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Title: "LEAD-BISMUTH EUTECTIC AS ADVANCED REACTOR COOLANT: OPERATIONAL EXPERIENCE"

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Lead-Bismuth Eutectic as Advanced Reactor Coolant: Operational Experience

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INTRODUCTION

Some proposed advanced reactor concepts would be cooled by lead or lead-bismuth eutectic (LBE). An LBE test loop was designed and built at Los Alamos to develop the engineering and materials technology necessary to successfully implement LBE as a coolant (Fig. 1). Operational since December 2001, this test loop has been used to develop and demonstrate safe operation, oxygen concentration and metal corrosion control, instrumentation, thermal-hydraulic performance of heat exchangers and recuperators, and free convection and forced pumping. This paper discusses the technology development and lessons learned from the operation of this facility.

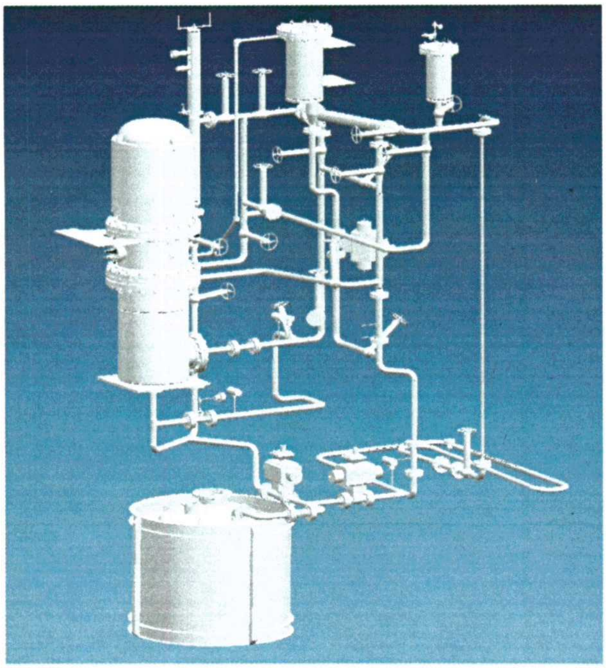

Fig. 1. LBE test loop isometric view.

TECHNOLOGY DESCRIPTIONS AND LESSONS LEARNED

Some of the key technology systems and lessons learned during the operation of the LBE loop are described in the following subsections:

Safety

Safe operation is paramount to the successful introduction of a new coolant technology. With the exception of the toxicity of the lead, all the hazards of temperature, pressure, electrically energized systems, etc., are similar to those posed by any coolant, varying only by degree, and can be managed in similar fashion. Personnel must be protected from ingestion or inhalation of lead by proper handling and containment. Vapors are not normally a hazard because of the low vapor density, but precautions must be taken to avoid exposure to airborne lead or lead oxide.

Lead safety implementation includes training, full enclosure of the loop with HEPA-filtered ventilation, occasional surface swipes to be analyzed for lead, written procedures, and annual blood lead testing.

Oxygen Content: Control and Measurement

It has been shown that control of oxygen concentration in molten LBE or lead systems is critical to minimizing the corrosion rate of steel piping and containment vessels. The theory of corrosion control for these systems has been expounded elsewhere.

In this test loop, oxygen concentration within a chosen range is maintained by injecting He6%H2 or He6%O2, as needed. The hydrogen mix is injected directly into the flowing LBE, while the oxygen mix is injected into the cover gas.

Oxygen concentration is measured using custom-designed sensors (Fig.2) based on technology developed in Russia. An yttria-stabilized zirconia electrolyte develops a voltage potential between the LBE and an oxygen-saturated Bi reference, as a function of temperature and the oxygen concentration in the LBE. This technique is demonstrated and fully operational. Improvements in design are ongoing.

Instrumentation

Temperature, pressure and flow are the primary instrumentation needs of a thermal-hydraulic system. Temperature is measured without difficulty using thermocouples.

Pressure measurements in the liquid are problematic above about 300ºC, the limiting temperature of commercial transducers. Where higher temperatures exist a stand-off tube is required, and it is critical that this tube be drained by gas pressure when shutting down to below the freeze temperature of the LBE.

Flow measurement is possible with electromagnetic devices, but these were proven to be unreliable, primarily because of calibration shifts. A venturi-type flow meter has proven extremely reliable, with no calibration drift after 15 months.

Fig. 2. Oxygen sensors, ready for installation. Ceramic electrolyte shown in inset.

Heat Exchangers

The loop is equipped with a LBE-to-LBE recuperator and a water-LBE heat exchanger, both of Russian design. The recuperator is shell-and-tube design with a compression ring seal for differential expansion. The heat exchanger is an annular counterflow design with variable active surface area. Both devices are being monitored for degradation in performance due to fouling or corrosion. To date, to deleterious phenomena have been observed.

RESULTS

A LBE test loop has been operational since December 2001. Using procedures, training, and engineering controls, this loop has operated without an accident. Continuous improvements in operation procedures and instrumentation over these years have resulted in a facility of high reliability, providing the groundwork for the use of LBE as a reactor coolant for temperatures up to 550°C.