Selection of Instruments for Measuring Process Parameters of a Sodium Test Loop

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1. Introduction

KAERI (Korea Atomic Energy Research Institute) is constructing a sodium test facility called STELLA-1 (Sodium integrated effect TEst Loop for safety simuLation and Assessment) in which the major components for an SFR (Sodium-cooled Fast Reactor) such as heat exchangers are to be experimented [1,2].

STELLA-1 includes pipes, heat exchangers, pumps, electrical heaters, tanks, and other supporting instruments and valves. These components should be in operation with the liquid sodium used as the heat transport fluid in the SFR.

Based on a general review and preliminary considerations on some instrumentation methods and requirements for sodium facilities in the previous literatures [2], this paper describes the selected instruments, which were investigated, designed, and engineered for measuring the process variables of STELLA-1 in which the high temperature liquid sodium is flowing.

2. Instrumentation Requirements

As the general purpose of the test facility is to investigate the performance of two heat exchangers, one is a sodium-to-sodium heat exchanger, the other one is a sodium-to-air heat exchanger, and a large mechanical sodium pump, it is required to measure all the typical process parameters that are usually monitored in a thermal-hydraulic loop. These parameters are the temperature of hundreds of points, liquid level of sodium tanks, sodium flow rate flowing in the pipes, pressure of the closed tanks, differential pressure between the inlet and outlet pipes of the heat exchangers, etc.

However, liquid sodium is different than water in physical and chemical properties, and the operational temperature of STELLA-1 is extremely high with a 200-550℃ range. Therefore, the selection and design of instrumentation methods shall be carefully considered, unlike the case of the water-steam process.

Section 3 describes the investigated instrumentation methods of each parameter and their features selected for STELLA-1

3. Discussions on measurement methods

3.1 Temperature Measurement

A practical and inexpensive way to measure the high temperature of liquid sodium is to use a K-type thermocouple capsulated in a stainless steel sheath and well. Except for this, there is no particular difference in using thermocouples for STELLA-1 compared to other applications.

The only consideration is the welding installation of thermo-wells in order to eliminate a possibility of sodium leak when it is mounted in a threaded manner.

3.2 Sodium Level Measurement

The strong reactive feature of liquid sodium with other materials makes it difficult to choose an appropriate type among industrial level sensors. These limitations in selection for sodium tank level instruments are as follows:

1) Any additional connection from a tank such as a outside chamber or a pressure impulse line are not suitable because of complexity in liquid sodium drain/charging and temperature control. (only top-mounted sensor is applicable)
2) The materials contacting sodium shall be stainless steel if possible because other materials may be corrosive in reaction with high temperature sodium.
3) Sodium vapor forming a solidified compound which attaches on the surface of the tank or pipe should be considered. This solid dust may cause an impact on electric insulation or mechanical movement.
4) The electronic part shall be separated from the sensing transducer in order to avoid any damage from the high temperature of the sodium tank.

The most promising and proven level sensors for liquid sodium are induction probes which generate a voltage in proportion to the mutual inductance depending on the length of a probe immerged in liquid sodium. However, no industrial manufacturer for such induction level transmitters exists in Korea. Also, it is investigated that the inaccuracy of an induction rod type level transducer is generally as high as 3-5%, because the output signal is influenced from several factors such as dimension of the tank, temperature, materials around the probe, etc. It is also difficult to calibrate the induction rod unless there is a special sodium facility for level verification in a sodium tank.

Alternate investigated candidates for a continuous and discrete measurement of high temperature liquid sodium level were a bubbler, a guided wave radar (GWR) level transmitter, an electrode type level sensor, and a displacer (buoyancy) type level sensor.

In consideration of high temperature capability, cost, calibration, and installation methods, the final design was determined to use several multi-point electrode type sensors as the primary level detection and a buoyancy or radar type level transmitter as a backup instrument. Fig. 1 illustrates the level detection method adopted for STELLA-1.

