PROGRESS REPORT ON THE OPERATION OF THE VARYING TEMPERATURE EXPERIMENT (HFIR-MFE-RB-13J)

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OBJECTIVE

The objective of this report is to summarize the irradiation history of the DOE/MONBUSHO Varying Temperature Experiment (HFIR-MFE-RB13J).

SUMMARY

Irradiation of the HFIR-MFE-RB-13J irradiation experiment began during this reporting period. Four cycles of operation were completed and the fifth cycle began during the reporting period. While the operating temperatures of the experiment are slightly higher than anticipated, control of the experiment has worked as expected including temperature control during reactor startup.

PROGRESS AND STATUS

A detailed description of the experiment and planned operating conditions have been reported [1,2]. The operating guidelines of the experiment were changed to accommodate a higher than expected heat generation rate within the experimental facility. The temperature of holders B, C, and D are higher than expected, as shown below. Specimens in Zone B operate at approximately 530°C. The average specimen temperature in Zone C during the low temperature operation is approximately 375°C. Specimen temperatures in Zone C are increased to match and follow those of Zone B during the high temperature phase of the irradiation. The average specimen temperature during the low temperature phase of the irradiation in Zone D is approximately 230°C. Zone A operates at the design temperature and the average temperature of specimens in Zone D are controlled to match those of Zone A during the high temperature phase of operation.

	Average Specimen Temperature (°C)		
Zone	Design	First 10%	Remainder
A	350	350	350
B	500	530	530
C	300	375	530
D	200	230	350

Several new control features developed for this experiment have perfomed well. Electrical resistance heaters can maintain desired specimen temperatures at all reactor power levels. Changes in the control gas mixtures take only 10-15 seconds to complete, which results in only small temperature fluctuations during the reactor power increases of a startup (provided that the correct flow rates are set before a power change is initiated). Thermal isolation between zones, and from the zones to the housing is better than expected, which may partially account for high operating temperatures.

Of the 36 heater elements in the capsule, four failed during pre-irradiation checkouts due to improper wiring at an instrument cabinet and one was taken out of operation after the first cycle because of a low electrical resistance to ground. The remaining 31 heaters operated for approximately 122-full power days and show no evidence of degradation to date.

The control system can maintain specimen temperatures during ascension to full reactor power in all four zones. Figure 1 shows the reactor power level in MW and the average indicated temperature of the four specimen holders during a startup and the transition of the variable temperature zones to the higher temperatures shortly after startup. Typically the temperature transitions occur approximately 2.4 days after startup, however this startup was a mid-cycle restart and the temperatures of Zones C and D were increased to match those of B and A soon after startup.

