Feasibility test of NaK filled pressure transducers for sodium test facility

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1. Introduction

The sodium experiments for PGSFR (Prototype Gen-IV Sodium-cooled Fast Reactor) are in progress at KAERI for specific design and licensing of PGSFR. Most of the sodium experiments are performed at the high temperature condition. And on account of the strong chemical reactivity of sodium and solidification in a room temperature, many pressure transducers cannot be adapted directly. To use existing pressure transducers without any intermediate medium, it must be equipped by heaters, valves and safety devices to avoid solidification and to prevent chemical reaction of sodium. The pressure transducer filled NaK (Sodium-potassium alloy is generally referred to as NaK.) is selected as pressure transducers for sodium test facility. The advantage of NaK over sodium is a lower melting point than a room temperature. The lower melting point can make a pressure transducer can be directly used without additional parts such as heaters and valves. However, in a sodium test facility for a sodium-cooled fast reactor (SFR), the pressure level could be lower than other thermal-hydraulic test facilities. In this paper, feasibility tests of NaK filled pressure transduces in a relatively low pressure level were performed for a sodium test facility. In the test, model KE pressure transducers made by GEFRAN were tested in a pressure range (i.e., up to 200 kPa) which usually expected for a sodium test facility. The validation of using in a low pressure level was confirmed by the feasibility tests as well as high pressure. Furthermore, NaK filled pressure transducer will be validated at high temperature and robustness in long term uses and repetition in our sodium test facility at KAERI.

2. Characteristics of Sodium, Potassium and NaK

2.1 Characteristics of Sodium

Sodium (Na) is the sixth most abundant metal on earth. It is a silvery metal, soft and ductile and having a density slightly less than that water in a room temperature. It melts at about 98℃ to form a silvery liquid and its normal boiling point is 881℃. Sodium's high thermal conductivity makes it an excellent coolant in SFR.

2.2 Characteristics of Potassium

Potassium (K) shows a behavior very similar to that of Sodium. But potassium has limited uses because of relatively high manufacturing cost. Potassium is a silvery-white metal that is ductile and soft, although less so than sodium. Its density at a room temperature is 86% of that water, with which it reacts slightly more violently than does sodium. Its normal melting point is 63℃ and normally boils at 756℃. The heat conductivity of potassium is about one-half that of sodium and this makes the latter the superior heat transfer fluid.

2.3 Characteristics of NaK

Sodium-potassium alloy is generally referred to as NaK. The sodium and potassium metals are miscible in all proportions. The alloy composition is given in weight percent of potassium following NaK. The melting point ranges downward from the melting point of sodium and potassium. The melting point of NaK-77.8 is -12.6℃ to the following Fig 1. Liquid NaK is similar to mercury in appearance. It is chemically more reactive than sodium and has lower thermal conductivity than sodium and potassium.

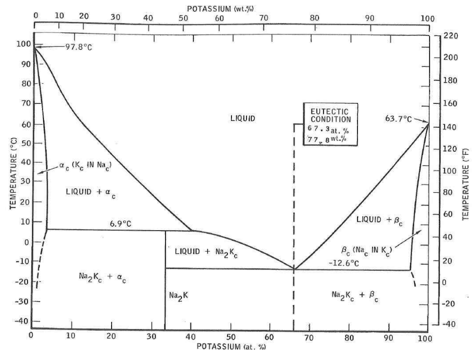

Fig.1.Sodium-potassium equilibrium diagram

3. Feasibility test of NaK filled pressure transducer

3.1 Features of the NaK filled pressure transducer

To use an existing pressure transducer in a sodium test facility, it should be equipped by heaters, valves and safety devices for avoiding solidification and chemical reaction of sodium. The model KE made by GEFRAN were used in the feasibility test. The KE is for use in high temperature applications where the process temperature may reach 538℃ such as high temperature sodium experiments. The KE is utilized as standard melt pressure principle. But that pressure transducer contains a near incompressible NaK. Its pressure range is 0~17 bar and accuracy is < ±0.25 FSO. The volume of NaK contained 40mm^3(0.00244in^3). The diaphragm is fabricated as Inconel 718 with GTP (Coating with high resistance against corrosion, abrasion and high temperature).

