ASSEMBLY OF THE MFE-RB-17J EXPERIMENT—A. L. Qualls, K. R. Thoms, D. W. Heatherly, and R. G. Sitterson (Oak Ridge National Laboratory)

OBJECTIVE

The objective of this work is to irradiate mostly vanadium alloy specimens in direct contact with lithium at temperatures of 450°C, 600°C and 700°C in a europium-shielded RB position of the High Flux Isotope Reactor (HFIR). Some steel and ceramic specimens are included but are isolated from the primary lithium bath.

SUMMARY

The 17J experiment is currently in the final stages of assembly in preparation for irradiation in a shielded RB position. The basic features of the design and assembly process are described. The specimen holders were loaded with specimens, filled with lithium, and then assembled into the experiment capsule, which will soon be connected to the control instrumentation.

PROGRESS AND SUMMARY

Design Description

In the MFE-RB-17J irradiation experiment three axially stacked specimen holders are contained within a common inner containment housing, which is itself contained in an outer containment housing. Figure 1 shows the arrangement of the inner housing. The two upper holders are made from the molybdenum alloy TZM and the lower holder is made from stainless steel. The holders are designed to irradiate three sets of metallurgical and ceramic test specimens in lithium baths at 700°C, 600°C and 450°C, in order from top to bottom within the experiment.

The holders are axially separated and loosely held together by stainless steel spacers, which are approximately 2-cm in length. Nine thermocouples and four temperature control gas lines, which are 0.020” in diameter, are passed from the top of the experimental region past the holders through axial grooves in the outer surface of the holders. Three thermocouples are assembled into a group at the bottom of each specimen holder and inserted upward into a thermocouple well that extends from the base of the holder into the specimen assembly and lithium bath.

Assembly

The test specimens were grouped by layer into vanadium baskets that fit inside each specimen holder over the holder thermocouple well. The baskets consist of a base, an outer cylindrical foil and a top cap, all of which are perforated to allow lithium to flow unobstructed through the specimens. Each specimen holder was assembled by loading the specimens into the specimen basket one layer at a time according to a pre-planned specimen loading arrangement. A separation disk was inserted after each specimen layer to ensure that specimens do not shift downward during transportation and operation. After the specimens were loaded into the basket the top cap was installed onto the top of the basket outer cylinder and tack welded into place.

The internal volumes of the holders and the total volume of the specimen basket assembly were carefully measured to determine the amount of lithium required to cover the top of the specimens when in the holder. The lithium level is carefully controlled so that the resulting pressure increase due to the change in volume of the lithium during operation will not cause the sealed specimen holders to fail.