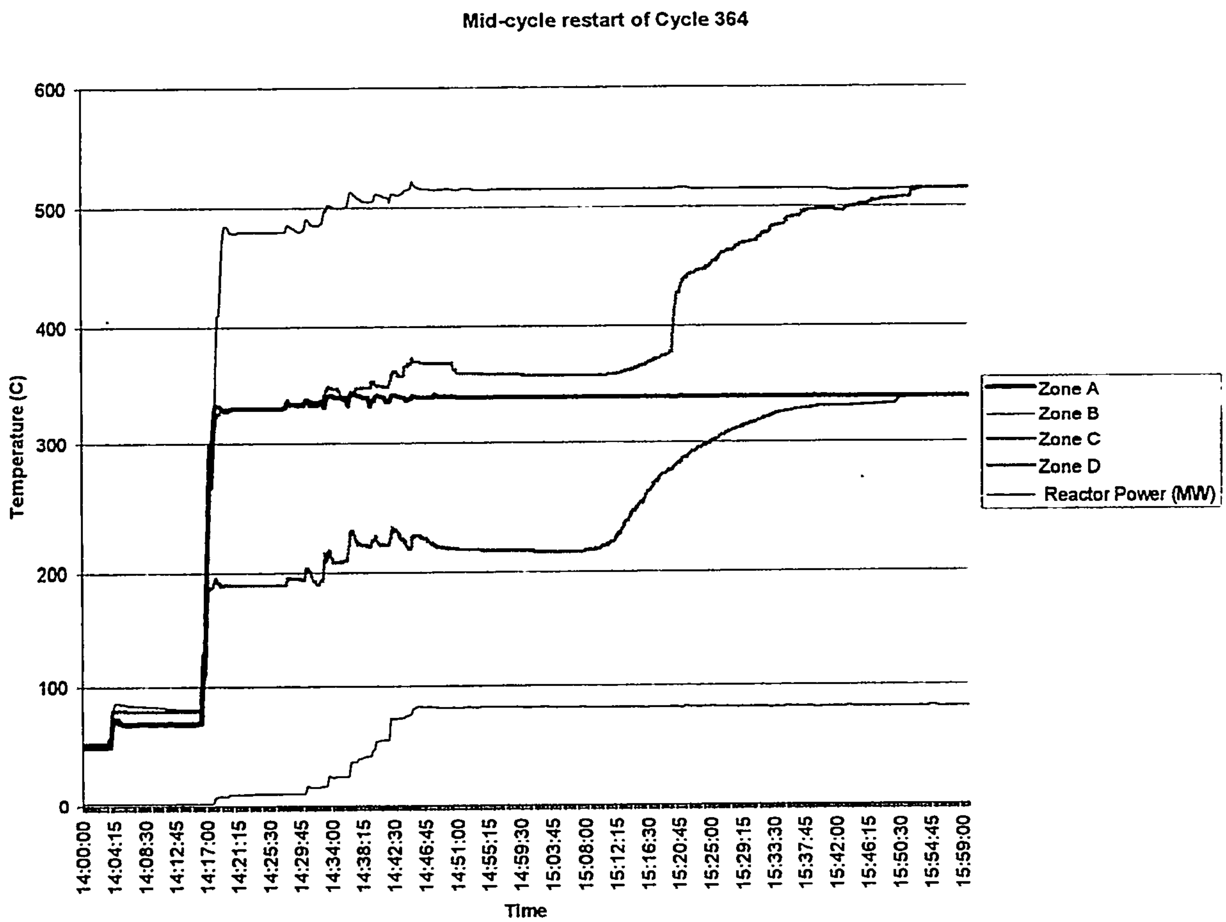

Figure 1: Average indicated temperature of each zone and the indicated reactor power during a restart of HFIR cycle 364. Soon after startup, the temperature of Zones C and D were increased to match their steady temperature counterpart.

Due to variations in each startup, reactor power changes will occasionally produce holder temperatures 10°C higher than the control system is trying to maintain. When this occurs, the safety systems of the experiment will automatically cool the holder, which results in short term irradiation of the specimens below the desired irradiation temperature. The temperatures are returned to normal within a few minutes. Figure 2 shows the average indicated temperature of each zone during a startup in which the gas flow adjustments made prior to an increase in reactor power were not sufficient to prevent automated cooling responses.

