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The Fabrication and Shakedown Testing of a Lead-Bismuth 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-I was designed to study the long-term corrosive effects of liquid lead-bismuth on structural and fuel cladding materials at temperatures up to 550℃. The first run of KPAL-I took place on September 12th, 2006 and dozens of hours of shakedown testing have been performed with an isothermal condition at about 450℃. The KPAL-I is scheduled to be ready for a 1000-hour material test at 450℃.

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

2. The Lead-Bismuth Corrosion Test Loop, KPAL-I

A schematic diagram and a photograph of the lead-bismuth corrosion test loop installed in KAERI are shown in Fig. 1 and Fig. 2, respectively. The KPAL-I was designed as a isothermal loop with basic components. It consists of an electromagnetic pump (EMP), two electromagnetic flow-meters (EMF), a test section, an oxygen control tank (an expansion tank), a calibration tank, a sump tank, a magnetic and a mechanical filter, 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 1.5 inch diameter and they were fabricated by the welding with metal gaskets (Graphite) for the prevention of a leakage of the liquid lead-bismuth. The components of the corrosion test loop except for the EMP were insulated to reduce the heat loss. An insulating material was a ceramic blanket with a 4 inch thickness. All of the components of the corrosion test loop had a heating system with sheath heaters. In the case of the piping system, sheath line heaters with range from 1kW to 3kW were installed. Also, sheath pipe heaters with range from 6kW to 12kW were installed at the sump tank, the oxygen control tank, and the calibration tank. Two pneumatic diaphragm valves and a dozen manual valves with the parallel slide gate type were especially installed for using the high temperature environment. The liquid lead-bismuth in the main test loop during a normal operation was circulated by the following path: (1) EMP (2) EMF (3) Oxygen control tank (4) Test section (5) Magnetic filter (1) Electro-magnetic pump.

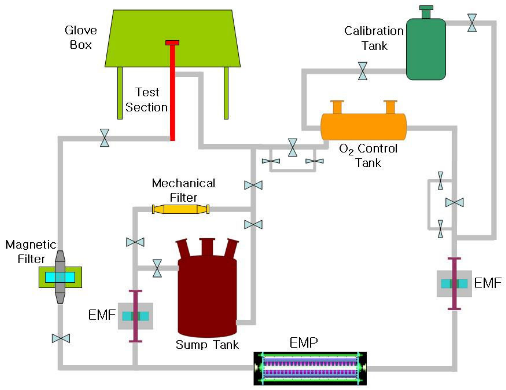

Fig. 1. The schematic diagram of lead-bismuth corrosion test loop at KAERI (KPAL-I)

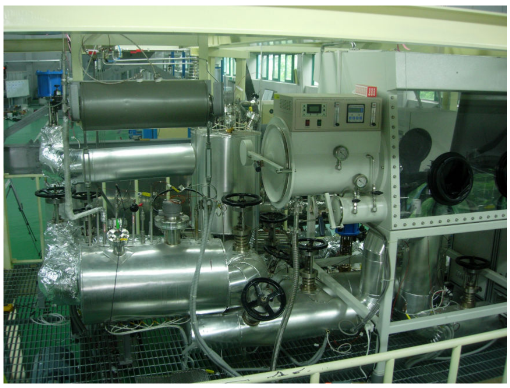

Fig. 2. The photograph of lead-bismuth corrosion test loop at KAERI (KPAL-I)

Table 1 shows the major specifications of the KPAL-I. The velocity of fluid was designed to be around 2m/s at the test section and the charging volume of lead-bismuth in the test loop is up to 30ℓ. In the case of a normal operation, the flow rate of the lead-bismuth is 33 ℓ/min and the KPAL-I was designed to perform a test in the isothermal condition from 450℃ to 550℃. The pressure drop of the main closed loop was estimated to be about 0.28MPa under a normal operation condition.

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

Maximum test temperature	550℃
Total Pressure drop (normal operation)	0.28 MPa
Maximum flow rate	40 ℓ/min
Maximum velocity at the test section	2.4 m/s
Volume of lead-bismuth in the test loop	30 ℓ

3. The Shakedown Testing of The KPAL-I

The first run of KPAL-I took place on September 12th, 2006. The corrosion test loop was heated up to 450℃ before charging the liquid lead-bismuth into the main corrosion test loop. The liquid lead-bismuth 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 calibration 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 2.0 bar and -0.6bar, respectively.

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

The performance test of the EMP was performed with the EMF. On the other hand, the flow rate is measured using the EMF and the calibration tank. Fig. 3 shows the variation of the electromotive force with the EMP output current.

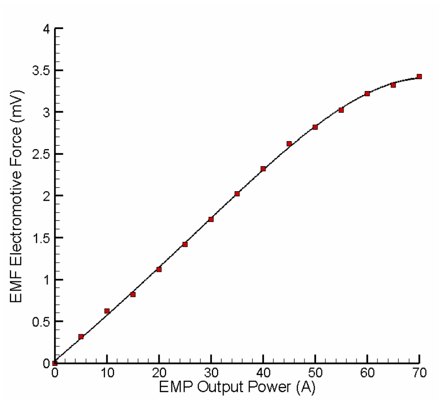

Fig. 3. The variation of electromotive force with the EMP output current

Fig. 4 shows the the variation of the electromotive force with the flow rate

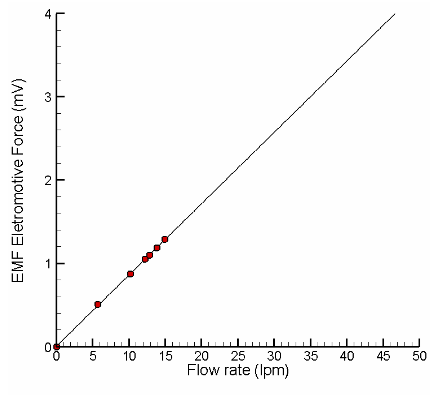

Fig. 4. The variation of electromotive force with the flow rate

From the results of the shakedown testing of KPAL-I, the EMP offered sufficient enough driving force for a corrosion test, which needs 2m/s at a test section.

4. Conclusions

Lead-bismuth corrosion test loop named KPAL-I (KAERI Pb-Alloy Loop I) has been designed and fabricated at the Korea Atomic Energy Research Institute (KAERI) and initial operation was performed recently. The first run of KPAL-I took place on September 12th, 2006 and dozens of hours of shakedown testing have been performed with an isothermal condition at about 450℃. From the results of the shakedown testing of KPAL-I, the EMP offered a sufficient enough driving force for a corrosion test, which needs 2m/s at a test section. The KPAL-I is scheduled to be ready for a 1000-hour material test at 450℃.

REFERENCES

[1] G. Y. Lai, “High Temperature Corrosion of Engineering Alloys,” ASM Int. Materials Park, OH 44073, 1990.

[2] Y. I. Orlov et al., “The Problems of Technology of the Heavy Liquid Metal Coolants (Lead-Bismuth, Lead),” Proc. of the Heavy Liquid Metal Coolants in Nuclear Technology, Obninsk, 1998.