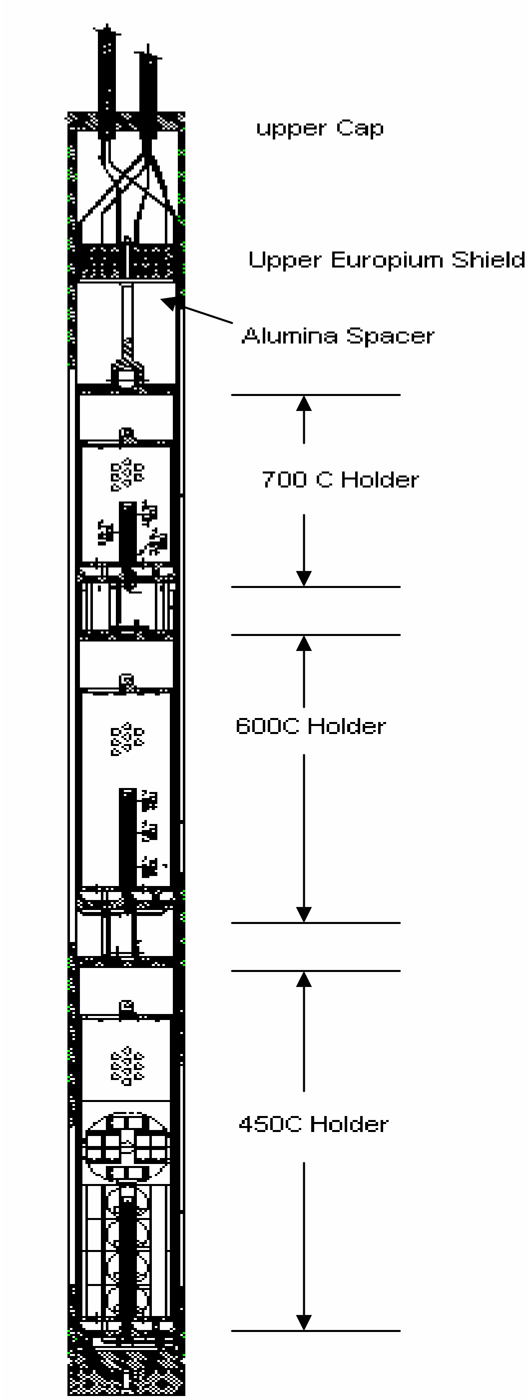

Figure 1. View of the MFE-RB-17J inner housing containment showing three specimen holders stacked axially and shielded by an upper europium shield. The inner housing is sealed with a welded top cap and the instrument leads are passed through penetrations which are sealed with specially designed braze configurations.

Once the amount of lithium required for each holder was determined, the holders, specimen baskets and the lithium were loaded into an argon-filled glove box which contained a specially fabricated, electrically heated furnace. Each holder was loaded into the furnace and the required amount of solid lithium was dropped into the holder. The holder and lithium were heated by controlling the electrical current flowing through a pair of heaters in the furnace until the lithium temperature was approximately 300°C, the point at which the lithium will wet the specimen surfaces as they are slowly lowered into the holder.

The furnace is equipped with a fixture for carefully lowering the specimen basket assembly into the molten lithium because it is important to prevent the lithium from being forced upward along the inner surface of the holder and contaminating the holder sealing cap welding surfaces. After the specimen baskets were successfully loaded into the holders, they were transferred to and welded in a separate atmospherically controlled welding glovebox. The holders were evacuated and backfilled with helium at one atmosphere of pressure prior to the installation and welding of the sealing caps.

The three completed specimen holders were assembled into a loosely connected stack and the experimental capsule was assembled around it. Instrumentation leads were routed from the top of the experimental assembly, through penetrations in the outer and inner housing caps to their termination points below the three specimen holders. The inner housing was inserted over the specimen holders and instrument leads from the bottom of the assembly and the inner housing upper cap was welded in place. The instrument leads were brazed into the upper cap penetrations using a specially designed brazing configuration that ensures braze material completely encases the leads in the penetration over a length of approximately 1 cm. The outer capsule housing was assembled over the inner capsule assembly and the second set of penetrations were sealed creating a third containment around the lithium in the experiment.

Operation

The assembled capsule will be operated in a europium-shielded RB position. The capsule and liner will generate approximately 65 kilowatts of heat due to nuclear interactions during normal steady state operation. The heat is removed from the capsule outer containment by reactor primary coolant water flowing over its outer surface at a rate of approximately 20 GPM.

The temperatures of the three holders are controlled independently by adjusting the thermal conductivity of the mixtures of inert gases flowing between the holders and the inner housing, which effectively controls the temperature difference from the holder to the inner housing. Gas supply lines can feed helium, neon or argon or a mixture of either helium and neon or helium and argon to the plenums below the three holders. Gas from lower holders become part of the mixture for upper holders, so while the temperature of the zones can be independently controlled, they are dynamically coupled. The complexity of the temperature control system makes it difficult to automatically control the holder temperatures, therefore the temperature control for the experiment will be performed manually by an operator.

A helium gas supply line, referred to as a Purge line, is routed to the lower holder lower plenum at the base of the inner housing. Helium flows through this line during the experiment passing upward past the specimen holders and out an effluent line open at the top of the inner containment. The purge line remains open at all times and the flow is increased in response to detected off-normal operating conditions while all other gas flows are stopped, guaranteeing that holder temperatures decrease.

Gas flow transmitter and control valves (FTCVs) in the Materials Irradiation Facility No. 5 (MIF5) Instrument Cabinet regulate the gas flow rate from pressurized sources through the gas supply lines. The use of neon and argon can be selected independently for the three holders at the instrument cabinet. If helium is to be mixed with the neon or argon, then this mixing occurs at the instrument cabinet.

The maximum amount of flow that can be achieved through a gas line is dependent upon the FTCV design limit (200 SCCM) unless the flow resistance through the gas supply line is too large to permit full FTCV flow for the available pressure differential. Flow testing suggests that flow restriction is not a significantly limiting factor for the lines used in the experiment.

Separate lines supply helium to the region between the inner and outer housing and instrument air to the experimental region above the outer housing upper bulkhead.