The sodium level is monitored and controlled by using the numbers of the electrodes to which the liquid sodium surface touches as the level is changing. The continuous level transmitter will be used as a backup measurement for applicability testing on the liquid sodium environment.

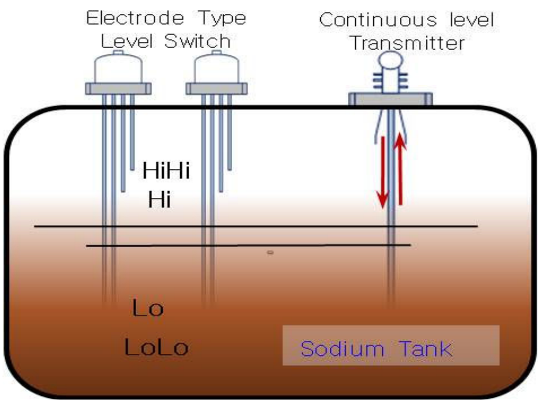

Fig. 1. Level Measurement of Sodium in a Tank.

3.3 Sodium Flow Measurement

The most commonly adopted technique in measuring a hot sodium flow is to use an electromagnetic flow meter. However, there was no proper industrial manufacturer of electromagnetic flow meters usable in the liquid sodium fluid with reliable accuracy.

We chose to introduce the Coriolis-type mass flow meter with the following two considerations for using it in STELLA-1.

1) The maximum operating temperature of the available Coriolis flow meters is 350℃. Therefore, KAERI designed to install the flow meters in low temperature sections in the sodium loop, for example, at the inlet area of the electric loop heaters.
2) For complete sodium draining in the Coriolis measuring tubes, the U-tube type meter shall be selected and installed in a vertical path.

3.4 Sodium Pressure Instrument

No commercial pressure transmitters investigated was able to operate by direct contacting with 500℃ liquid sodium. The highest temperature allowable to the contacting part of a remote diaphragm seal type pressure instrument was 315℃.

However, the static pressure of sodium in a tank is able to be sensed by measuring the pressure value of the cover gas in the tank which is supplied from an argon gas supply system.

The pressure of sodium flowing in a pipe can be measured only by a diaphragm system which directly transfers the pressure from the process side to the instrument side. As we intended to use a commercial instrument for sodium pressure measurement, the following requirements were identified during the design phase.

1) Because of the operating temperature limit of the filled material between the diaphragm and the transducer of a pressure transmitter, the maximum temperature at the remote diaphragm contacting the sodium shall not exceed 300℃
2) Because the hot liquid sodium becomes solid below 98℃, the temperature of the impulse tube line shall be above 150℃ including the margin
3) For easy drainage of liquid sodium in the impulse line, there shall not exist any dip or depression where liquid may be trapped after a sodium drain operation.

Considering these limitations, the final design was determined to attach a tracing heater and a temperature sensor to keep the impulse line in the temperature between a high limit and low limit with a declining sloped configuration as illustrated in Fig. 2.

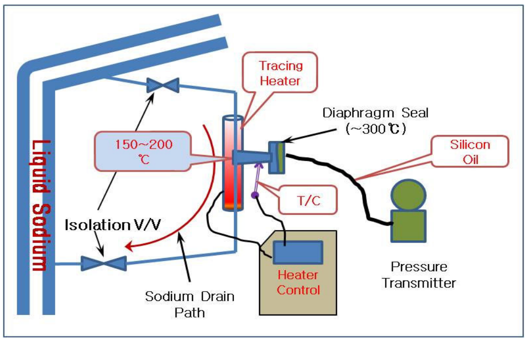

Fig. 2. Configuration for Sodium Pressure Measurement

4. Conclusions

Through wide investigation and review on sodium instrumentation concepts for the design and construction of the STELLA-1 facility, the final compromising selection was made based on the technical and cost aspects. Although every method was based on using commercial devices available in other industries, it had to be modified and engineered in accordance with the fluid and operating conditions in which the intended measurement method is applied.

ACKNOWLEDGEMENT

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