IRRADIATION START OF MFE-RB-17J EXPERIMENT—D. K. Felde, A. L. Qualls, K. R. Thoms, D. W. Heatherly, R. G. Sitterson, and R. L. Wallace (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 was installed in a europium-shielded RB* position of HFIR and irradiation began with cycle 400 on April 27, 2004. The capsule temperatures were maintained near the target values with the exception of the lower capsule. An apparent temperature-dependent blockage of the purge gas line limited operation of the lower capsule to ~ 425°C.

PROGRESS AND STATUS

Background

The MFE-RB-17J irradiation experiment was described in an earlier report [1]. Three axially stacked specimen holders are contained within a common inner containment housing, which is itself contained in an outer containment housing tube. 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 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 each of 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.

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.

Operation

HFIR operating cycle 400 was initiated on April 27, 2004. A plot showing temperatures for the three zones along with reactor power is shown in Fig. 1. A detail of the early part of the cycle is shown in Fig. 2. The initial operation included two reactor startups for operator training purposes along with an approximate 3 hour hold at 10% power associated with neutron scattering experiments. A detailed breakdown of the power history for cycle 400 is provided in Table 1.

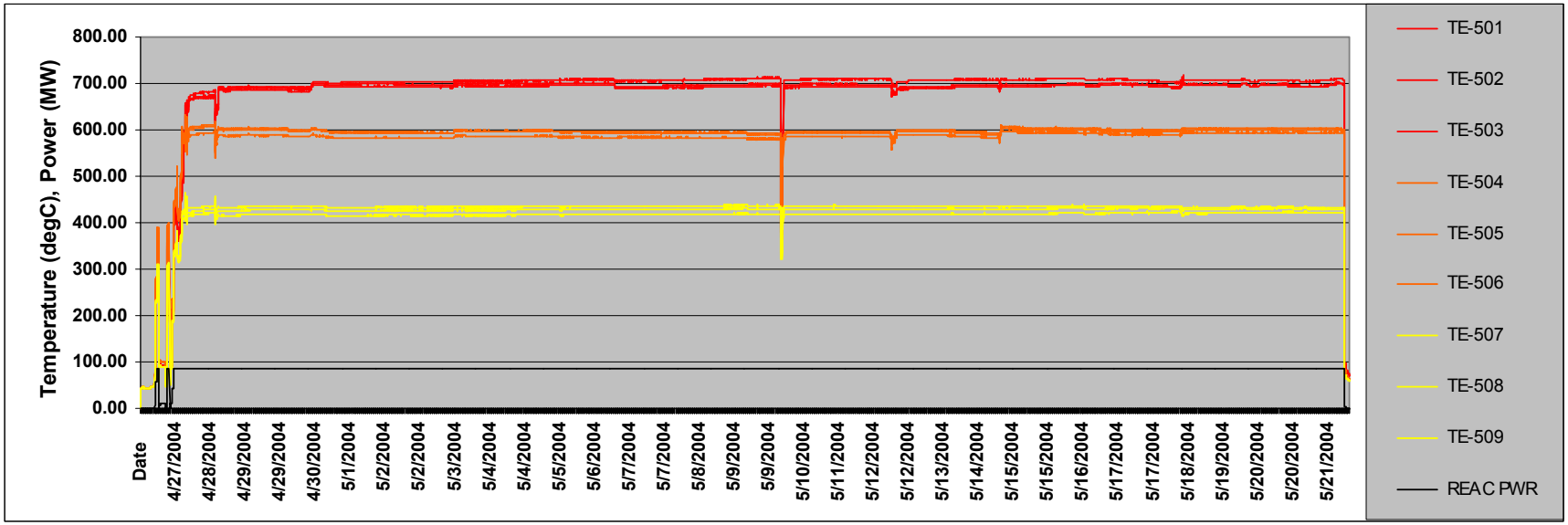

Fig. 1. 17J temperature and power history for HFIR operating cycle 400.

