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 5 of the 10 planned cycles in the HFIR for a total of 9930 MWD. Cycles 403A, 404, and 403B were conducted during this reporting period. The upper capsule that had been operating below the target temperature of 700°C for the previous 2 cycles degraded further in Cycle 403A, falling more than 200°C below the target temperature. A possible cause is lithium leaking from the capsule and forming a thermal conduction path to the housing wall. The middle capsule has operated near its target temperature of 600°C, although a cooling trend has also been experienced for this capsule. This trend required increasing percentages of argon gas to maintain temperature. By the end of cycle 403B (performed after cycle 404), more than 95% argon was required to maintain temperature in the middle holder. The reason for the cooling trend is unknown at this time. Speculation includes possible swelling of the molybdenum capsule walls leading to a reduced gas gap or possible effects from lithium leaking from the upper capsule. The uncertainty in the cause of the cooling trend and the risk of not being able to maintain desired temperature for a marginal increase in dose based on the projected HFIR operating schedule led to a decision to discontinue irradiation of the experiment.

PROGRESS AND STATUS

Background

The MFE-RB-17J irradiation experiment was described in an earlier report [1] and the first three operating cycles are described in previous progress reports [2, 3]. 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.

Operation

HFIR operating cycles 403A, 404, and 403B were conducted during the reporting period. Cycle 403A was initiated on January 26, 2005, with premature shutdown on February 4, 2005, for administrative reasons related to a review of seismic analysis of the reactor supports. A plot showing temperatures for the three zones along with reactor power is shown in Fig. 1. Of note is the rapid decrease in the upper holder temperature occurring a few hours after startup, followed by a continued trend downward. The upper holder with a target temperature of 700°C had exhibited problems in earlier cycles with maximum achievable temperatures below target by ~ 50°C for the previous cycle [3]. A temperature of only 600°C was reached at the start of this cycle before the precipitous decrease was observed. Although it will not be known until the experiment is disassembled, it is possible that a lithium leak created a thermal conduction path to the inner housing wall. Efforts to control the temperature for this holder were discontinued after this event. Temperatures were maintained for the two other holder positions at the nominal target temperatures of 600°C and 425°C.

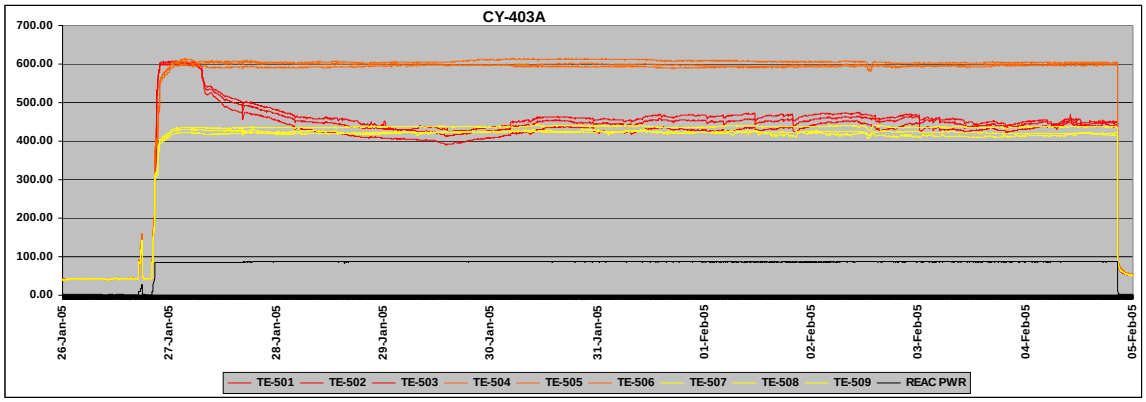

Fig.1. 17J temperature and power history for HFIR cycle 403A.

Cycle 404, with new fuel elements, was started on April 6, 2005. The fresh core was installed to accommodate installation work for a new hydraulic rabbit tube system. The startup portion of cycle 404 is shown in Fig. 2 and the full cycle is shown in Fig. 3. Temperatures were maintained at nominal target values of 600°C and 425°C for the middle and lower holders. No attempt was made to control the upper holder temperature per the above discussion. Although not shown in the temperature plots, a noticeable trend upward in the percentage of argon gas required to maintain temperature for the middle capsule was observed (as compared to a similar point in previous operating cycles since the power profile changes over the cycle).

