IRRADIATION PROGRESS OF MFE-RB-17J EXPERIMENT—D. K. Felde 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 has been irradiated for 3 of 10 planned cycles in the HFIR. The upper capsule has been operating 20 to 50°C below the target temperature of 700°C for the last two cycles. The cause has not been determined. The middle capsule has operated at its target temperature of 600°C. A partial blockage of the purge gas line observed in the first cycle of irradiation led to a reduction in the target temperature for the lower capsule to ~425°C (from an original target of 450°C). Further degradation of this blockage has caused some operational difficulties resulting in this capsule running at slightly lower temperatures, ~418°C average, for part of cycle 402.

PROGRESS AND STATUS

Background

The MFE-RB-17J irradiation experiment was described in an earlier report [1] and the initial operating cycle is described in the previous progress report [2]. 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 mixture of inert gases flowing between the holders and the inner housing, which effectively controls the thermal conductivity and consequently the temperature difference across the gas gap between the holder and 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 passing upward past the specimen holders and out an effluent line opening at the top of the inner containment. The purge line remains open at all times and the flow is automatically increased in response to detected off-normal operating conditions while all other gas flows are stopped, ensuring that holder temperatures decrease.

As described in the previous report [2], an apparent temperature dependent plugging of the helium purge line that discharges below the lower (450°C) subcapsule was observed. After completion of operating cycle 400, the purge line and control gas line supplying the lower zone were switched at the control cabinet. Further plugging of the tube in this configuration would result in lower temperatures as argon flow would be restricted rather than helium.

Operation

HFIR operating cycles 401 and 402 were conducted during the reporting period. Cycle 401 was initiated on July 16, 2004 with shutdown on August 9, 2004. A plot showing temperatures for the three zones along with reactor power is shown in Fig. 1. A more detailed look at the startup portion of the cycle is shown in Fig. 2. Of particular note is the lower temperature for the 700°C zone. It was not possible to reach the 700°C average that was obtained during cycle 400, even with higher argon gas percentages in the mixture. Average temperatures closer to 670–680°C were reached during the early portion of the cycle. Somewhat higher temperatures were reached as the cycle progressed due to normal power shifting in the reactor. The temperature transients observed during the early startup portion are believed to be caused by argon gas flow instabilities at the high argon flow rates in the upper capsule region. Argon flow rate was raised well above 100 sccm in an attempt to increase the temperature in the upper zone and it is believed that these flows were high enough to push argon into the middle zone, resulting in a rapid temperature increases in that zone. It was necessary to cut argon flow and increase helium flow rates in order to regain temperature control of the middle capsule.

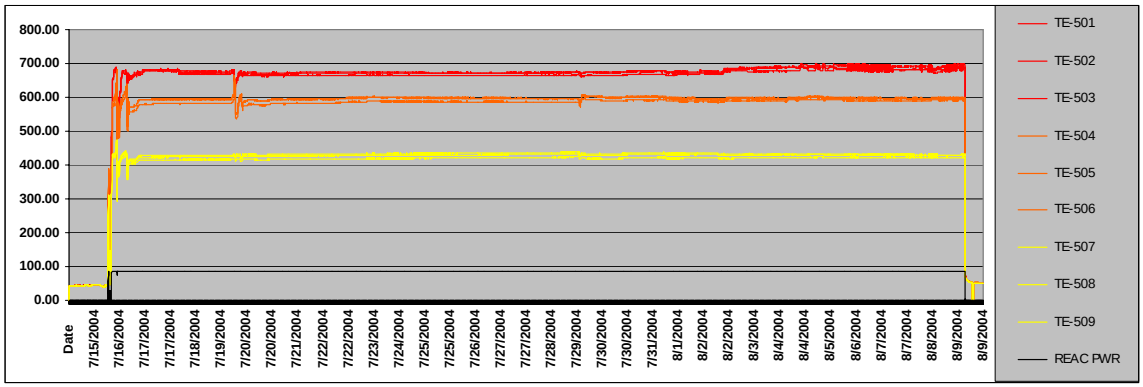

Fig. 1. 17J temperature and power history for HFIR cycle 401.