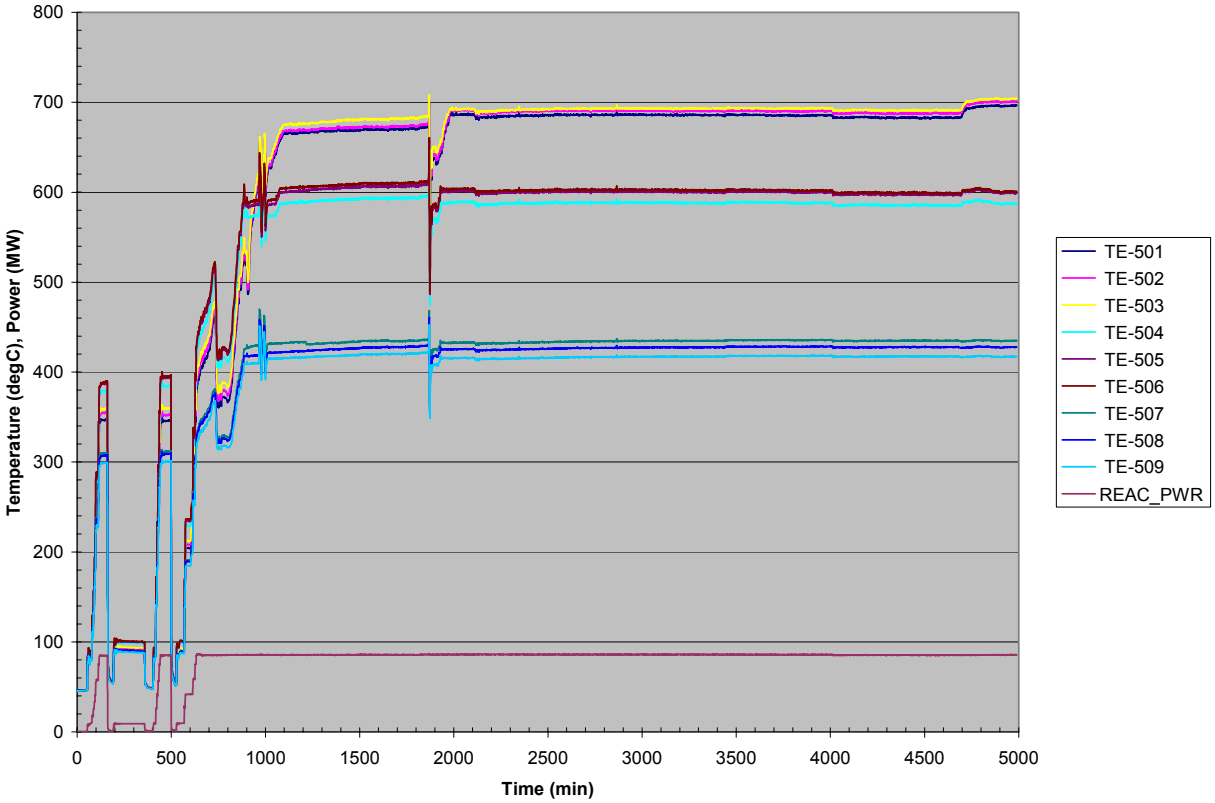

Fig. 2. 17J experiment – startup portion of HFIR operating cycle 400.

The lower thermal conductivity of the helium/argon mix was required in order to reach the desired target temperatures in all three of the capsule regions, with an approximate 70%, 50% and 80% argon concentration in the lower, middle, and upper zones, respectively, at the beginning of the cycle. It was observed during startup that as temperature was increased in the lower zone above ~ 430°C the pressure difference required to flow the helium purge gas to the system increased significantly, eventually causing a decrease in the amount of helium flow when the regulated supply pressure was reached. This reduction in helium led to increasing temperatures in all of the capsules. This occurred in two separate instances as gas flow rate adjustments were made to increase temperatures, one while adjusting flow rate in the helium purge line and the other when increasing argon flow to the same region. These temperature excursions can be seen at ~ 700 and 1800 minutes in Fig. 2. Both occurred within a couple of degrees of the same lower capsule average temperature of 430 °C (whereas the middle and upper capsules were at different temperatures for the two cases). This appears to indicate that the purge line has a pinch point that is temperature dependent.