Temperature Control

Operating temperatures of the holders are determined by the amount of heat generation within capsule components (which is position and material dependent), the size of the gas gaps between the holders and housings, and the thermal conductivity of the gases in those gaps. The dimensions that determine the size of the gas gap between the specimen holder and the inner housing were based on conservative estimates of the heat generation rates within capsule components. It is planned to operate the experiment with neon and helium mixtures, however if neon cannot produce the desired temperature then argon will be substituted.

The lower specimen holder has the lowest target temperature (450°C). Because the experiment is doubly contained in stainless steel containment housings, experience suggests that it may be difficult to achieve this target temperature. The difficulty in achieving low temperatures is compounded by the fact that molybdenum specimen holders expand less than the stainless steel inner housing as temperatures are increased. This causes the temperature control gas gap for molybdenum holders to actually increase in size as the experiment begins operation. Also, molybdenum suffers from irradiation induced embrittlement when irradiated at 450°C. Because of these considerations the 450°C specimen holder is made of stainless steel with a cold (room temperature) radial gas gap of approximately .002”, which is as small as it can be and still ensure successful assembly.

Heat generation within capsule components throughout the HFIR cycle evolves through a repeatable pattern. The amount of heat produced in those components near the reactor mid-plane (600°C holder) will remain reasonably constant over the course of a cycle, while the amount of heat generated in those capsule components near the end of the experimental region (450°C and 700°C holders) will increase throughout the cycle. In order to maintain a constant temperature within the holders at the ends of the experimental region the gas mixture must gradually become more conductive, that is richer in helium. The thermal conductivity of the gas mixture in the centrally located temperature zones must remain more consistent throughout the cycle. Because the three holders are coupled, periodic gas mixture adjustments will be required in each zone. These adjustments will occur approximately once a day initially but will increase in frequency during the final two or three days of the 22 day cycle.

MFE-RB-17J Specimen Loading List

<u>17J 700°C Level #1 (Begin approximately 12 cm above reactor mid-plane)</u>

DFMB
UN12, UB05, UB12, UB13, UN05, UN13

Vanadium Envelopes
7-1, 7-2, 7-3

Tensile bundles
UY25-UY13, UT25-UT14, UV29-UV10, GK35-BLANK, US10-US29, GN15-GK28, UF09-UG11, UP08-UP33, FKB4-BLANK, FA27-FA26, FKH1-FKH0, FG12-BLANK, T006-TA99, TN90-BLANK, T397-TA90, AV46-BLANK, UR23-UR09, UB48-UE08, TY96-BLANK, TV92-BLANK, FB27-FB14

<u>17J 700°C Level #2 (Begin approximately 14 cm above reactor mid-plane)</u>

Tensile bundles
UM08-UH11, T190-T199, UC06-BLANK, FHF3-FHF2, FF14-FD12, TB99-TB90, TR90-BLANK, TT97-TT90, TX97-TX90, FA42-BLANK,

TEM Tubes
26, 31, 19, 28, 13, 10, 27, 18, 8, 9

Vanadium envelopes
7-4, 7-5, 7-6

Ceramic specimen holders – 3A, 3B

70.1260g total mass of loaded basket

17J 600°C Level #1 (Begin approximately 1 cm below reactor mid-plane)

Tensile Bundles
UC-O4-BLANK, US09-US24, UM07-UN04, UB42-UP04, UV05-UV24, FA36-BLANK, TR86-BLANK, UY06-UY20, UT20-UT09, FB22-FB10, TY80-BLANK, UP19-UP28, FHA5-FHG6, TV86-BLANK, T003-BLANK, TX88-TX89, TT80-BLANK, GK14-BLANK, FB06-BLANK, FKD9-FHG7, TA88-TA80, GK24-BLANK, TB80-TB89, FF09-BLANK, T180-BLANK, UF04-UF07

17J 600°C Level #2 (Begin approximately 2 cm above reactor mid-plane)

Tensile Bundles
T381-BLANK, AV45-BLANK, FK65-BLANK, UR16-UR07

TEM Tubes
7, 12, 23, 30, 6, 17, 24, 5, 25, 16

DFMB
UB11, UN11, UN04, UN10, UB10, UB04

PCBB
UG12, UG10, UF15, UB16, UG14, N17/U-7/UN1, N16/U-6/UN, B12/U-2/UB1, B17/U-7UB1, N15/U-5/UNI, N14/U-4/UNI, B15/U-5/UB1, B14/U-4/UB1

