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The Fabrication and Shakedown Testing of a Lead Corrosion Test Loop

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1. Introduction

Recently, Lead-bismuth eutectic (LBE) or Lead has newly attracted considerable attraction as a coolant to obtain a greater inherent safety. Above all, LBE is preferred as the coolant and target material for an accelerator-driven system (ADS) due to its high production rate of neutrons, effective heat removal, and a very small amount of radiation damage properties. But, the LBE or lead as a coolant has a challenging problem in that the LBE or Lead is more corrosive to the construction materials and fuel cladding material than sodium because the composing materials of steel, Ni, Cr, and Fe, dissolved in liquid lead or LBE.[1][2] After all, LBE or Lead corrosion has been considered as an important design limit factor of ADS and LMFBR.

Lead-alloy corrosion test loop named KPAL (KAERI Pb-Alloy Loop) has been designed and fabricated at the Korea Atomic Energy Research Institute (KAERI) and the initial operation was performed recently. The test fluids of KPAL-I and KPAL-II were LBE and lead, respectively.

The KPAL-II was designed to study the long-term corrosive effects of liquid lead on structural and fuel cladding materials at temperatures up to 600℃. The first run of KPAL-II took place on March 15th, 2006 and three hundred hours of shakedown testing have been performed with an isothermal condition at about 450℃. The KPAL-II is scheduled to be ready for a 500-hour material test at 450℃, 550℃, 600℃.

The main objective of the present paper is an introduction of KPAL-II and the results of the shakedown testing.

2. The Lead Corrosion Test Loop, KPAL-II

A schematic diagram and a photograph of the lead corrosion test loop installed in KAERI are shown in Fig. 1 and Fig. 2, respectively. Although the KPAL-II was designed as a non-isothermal loop, in the meantime, it had been built as an isothermal loop with basic components. The modification of the KPAL-II for a non-isothermal test will be progressed in the future. It consists of an electromagnetic pump (EMP), an electromagnetic flow meter (EMF), a test section, an oxygen control tank (an expansion tank), a sump tank, an ultra-sonic flow meter (USF), and argon or argon with a 5% hydrogen gas system. Most parts of the piping system were made of seamless STS 316L pipe with a 1 inch diameter and they were fabricated by the welding with a metal gasket (Copper) for the prevention of a leakage of the liquid lead. The components of the corrosion test loop except for the EMP were insulated to reduce the heat loss. All of the components of the corrosion test loop except for the Pneumatic valves had a heating system with a mold type. In the case of the piping system, the mold heater with a 4 inch outer diameter was installed. Also, the heating chamber was installed at the sump tank and the oxygen control tank. After all, the mold heater performed the heating and the insulation at the same time. The Pneumatic diaphragm valves with the parallel slide gate type were especially installed for using the high temperature environment. The liquid lead in the main test loop was circulated by the following path: (1) Electro-magnetic pump (2) Electro-magnetic flow-meter (3) Test section (4) Oxygen control tank (5) Ultra-sonic flow-meter (1) Electro-magnetic pump.

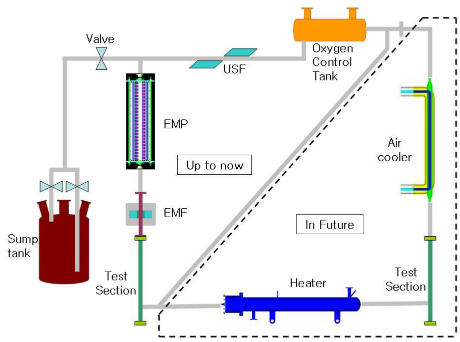

Fig. 1. The schematic diagram of lead corrosion test loop at KAERI (KPAL-II)

Fig. 2. The photograph of lead corrosion test loop at KAERI (KPAL-II)

Table 1 shows the major specifications of the KPAL-II. The velocity of the fluid was designed to be around 2m/s at the test section and the charging volume of lead in the loop is up to 20ℓ. In the case of a normal operation, the flow rate of the lead is 12ℓ/min and the KPAL-II was designed to perform a test in the isothermal condition from 450℃ to 600℃. The pressure drop of the main closed loop was estimated to be about 0.2MPa under a normal operation condition.