As the control system is currently set up, a Hi Alarm is notification only, with no automatic actions. A Hi-Hi Alarm condition will shut off the argon/neon flow to the control gas lines. An Emergency Cooling temperature set point is reached above the Hi-Hi Alarm condition and shuts off all gas flow to the control gas lines, leaving only helium flow via the purge line. During the first case above, argon flow was manually reduced to cool the system down. During the second case mentioned above, the temperatures reached the Hi-Hi set point and the consequent shut off of argon resulted in the relatively rapid cool down of the capsules.

Table 1. Power history for HFIR operating cycle 400

CYCLE # (days)	Begin time (m/d/y hh:mm)	End time (m/d/y hh:mm)	Elapsed time (hours)	Reactor power (MW)	Integrated power (MWD)	COMMENTS
SOC 400	4/27/04 0232	4/27/04 0255	0.4	0.0	0	
	4/27/04 0255	4/27/04 0319	0.4	8.5	0	
	4/27/04 0319	4/27/04 0326	0.1	17.0	0	
	4/27/04 0326	4/27/04 0332	0.1	25.5	0	
	4/27/04 0332	4/27/04 0336	0.1	34.0	0	
	4/27/04 0336	4/27/04 0339	0.0	42.5	1	
	4/27/04 0339	4/27/04 0353	0.2	59.5	1	
	4/27/04 0353	4/27/04 0357	0.1	76.5	1	
	4/27/04 0357	**4/27/04 0442**	**0.8**	**85.0**	**4**	Dose meas. On HB-4 at Low power
	4/27/04 0442	4/27/04 0515	0.6	0.0	4	
	4/27/04 0515	4/27/04 0800	2.8	8.5	5	
	4/27/04 0800	4/27/04 0830	0.5	0.0	5	
	4/27/04 0830	4/27/04 0845	0.3	0.0	5	
	4/27/04 0845	4/27/04 0858	0.2	8.5	5	Training
	4/27/04 0858	4/27/04 0910	0.2	25.5	5	
	4/27/04 0910	4/27/04 0916	0.1	42.5	5	
	4/27/04 0916	4/27/04 0922	0.1	59.5	6	
	4/27/04 0922	4/27/04 0926	0.1	76.5	6	
	4/27/04 0926	**4/27/04 1020**	**0.9**	**85.0**	**9**	
	4/27/04 1020	4/27/04 1056	0.6	0.0	9	
	4/27/04 1056	4/27/04 1129	0.6	8.5	9	Training
	4/27/04 1129	4/27/04 1132	0.0	25.5	9	
	4/27/04 1132	4/27/04 1214	0.7	42.5	11	
	4/27/04 1214	4/27/04 1226	0.2	59.5	11	
	4/27/04 1226	4/27/04 1231	0.1	76.5	11	4/27/2004 22:35
	4/27/04 1231	**5/21/04 1735**	**581.1**	**85.0**	**2069**	23.79166667
EOC 400	5/21/04 1735	6/16/04 1200	618.4			

One other temperature transient can be seen on the plot in Fig. 1. A Watchdog Timer alarm that monitors communication within the control system was received and resulted in initiation of the Emergency Cooling mode. The alarm was apparently caused by some power switching work being done for the ORNL site. With helium only, the zone temperatures dropped to the 300-400 C range. The system was reset and temperatures were back up to near operating level within ~1 hour of the transient.

The lower capsule operating temperature was lowered to ~425 °C in order to avoid the transient conditions caused by the blocked flow. The apparent temperature-dependent blockage of the control gas line is not repairable, and a decision was made to operate at this lower temperature for the remainder of the follow-on cycles as well.

After the completion of cycle 400, the purge line and control gas line supplying the lower zone were switched at the control cabinet. This will result in blockage of argon to the zone as temperature increases, rather than helium.

References

[1] A. L. Qualls et al., Fusion Materials Semiannual Progress Report for Period Ending December 31, 2003, DOE/ER-0313/35, U.S. Department of Energy, 242-249.