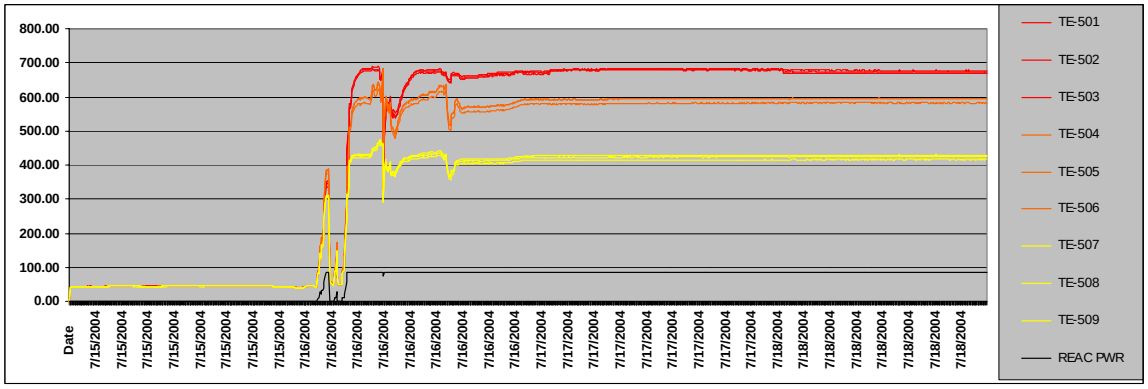

Fig. 2. 17J – Startup portion of HFIR operating cycle 401.

Cycle 402 was initiated on September 28, 2004. The cycle was shutdown after 10 days for administrative reasons and was restarted on November 10, 2004. The cycle was completed on November 23, 2004. The temperature and power history are shown in Fig. 3 where the two portions of the interrupted cycle are referred to as cycle 402A and 402B. The startup portion of cycle 402A is shown in Fig. 4 and the startup of cycle 402B is shown in Fig. 5.

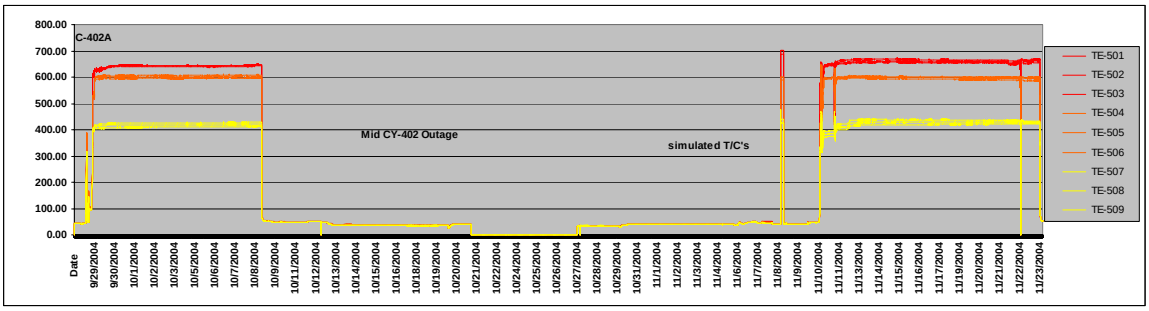

Fig. 3. 17J temperature history for HFIR cycle 402.

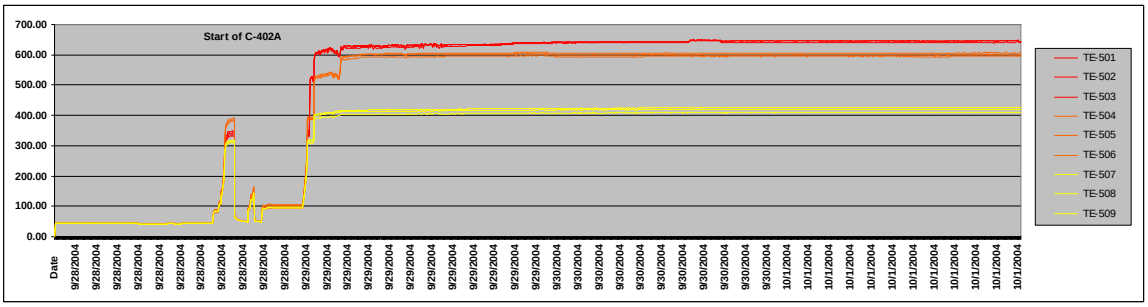

Fig. 4. 17J startup portion temperature history for HFIR cycle 402A.