Fig.2. the pressure transducer filled NaK (KE)

3.2 System design and test procedure

The purpose of this test is to confirm feasibility of pressure transducer filled NaK. This test is consisted of argon gas for filling test section, reference pressure transducer calibrated and test container (pressure tank). And the experimental data measured by reference pressure transducer (uncertainty: 0.012%) and so on separate PC's hard disks using Labview program were respectively stored.

Furthermore, KAERI is developing a sodium test facility: SELFA (Sodium thermal-hydraulic Experiment Loop for Finned-tube sodium-to-Air Heat exchanger). The SELFA will use the pressure transducer filled NaK for measuring a pressure difference in a sodium-side. Fig. 3 is the 3D model of SELFA which will be constructed. The operating range of the pressure transducer is 17 bar. But the expected pressure range in SELFA is only up to 200 kPa. The low pressure range is more important than high pressure range in SELFA. In low pressure range, experiment will be conducted not in a high pressure range, but in a low pressure range.

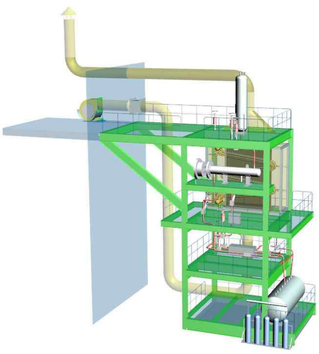

Fig.3. the 3D model of the sodium test facility (SELFA)

3. Results and discussion

The purpose of feasibility test is to validate pressure transducer filled NaK (KE). The tests were conducted with 4 pressure transducers with NaK because of SELFA's measuring pressure point. The feasibility tests were conducted in a pressure ranges until 100 kPa every 2 kPa. And after that, the tests were conducted in a pressure range from 100 kPa to 200 kPa every 10 kPa. The Fig. 4 shows the results by Eq. (1). Maximum value of standard deviation is 0.007. This represents the comparatively good linearity.

$$M = S \cdot (P - P_{min}) + M_{min} \qquad (1)$$

P: pressure M: mA d.c. S: transmission coefficient

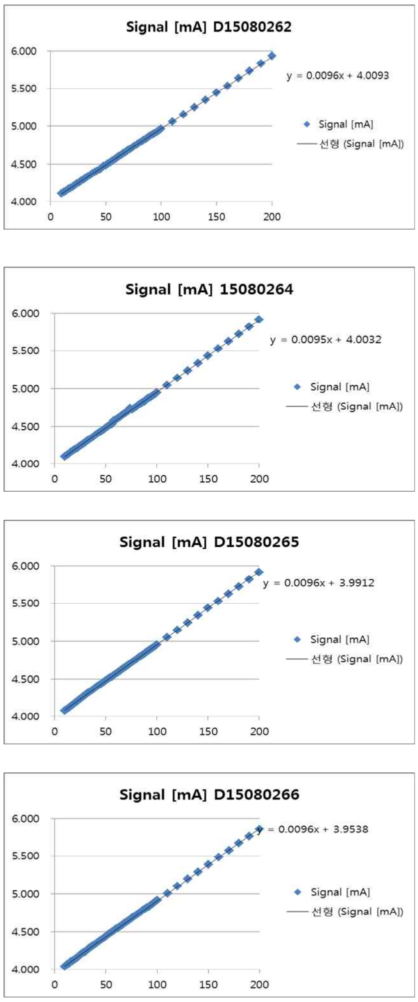

Fig.4. the linearity of the feasibility tests of the pressure transducers in a relatively low pressure range

3. Conclusions

The lower melting point of NaK can make a pressure transducer simple without many devices such as heater, valve, leak detector and many electronic measuring points. In this paper, application of pressure transducers filled NaK (KE) to sodium test facility (SELFA) was described. In an expected pressure range, the linearity is still represented considerably. In the near future, the pressure transducer with NaK will be adapted to a sodium test facility.

Acknowledgement

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

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