6.1 Liquid Metal Compatibility — S. J. Pawel (Oak Ridge National Laboratory)

OBJECTIVE

The objective of this task is to identify potential structural materials having sufficient compatibility with flowing Pb-Li eutectic that the maximum metal temperature for operation can be increased to improve overall system efficiency.

SUMMARY

Fabrication of the first thermal convection loop (TCL) using dispersion strengthened FeCrAl (Kanthal APMT) tubing was completed in the previous reporting period. This alloy is known for high strength and creep resistance at elevated temperature and, based on capsule testing, it is anticipated to have excellent resistance to Pb-Li. Recent accomplishments include initial refurbishment of suitable laboratory space in which to operate the TCL, acquisition and chemical analysis of the Pb-17at%Li that will be used as a working fluid, and preparation of the Kanthal APMT test coupons that will be used in the specimen chains that will be inserted into each vertical leg of the TCL.

PROGRESS AND STATUS

Introduction

Currently, the maximum allowable wall temperature for the dual coolant lead-lithium (DCLL) blanket concept is set at 475˚C based primarily on corrosion limitations of the structural containment materials. To increase overall system efficiency, potential structural materials are being sought with a combination of high strength and creep resistance with simultaneous resistance to dissolution in eutectic Pb-Li at temperatures > 500˚C. Preliminary research using static capsule exposures has indicated that dispersion strengthened FeCrAl (Kanthal APMT) may be resistant to dissolution in eutectic Pb-Li at temperatures in the range of 600-800˚C, at least in part due to the stability of an Al-rich oxide film. However, corrosion data in a flowing system must be generated to analyze the potential for issues associated with thermal gradient mass transfer – relatively high dissolution in hotter portions of the flow system with concomitant deposition in the colder portions – which has been known to disrupt heat transfer and even plug flow paths completely in some temperature gradient – material combinations.

Thus, thermal convection flow loops (TCLs) are being incorporated as the follow-on step to capsule testing for evaluation of liquid metal compatibility. The initial laboratory testing associated with this effort will utilize a monometallic TCL fabricated of Kanthal APMT with APMT specimens inserted within each of the hot leg and cold leg of the TCL for use in post-exposure evaluation. Fabrication of the first such TCL utilizing APMT tubing (26.7 mm OD, 3.1 mm wall), which evaluated welding and heat treatment procedures to be used in subsequent TCL construction with this alloy, was successfully completed near the end of FY13. Preparations for loop operation and corrosion testing are now underway.

Results

Figure 1 shows a schematic of the APMT loop, as it will appear in assembled form. The loop is about 1 m tall and 0.5 m wide in the flow path. Heating on one side of the loop (the “hot” leg) will cause the density of the liquid Pb-Li material to decrease relative to the liquid in the

unheated leg; the density difference drives flow (down on cooled side, up on heated side) once a steady temperature gradient is established. [In Figure 1, the liquid metal flow direction would be counterclockwise.] This loop will contain two specimen chains – one in each vertical leg of the loop. Test coupons of APMT have been prepared in the form of miniature tensile specimens, and will be strung together with APMT wire (see Figure 2 for an example from a previous TCL experiment in this laboratory). Most of the APMT test specimens received the same high temperature oxidation treatment afforded the loop itself, but a few of the specimens remain in the as-machined (no oxide) condition to permit ready comparison of compatibility with Pb-Li as a function of temperature around the loop. In addition to APMT coupons, a few small rectangular specimens of commercially pure tungsten have been prepared for incorporation at the bottom of each specimen chain to act as a "sinker" to keep the relatively low-density specimen chains from floating in the Pb-Li test fluid.

Completion of laboratory space preparation and the loop test stand has been delayed somewhat by lack of space availability and limited craft resources to finish electrical wiring and ventilation cabinet construction. At present, it is expected that these activities will be completed in time to permit loop operation to commence in mid-to-late March 2014.

Independent compositional analyses of the Pb-Li alloy that will be used for these experiments (purchased from a commercial supplier in Europe) was completed; results from a range of positions within several units of material (ingots shown in Figure 3) uniformly yielded 83.0 at% Pb and 17.0 at% Li with about 1200 ppm oxygen and 240 ppm carbon and all other elements below the detectability limit (~ 1-5 ppm).

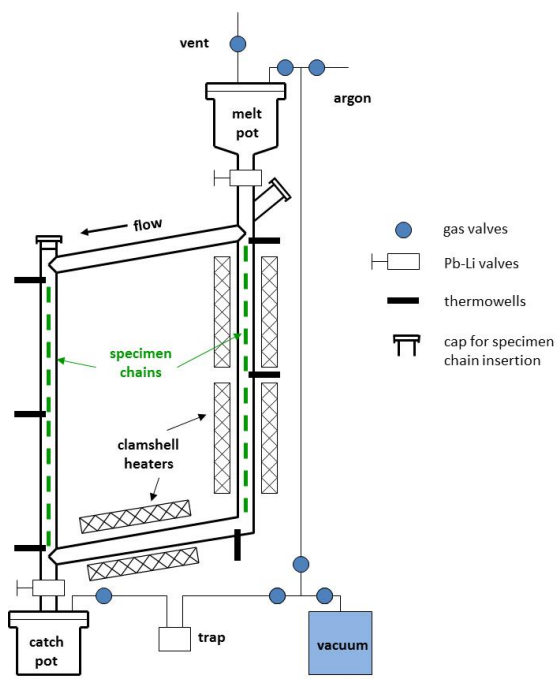

Figure 1. Schematic of the thermal convection loop for Pb-Li experiments. Actual dimensions are approximately 1 m x 0.5 m in the liquid metal flow path around the loop.

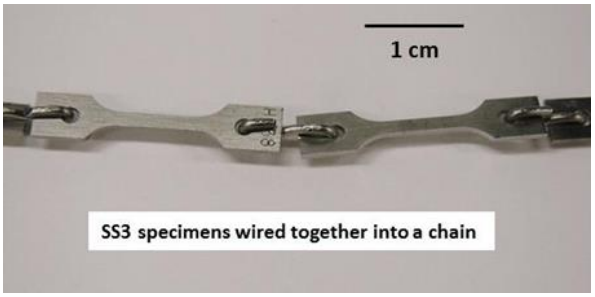

Figure 2. Representative example of miniature tensile specimens ("SS3" design) wired together as part of a specimen chain for a thermal convection loop experiment. The SS3 specimens are about 25 mm long, 5 mm wide, and 1 mm thick.

Figure 3. Ingots of Pb-17at%Li just prior to shipment to USA. Each ingot is approximately 4.5kg of high purity eutectic alloy.