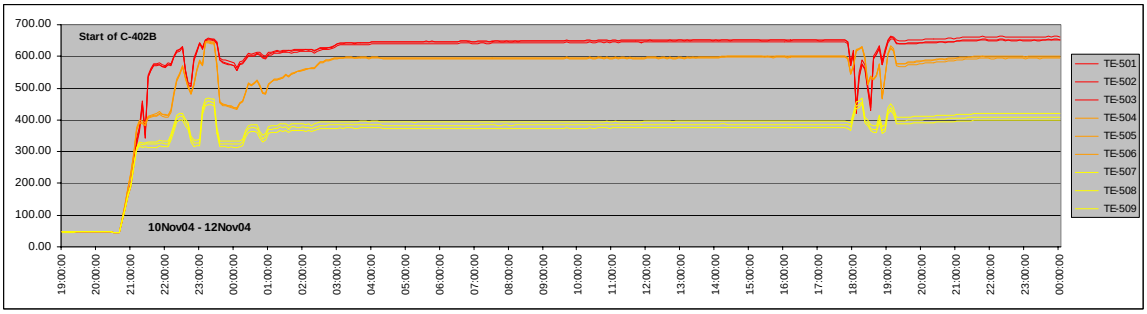

Fig. 5. 17J startup portion temperature history for HFIR cycle 402B.

Of particular note is the further decrease in the temperature achievable for the 700°C zone, where the maximum average temperature reached at the beginning of cycle 402A is ~650°C. The cause for the downward trend in temperature has not been determined. The partially restricted line carrying argon to the lower 450°C zone also showed some degradation in flow capacity from the previous cycle. For cycle 401, approximately 15 sccm of argon was used to maintain the average temperature at 428°C. At the start of cycle 402A, argon flow was restricted to <10 sccm. This limited the temperature in the lower capsule to an average of ~418°C at the start of the cycle.

During the outage between cycle 402A and 402B, the purge line and gas control line were switched back to the original configuration, with the helium purge gas flowing through the restricted line. Further degradation of the line, however, caused operational problems early in the startup portion of cycle 402B, as indicated by the temperature transients shown on Fig. 5 and so the lines were switched back. The solenoid valve on the control gas line was also bypassed to give more flexibility in operation. It was possible to maintain an average temperature of ~425°C in the lower zone during cycle 402B.

The 17J experiment has been irradiated for 3 full cycles in the HFIR. The estimated peak displacements per atom in vanadium for the RB* position is 0.74/cycle. The power history timeline for cycles 401 and 402 is shown in Tables 1 and 2, respectively. This provides information on low power portions of the cycle where specimens are not at temperature (e.g., startup, operator training, etc.).

References

[1] A. L. Qualls et al., Assembly of the MFE-RB-17J Experiment, Fusion Materials Semiannual Progress Report for Period Ending December 31, 2003, DOE/ER-0313/35, U.S. Department of Energy, pp. 242–249.
[2] D. K. Felde et al., Irradiation Start of MFE-RB-17J Experiment, Fusion Materials Semiannual Progress Report for Period Ending June 30, 2004 (to be published).