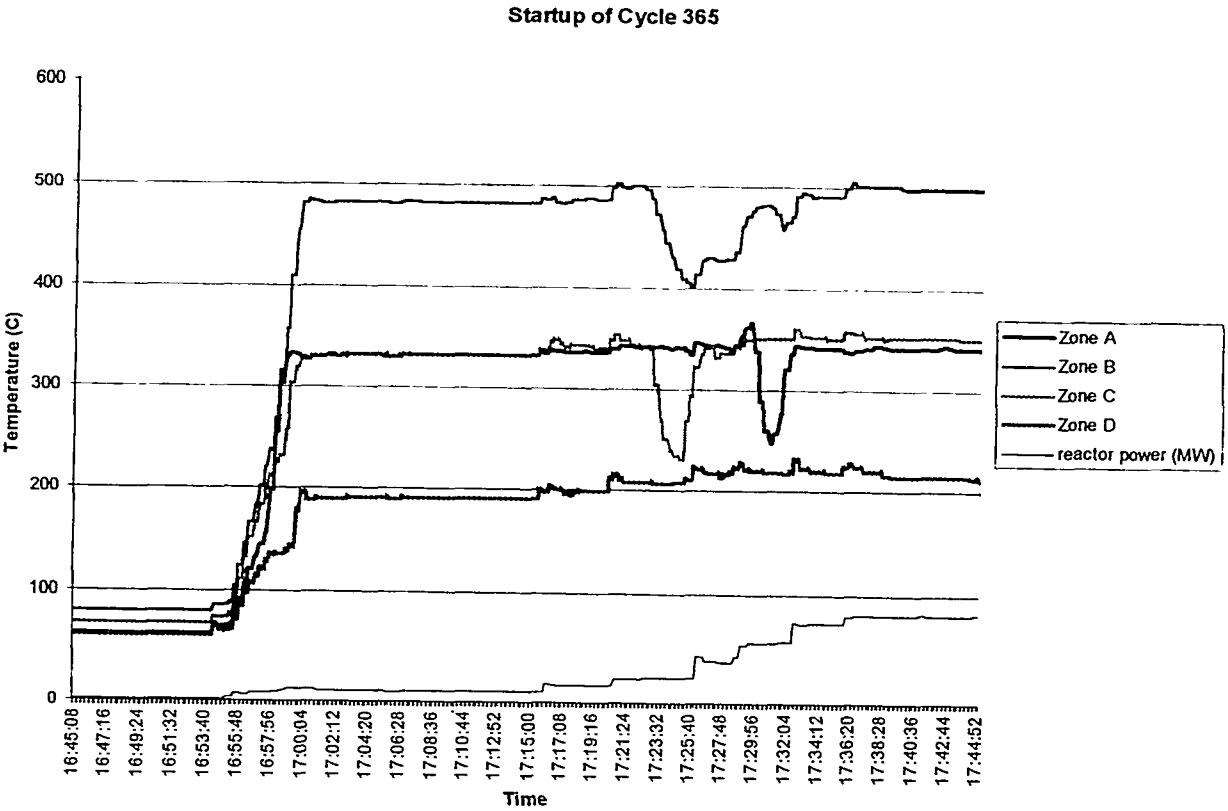

Figure 2: Average indicated temperature of each zone and the indicated reactor power during startup of cycle 365. The temperature of Zones A, B and C experienced some low temperature operation during the startup.

The heaters are rated for 10 amps, but are limited by the control system to an operational range of 6 amps. The thermal conductivity of the control gas mixture for each zone is varied independently to keep the required heater power within the operational range of the heaters at all power levels. Once the reactor reaches full power, the gas mixtures are adjusted throughout the cycle to keep current demands between 1 and 2.5 amps. Gas mixture adjustments are required every other day at the beginning of a cycle and every day near the end of a cycle.

Zones C and D operate with pure helium (the highest thermally conductive gas available) as the temperature control gas during the low temperature phase of operation. Argon is added to the helium to increase their temperature to match those of the steady temperature zones. Because Zone B operates above the design temperature, pure helium is maintained in its gas gap and little or no heater input is used in Zone B during full power operation. Because the temperature of Zone B is not actively controlled, its temperature increases approximately 5°C when the temperatures of the variable temperature zones are increased. This small temperature change implies that the gas separation seals between zones are working as planned and the thermal insulation provided by the stainless steel holder spacers is very good. Within an experimental length of 44 cm, four zones with temperature differentials as large as 300°C can be essentially independently controlled.

Another consequence of not actively controlling the temperature of Zone B is that its temperature increases approximately 15°C over the course of a 24-day cycle. This is due to increased heat generation within the holder (mostly at the end displaced from the reactor mid-plane) that occurs as the control plates are pulled from the center of the core to compensate for fuel burn-up near the mid-plane. The use of electric heaters to control temperature in the other zones allows the response time of the control system to be sufficient to accommodate minor changes in reactor power and primary coolant conditions that can occur when control plates are moved. These operational necessities can cause short-term temperature changes on the order of 2°C to 4°C in capsules that are controlled by gas mixture adjustment alone. The use of electrical heaters for temperature control typically reduces the magnitude of the temperature excursions to 0.1°C.