CPS
CA22, CJ98, CJ91, CA26, CJ94, CA23, CA14, CJ90, CA24, CA20, CA27, CJ95, CA15, CA18, CA17

Ceramic Holder 2A, 2B

17J 600°C Level #3 (Begin approximately 4 cm above reactor mid-plane)

PCBB
N13/U-3/UN1, UF16, UF12, UF11, UG11, UG13, UF14, UB13, UF13, N12/U-2/UN1

17J 600°C LEVEL #4 (Begin approximately 5 cm above reactor mid-plane)

Vanadium envelopes
6-1, 6-2, 6-4, 6-5, 6-3, 6-6

Pressurized Tubes
UB00, UB15, UB08, UB12, UB03, UB06, UN19, UN08, UN13, UN12, UN02, UN05, UN17, UB19

101.3325 g Total mass of loaded basket

17J 450°C Level #1 (Begin approximately 17 cm below reactor mid-plane)

DCT
UN18, UN8, UN09, UN14, UN16, UN02, UN05, UN19 (First row of bottom of level #1)
UB01, UB-11, UB16, UB02, UB04, UB10 (Second row of bottom of level #1)

JCVN
RB09, TA25, FB01, RAO7, FA11, FA10, FA07, FA04, FA03, FA09, RB04, FA15, RB01, RB10, RA02, TA06, TN09, TN13, TA04, RB08, TN23, TN01, TN04, TA24, FA13, FB07, TN02

17J 450°C Second Level #2 (Begin approximately 15 cm below reactor mid-plane)

DCT
UB07, UB19 (lower level of level#2),

Ceramic specimen holder 1-B

Tensile Bundles
GN04, GK08 & GK04, FHD0, FA01, FA50 & FA31, TA72 & TA70, FKK2

JCVN
TN05, TN21, TA02, TN08, RA06, TA03, RA08, RB03, TN24, RA10, FB04, RB02, RB07, TN00, FB09, RA05, TA07, TA23, FA06, TN22, TN20, FB10, FB03, TN12, RB05, TN03, TN14, TN07, RA04, FA01, FA05, FB08, TA05, TA01, FA12, RB06, FB05, TN11, TA21, TA08, TA22, FA14, RA01, TN06, RA03, TN10, FB06, FB02, FA02

CPS
CA07, CJ85, CJ80

17J 450°C Level #2A (Begin approximately 13 cm below reactor mid-plane)

TEM Tubes
20, 29, 22, 14, 21, 15, 2, 3, 11, 4, 1

Tensile Bundles
UR00-UR15, UE03-UP15, UB30-UB41, UF00-UGO3, UN09, UW00-UW05, UP27-UP02, UT00-UT19, UD00-UD12, UV04-UV18, UY03-UY00, US00-US19, UC12-UG00, UH00-UM00,FB04 – FB05, TY74, FG01-FHA4, TN79-TN71, FKAO, TB74, TX74-TX77, TW02-TW05

Ceramic specimen holder 1-A

<u>17J 450°C Level #3 (Begin approximately 10 cm below reactor mid-plane)</u>

PCBB
UW07, UF07, UG06, NO1 – UNO, B11/U-11/UB, NO0/U-0/UN0, UG09, BO5/U-5/UB0, N07/U-UN0, UW05, UG04, UG07, UG00, NO4/U-4/UN0, NO2/U-2/UNO, UG01, N10/U-U/N10, BO9/U-9/UB0, BO8/U-B/UB0, NO9/U-9/UN0, BO4/U-4/UB0, NO3/U-3/UN0, UW03, UF02, UG08, UF00, UW01, BO1/U-1/UBO, BO6/U-6/UB0, BO2/U-2/UB0, BO3/U-3/UB0, B10/U-0/UB1, B00/U-0/UB0, B07/U-7/UB0, N08/U-8/UN0, N05/U-5/UN0, N11/U-11/UN, NO6/U-6/UN0, UW00, UW02, UW06, UW04, UG05, UG02, UF01, UF06, UF05, UF08, UF03, UF09, UG03, UF04

Tensile Bundles
FD01, T170, TV78-TV73, TT77, TR71-TR74, AV10, T370-T372

<u>17J 450°C Level #4 (Begin approximately 8 cm below reactor mid-plane)</u>

Pressurized Tubes
UN00, UN20*, UN09, UN16*, UN06, UN07*, UN14, UB02, UB07, UB16, UB22, UB11, UB09, UB05

*center specimens

186.7g total mass of 450°C loaded holder