6.1 LIQUID METAL COMPATIBILITY – A THERMAL CONVECTION LOOP FOR Pb-Li COMPATIBILITY TESTING

— S. J. Pawel, A. W. Willoughby, M. S. Stephens, Z. M. Burns, B. A. Pint, and J. D. McNabb (Oak Ridge National Laboratory, USA)

OBJECTIVE

The objective of this task is to develop structural materials having sufficient compatibility with flowing Pb-Li eutectic that the maximum metal temperature for operation can be increased. This will improve overall system efficiency of fusion reactor power conversion systems.

SUMMARY

Fabrication of the first Pb-Li thermal convection loop has been completed. The loop was fabricated using dispersion strengthened FeCrAl (Kanthal APMT) tubing. This alloy is known for high strength and creep resistance at elevated temperature, and based on capsule testing, it is also anticipated to have excellent resistance to Pb-Li.

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 mono-metallic TCL fabricated of Kanthal APMT with APMT specimens for post-exposure evaluation in each of the hot leg and cold leg of the TCL. 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 at the end of the reporting period. Corrosion testing is expected to begin early in FY14.

Results

Figures 1-3 depict key aspects of the fabrication process. The loop was fabricated in two major steps – completion of all saddle welds to join tubing sections, and then completion of all welds to insert the thermowells – with each step followed by post weld heat treatment (PWHT) of the entire loop within a large box furnace at 850˚C (1 h in air, slow cool). Heat tapes were used to maintain pre-heat temperatures (250˚C) at all weld locations prior to PWHT. After each PWHT

event, welds were inspected with a combination of visual examination (borescope for loop internals), radiography, and dye-penetrant. A helium leak check of the final assembly revealed one small pinhole in the weld of a thermowell insert, which was repaired and followed by PWHT. Subsequently, the entire loop was subjected to pre-oxidation treatment (1050˚C in air, 8 h, slow cool) to prepare it for service in Pb-Li. The completed loop passed the final inspection and leak check.

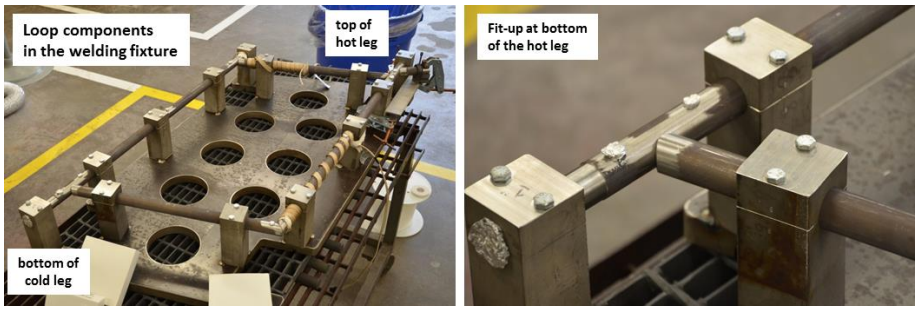

Figure 1. Initial loop fabrication. At left, the sections of loop tubing are shown positioned within the support fixture, with the first of several heat tapes already in place (for maintenance of pre-heat requirements). At right, detail of a saddle weld fit-up prior to welding.

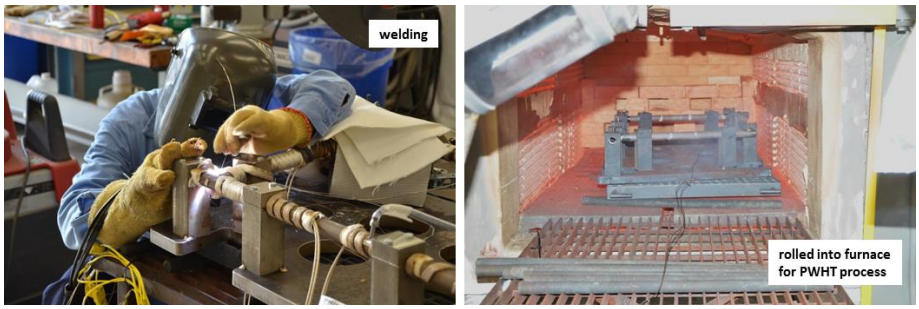

Figure 2. Welding and heat treatment. At left, completion of a saddle weld at the bottom of the loop. At right, the loop is shown within the box furnace for post-weld heat treatment (PWHT).

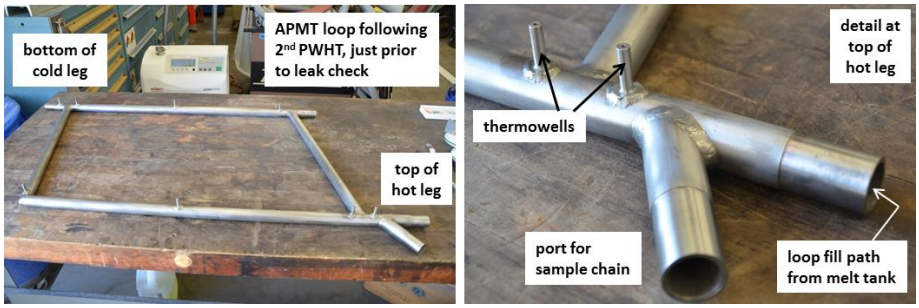

Figure 3. Completed thermal convection loop. At left, the loop is shown with all saddle welds and thermowell inserts in place after completion of PWHT (approximate dimensions are 120 cm tall and 60 cm wide). At right, detail at the top of the hot leg is shown. After final pre-oxidation heat treatment (not shown here), the loop developed a uniform dull straw-brown discoloration.