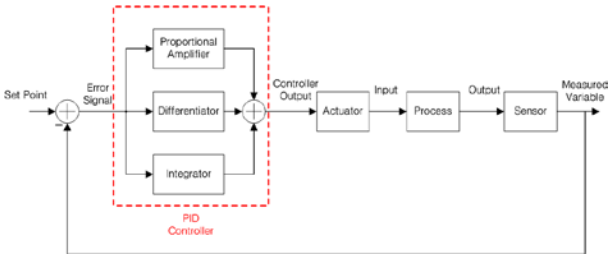

Fig. 7. Block diagram of PID feedback control for continuous control variable

2.3 Control Systems for SELFA

Instrumentation systems and control systems are closely related with each other since the control systems use information from the instrumentation systems. The control systems for SELFA consist of several controllable components, local control panel, and Human Machine Interface. The configurations of control systems for SELFA is as follows. First, line heater and electric loop heater are required to be controlled in order to make appropriate sodium temperature which satisfies test condition and prevent solidification of sodium. Proportional-Integral-Differential (PID) feedback control shown in Fig. 7 is applied to heater control to improve performance. AI signal from thermocouple is the input to PID feedback controller and the output of PID controller, which is AO signal is sent to Thyristor Power Regulator (TPR) shown in Fig. 8 to adjust input power of heater within the range from 0 to 100 %. Second, a blower in the air side which provides air flow rate to shell side of M-FHX is also controlled by PID feedback control. The output of PID feedback controller is sent to an inverter shown in Fig. 8. The inverter which is a kind of variable voltage variable frequency (VVVF) controller is used to adjust revolutions per minute (RPM) of the blower from 0 to 100% by changing frequency from 0 to 60Hz. Third, an EM pump which provides sodium flow rate to main sodium loop of SELFA is also controlled by PID feedback control. The output of PID feedback controller is sent to a slidacs. The slidacs which is variable

transformer is used to adjust input power of the EM pump from 0 to 100%. Finally, all the controllable components such as EM pump, heaters, pneumatic valves, blower of SELFA can be controlled and monitored at Human Machine Interface (HMI) as shown in Fig. 9. Also, all the control logics such as on/off control and PID feedback control are implemented in HMI.

3. Conclusions

In this paper, we have provided configurations of instrumentation and control systems for Sodium thermal hydraulic Experiment Loop for Finned-tube sodium-to-Air heat exchanger (SELFA). The instrumentation and control systems of SELFA have been implemented based on the expected operation ranges and lesson learned from operational experience of "Sodium integral effect test loop for safety simulation and assessment-1" (STELLA-1). It would be worth noting that some design features and operational experiences of instrumentation and control systems of SELFA could be applied to design and implementation of instrumentation and control systems for STELLA-2.

4. Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025635)

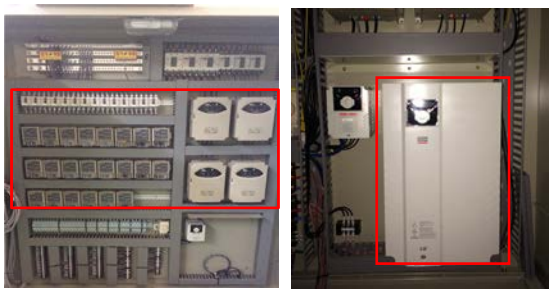

Fig. 8. Thyristor power regulator (left) for line heater control and inverter (right) for blower control in local control panel

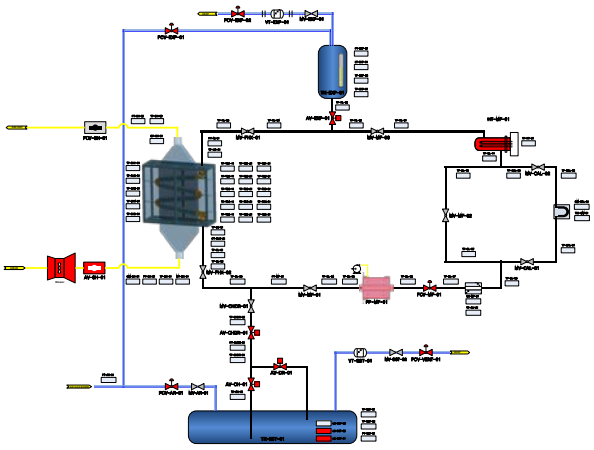

Fig. 9. Human Machine Interface (HMI) of SELFA

REFERENCES

[1] Y.-I. Kim, Y.B. Lee, C.B. Lee, D.H. Hahn, "Status of SFR Development in Korea", International Conference on Fast Reactors and Related Fuel Cycles: Safe Technologies and Sustainable Scenarios (FR-13), Paris, France, March 4-7 (2013).
[2] Test Requirements of FHX Performance Experiment, SFR Development Division, "SFR-IOC-F/T-1-019", KAERI (2015)