The experiment is rotated 180° after each cycle to ensure that specimens receive a balanced dose over the course of the irradiation. The angular location within the experimental region designated Top-Dead-Center (TDC) is closest to the reactor centerline for cycles 2, 4, 6, 8 and 10, and is farthest from the centerline for cycles 1, 3, 5, 7 and 9. The average indicated temperature of Zone B changes from cycle-to-cycle due to the orientation of the thermocouples within the zone. The temperature of Zone C is controlled to match that of Zone B. The temperature of specimens close to TDC will, (on average), experience the largest change in temperature due to capsule rotation. The average indicated temperature of Zone C is shown in Figure 3 during cycles 3 and 4 along with the indicated temperature of a group of instrumented stainless steel CVN and TEM specimens, which are located 15° from TDC. The indicated temperatures of the specimens are approximately 530°C +/- 8°C in Zone C during the high temperature phase of irradiation of both cycles. These values are considered typical for stainless steel specimens in Zones B and C, however additional analysis is required.

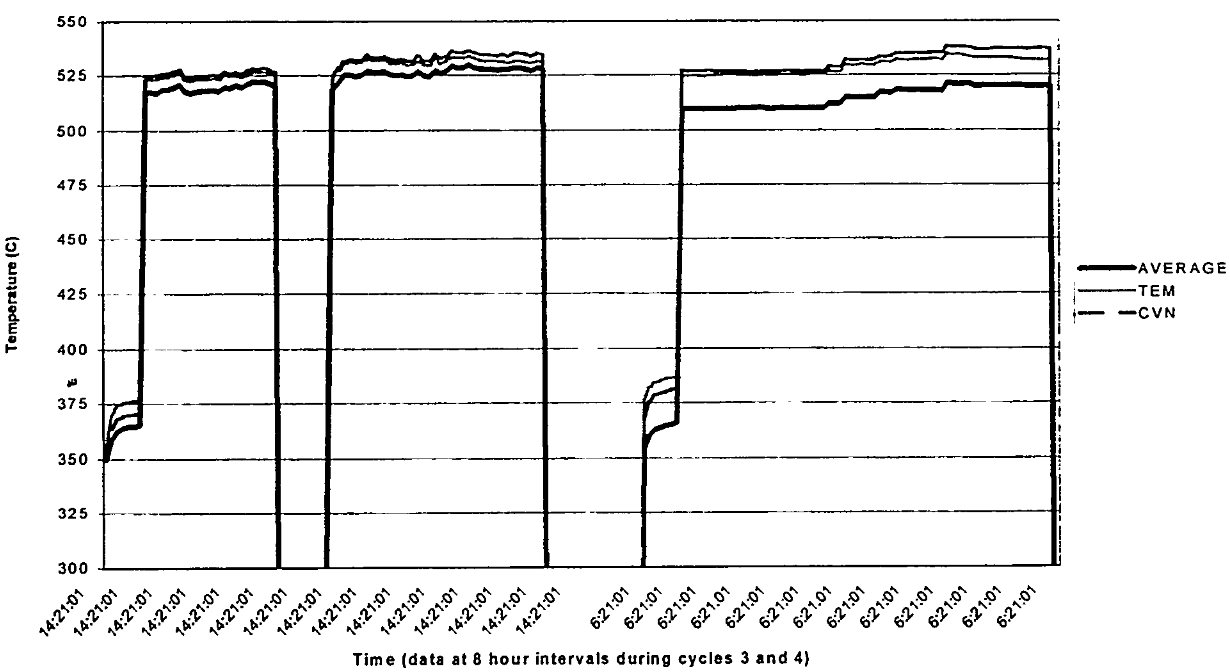

Figure 3: Average indicated temperature of Zone C and the measured temperature of stainless steel TEM and CVN specimens in Zone C for cycles 3 and 4 of a 10-cycle irradiation. The indicated temperature of the zone changes due to rotation from cycle to cycle but the indicated specimen temperatures remain the same.

One positive temperature excursion occurred in Zone B due to a control computer failure. The temperature of the zone increased to a maximum value of approximately 570°C during an excursion, which lasted approximately 15 minutes. Selected individual thermocouple readings from each zone are shown in Figure 4 during the transient.

The 10-cycle irradiation of HFIR-RB-13J is projected to be complete in July 1999.