Table 1. The major specifications of the lead corrosion test loop

Maximum test temperature	600℃
Total Pressure drop (normal operation)	0.2 MPa
Maximum flow rate	12 ℓ/min
Maximum velocity at the test section	2 m/s
Volume of lead in the loop	20

3. The Shakedown Testing of KPAL-II

The first run of KPAL-II took place on March 15^{th}, 2006. The corrosion test loop was heated up to 450℃ before charging the liquid lead into the main corrosion test loop. The liquid lead was charged from the sump tank into the corrosion test loop by pressurizing the argon cover gas in the sump tank and evacuating the argon cover gas in the oxygen control tank at the same time. The pressure of the sump tank and oxygen control tank when the corrosion test loop was fully filled with liquid lead were 3.3 bar and -1.0bar, respectively.

Three hundred hours of shakedown testing have been performed with an isothermal condition at about 450℃.

The performance test of the EMP was performed with the EMP and the USF. In the case of the USF, we tried several times to measure the flow rate and velocity of the liquid lead in the corrosion loop. But, there were some problems. No meaning data could be obtained from the USF. To obtain the meaning data, an investigation of the cause is now under way.

On the other hand, the flow rate is measured with an electro magnetic flow meter based on Faraday's induction law.[3] Fig. 3 shows the variation of the electromotive force with the EMP output current.

Shercliff derived the electro magnetic flow meter theory for the flow measurement of a liquid metal.[3] The electric potential between electrodes was obtained as follow:

$$\Delta U = \frac{2(\frac{d}{D})^2 B v_m d}{1+(\frac{d}{D})^2 + (\frac{\sigma_w}{\sigma_f})(1+\frac{2\tau\sigma_f}{d})(1-(\frac{d}{D})^2)} \quad (1)$$

where d is the inner diameter of the flow pipe, D is the outer diameter of the flow pipe, B is the magnetic field strength, v_m is the average flow velocity, τ is the contact resistance, σ_f and σ_w are electrical conductivities of the liquid metal and the flow pipe, respectively.[3]

In a previous work[4], the theoretical and the corrected electrical potentials were calculated with Eqn. (1). The design and manufacture of the EMF are based on the EMF of the LBE corrosion test loop except for the magnetic field strength of the magnet. In this case, the magnetic field strength of the permanent magnets was 1700 Gauss. From the results of the shakedown testing of KPAL-II, the EMP offered sufficient enough driving force for a corrosion test, which needs 2m/s at a test section.

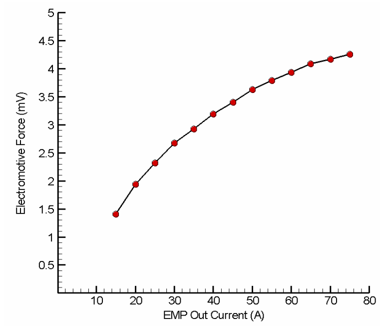

Fig. 3. The variation of electromotive force with the EMP output current

4. Conclusions

Lead corrosion test loop named KPAL-II (KAERI Pb-Alloy Loop II) has been designed and fabricated at the Korea Atomic Energy Research Institute (KAERI) and initial operation was performed recently. The first run of KPAL-II took place on March 15^{th}, 2006 and three hundred hours of shakedown testing have been performed with an isothermal condition at about 450℃. From the results of the shakedown testing of KPAL-II, the EMP offered a sufficient enough driving force for a corrosion test, which needs 2m/s at a test section. The KPAL-II is scheduled to be ready for a 500-hour material test at 450℃, 550℃, 600℃.

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