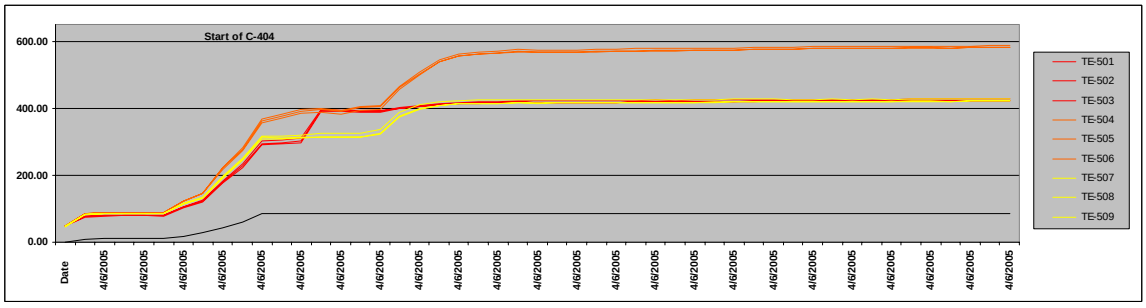

Fig. 2. 17J startup portion of HFIR operating cycle 404.

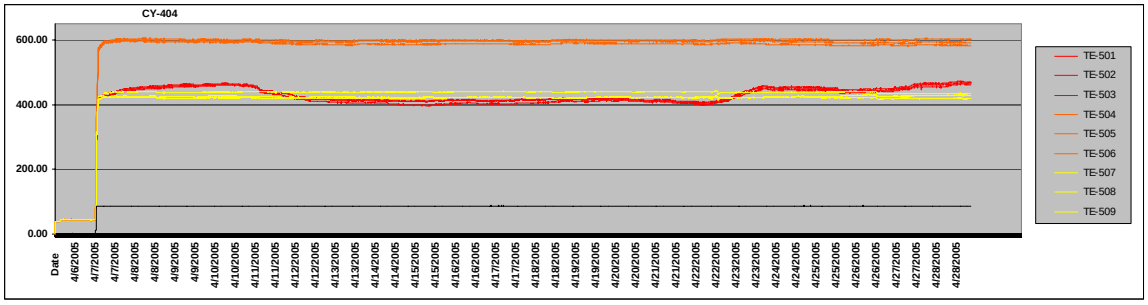

Fig. 3. 17J temperature history for HFIR cycle 404.

The cycle 403 fuel was re-installed and cycle 403B was initiated on May 5, 2005. The cycle was completed on May 18, 2005. The temperature and reactor power history for this portion of the cycle is shown in Fig. 4. The middle capsule operated near its target temperature of 600°C, although, as noted for cycle 404, a trend requiring increasing argon gas percentage continued. By the end of cycle 403B (performed after cycle 404), more than 95% argon was required to maintain temperature in the middle holder. Additionally, the target temperature of the lower capsule was increased from ~ 425°C to ~ 450°C (~ May 10 on the trend plot in Fig. 4) allowing higher argon concentration at the middle 600°C holder. Fig. 4 shows two other anomalies: one of three thermocouples in the middle holder failed on May 15 and a data acquisition problem (a full hard drive) early in the morning on May 16 resulted in missing data for a number of hours (control functions were not affected).

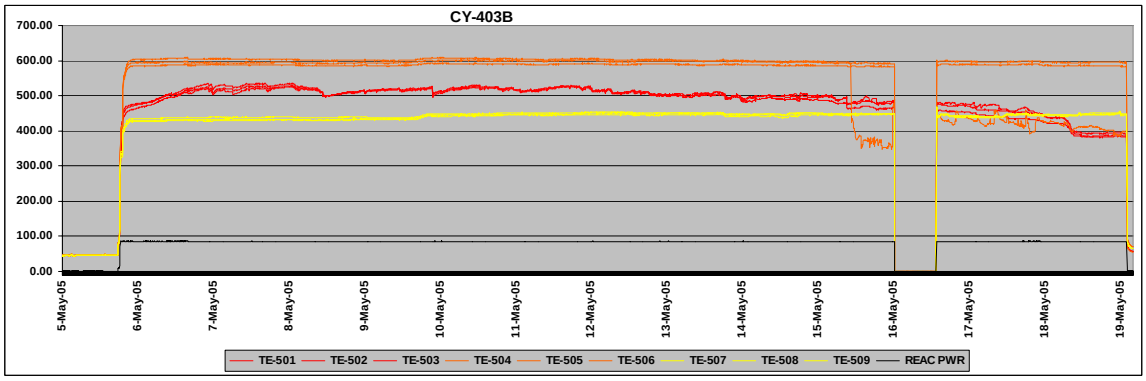

Fig. 4. 17J temperature history for HFIR cycle 403B.