Table 1. Power history for HFIR Operating Cycle 401

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 401	7/15/04 2134	7/15/04 2137	0.0	0.0	0		
	7/15/04 2137	7/15/04 2152	0.3	0.0	0		
	7/15/04 2152	7/15/04 2209	0.3	8.5	0		
	7/15/04 2209	7/15/04 2220	0.2	25.5	0		
	7/15/04 2220	7/15/04 2228	0.1	34.0	0		
	7/15/04 2228	7/15/04 2232	0.1	42.5	1		
	7/15/04 2232	7/15/04 2239	0.1	59.5	1		
	7/15/04 2239	7/15/04 2241	0.0	76.5	1		
	7/15/04 2241	**7/15/04 2307**	**0.4**	**85.0**	**3**	Training SU	
	7/15/04 2307	7/15/04 2328	0.4	0.0	3		
	7/15/04 2328	7/15/04 2338	0.2	0.0	3		
	7/15/04 2338	7/15/04 2354	0.3	8.5	3		
	7/15/04 2354	7/16/04 0000	0.1	25.5	3	Training SU	
	7/16/04 0000	7/16/04 0017	0.3	0.0	3		
	7/16/04 0017	7/16/04 0026	0.1	0.0	3		
	7/16/04 0026	7/16/04 0042	0.3	8.5	3		
	7/16/04 0042	7/16/04 0046	0.1	25.5	3		
	7/16/04 0046	7/16/04 0049	0.0	34.0	3		
	7/16/04 0049	7/16/04 0051	0.0	42.5	3		
	7/16/04 0051	7/16/04 0056	0.1	59.5	3		
	7/16/04 0056	7/16/04 0059	0.0	76.5	3		
	7/16/04 0059	7/16/04 0447	3.8	85.0	17		
	7/16/04 0447	7/16/04 0453	0.1	76.5	17	Setback per MFE request	
	7/16/04 0453	**8/9/04 1000**	**581.1**	**85.0**	**2075**		24.41520833
EOC 401	8/9/04 1000	9/28/04 1140	1201.7	0.0	0	Extended outage due to PISA concerns	

Table 2. Power history for HFIR Operating Cycle 402

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 402	9/28/04 1140	9/28/04 1214	0.6	9.9	0	
	9/28/04 1214	9/28/04 1228	0.2	17.8	0	
	9/28/04 1228	9/28/04 1235	0.1	24.8	1	
	9/28/04 1235	9/28/04 1240	0.1	33.4	1	
	9/28/04 1240	9/28/04 1245	0.1	40.5	1	
	9/28/04 1245	9/28/04 1248	0.0	59.3	1	
	9/28/04 1248	9/28/04 1251	0.0	74.3	1	
	9/28/04 1251	**9/28/04 1516**	**2.4**	**85.0**	**10**	
	9/28/04 1516	9/28/04 1529	0.2	9.1	10	
	9/28/04 1529	9/28/04 1535	0.1	17.3	10	
	9/28/04 1535	9/28/04 1638	1.1	23.6	11	
	9/28/04 1638	9/28/04 2038	4.0	9.9	12	
	9/28/04 2038	9/28/04 2043	0.1	17.8	13	
	9/28/04 2043	9/28/04 2048	0.1	25.3	13	
	9/28/04 2048	9/28/04 2053	0.1	33.5	13	
	9/28/04 2053	9/28/04 2058	0.1	42.4	13	
	9/28/04 2058	9/28/04 2102	0.1	59.2	13	
	9/28/04 2102	9/28/04 2105	0.0	74.4	13	
	9/28/04 2105	**10/8/04 2010**	**239.1**	**85.0**	**860**	242.8077647
EOC 402A	10/8/04 2010	11/10/04 1541	787.5	0.0	860	
SOC 402B	11/10/04 1541	11/10/04 1549	0.1	8.5	860	
	11/10/04 1549	11/10/04 1552	0.0	17.0	860	
	11/10/04 1552	11/10/04 1554	0.0	25.5	860	
	11/10/04 1554	11/10/04 1558	0.1	34.0	860	
	11/10/04 1558	11/10/04 1602	0.1	42.5	860	
	11/10/04 1602	11/10/04 1607	0.1	59.5	860	
	11/10/04 1607	11/10/04 1609	0.0	76.5	861	
	11/10/04 1609	**11/23/04 1527**	**311.3**	**85.0**	**1963**	554.2894314
EOC 402B	11/23/04 1527					311.4816667