A comparison of argon gas percentage for similar times in the 5 operating cycles is shown in Table 1 for the lower and middle holders. The middle holder, in particular, shows significant increases in argon gas percentage as the irradiation progresses. The reason for the trend is unknown at this time. Speculation includes possible swelling of the molybdenum capsule walls leading to a reduced gas gap or possible effects from lithium leaking from the upper capsule. A thermal analysis based on gas gap changes does indicate that the observed trend could be consistent with possible Mo swelling characteristics. The uncertainty in the cause of the cooling trend and the risk of not being able to maintain desired temperature for a marginal increase in dose based on the projected HFIR operating schedule led to a decision to discontinue irradiation of the experiment.

Table 1. Comparison of argon gas percentages for 17J, ~ 6 days before end-of-cycle (EOC)

17J Experiment	**Lower Zone - 450 C Capsule**					**Middle Zone- 600 C Capsule**			
	FT-546	FT-531C	FT-506C	Argon %	Avg. Temp	FT-531B	FT-506B	Argon %	Avg. Temp
	He(sccm)	Ar(sccm)	He(sccm)	%	(degC)	Ar(sccm)	He(sccm)	%	(degC)
Cycle 400 6 days before EOC	15.86	21.24	0	**57.3**	**428**	4.95	4.93	**55.7**	**600**
Cycle 401 ~6 days before EOC	10.78	10.68	0	**49.8**	**429**	5.87	0	**60.6**	**595**
Cycle 402 ~6 days before EOC	7.07	12.83	4.88	**51.8**	**428**	24.22	0	**75.6**	**595**
Cycle 404 ~5 days before EOC	2.04	6.57	2.91	**57.0**	**429**	33.49	0	**89.0**	**594**
Cycle 403B(current) ~6 days before EOC	0.71	7.38	2.6	**69.0**	**445**	50.76	0	**94.6**	**596**

The 17J experiment has been irradiated for 5 full cycles in the HFIR for a total of 9930 MWD. The estimated peak displacements per atom in vanadium for the RB* position is 0.74/cycle. The power history timeline for cycles 403A, 404, and 403B is shown in Table 2. This provides information on low power portions of the cycle where specimens are not at temperature (e.g., startup, operator training, etc.). Similar information for cycles 400 through 402 has been reported previously [2, 3].

Table 2. Power history for HFIR operating cycles 403A, 404, and 403B

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 403	1/26/05 1156	1/26/05 1221	0.4	8.5	0	
	1/26/05 1221	1/26/05 1234	0.2	17.0	0	
	1/26/05 1234	1/26/05 1249	0.3	25.5	1	
	1/26/05 1249	1/26/05 1252	0.0	34.0	1	
	1/26/05 1252	1/26/05 1506	2.2	0.0	1	
	1/26/05 1506	1/26/05 1542	0.6	8.5	1	
	1/26/05 1542	**2/4/05 1535**	**215.9**	**85.0**	**765**	9.005138889
EOC 403A	2/4/05 1535	3/10/05 0800	808.4	0.0	0	RX diown due to seismic concern
	3/10/05 0800	4/6/05 1958	660.0	0.0	0	Cycle 403B to be concluded at a later date
SOC 404	4/6/05 1958	4/6/05 2028	0.5	8.5	0	
	4/6/05 2028	4/6/05 2034	0.1	17.0	0	
	4/6/05 2034	4/6/05 2036	0.0	25.5	0	
	4/6/05 2036	4/6/05 2038	0.0	34.0	0	
	4/6/05 2038	4/6/05 2042	0.1	42.5	0	
	4/6/05 2042	4/6/05 2045	0.0	59.5	1	
	4/6/05 2045	4/6/05 2047	0.0	76.5	1	
	4/6/05 2047	***4/29/05 1205***	**543.3**	**85.0**	**1925**	
EOC 404	4/29/05 1205	5/5/05 1323	145.3	0.0	0	
SOC 403B	5/5/05 1323	5/5/05 1343	0.3	0.0	0	
	5/5/05 1343	5/5/05 1403	0.3	8.5	0	
	5/5/05 1403	5/5/05 1406	0.0	17.0	0	
	5/5/05 1406	5/5/05 1410	0.1	25.5	0	
	5/5/05 1410	5/5/05 1414	0.1	34.0	0	
	5/5/05 1414	5/5/05 1417	0.0	42.5	0	
	5/5/05 1417	5/5/05 1418	0.0	59.5	0	
	5/5/05 1418	5/5/05 1421	0.0	76.5	1	
	5/5/05 1421	**5/18/05 2201**	**319.7**	**85.0**	**1133**	**Total for A&B = 1898 MWD**

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, 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, DOE/ER-0313/36, U.S. Department of Energy, 120–123.

[3] D. K. Felde and R. L. Wallace, Irradiation Progress of MFE-RB-17J Experiment, Fusion Materials Semiannual Progress Report for Period Ending December, 31, 2004, DOE/ER-0313/37, U.S. Department of Energy, 158–163.