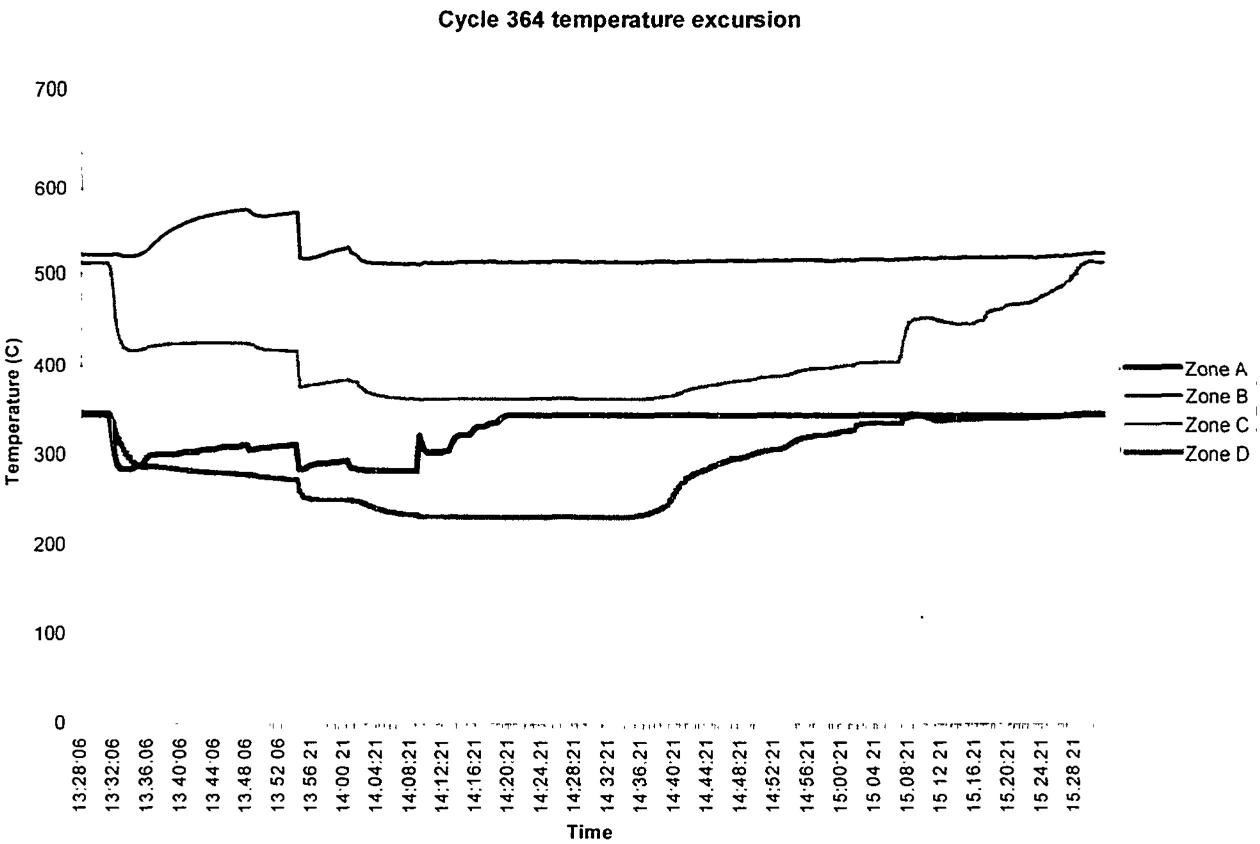

Figure 4: Temperature of an individual thermocouple from each zone during a temperature transient caused by a computer malfunction. Normally the temperature of all zones would decrease during such a failure, however the temperature of Zone B increased due to argon from the other zones mixing with the initially pure helium in the Zone B gas gap. The control system has been modified to prevent additional positive temperature excursions.

REFERENCES:

1. A. L. Qualls and T. Muroga, "Progress on the Design of a Varying Temperature Irradiation Experiment for Operation in HFIR, "Fusion Materials Semiannual Progress Report for Period Ending December 31, 1996, p. 255.

2. A. L. Qualls, M. T. Hurst, D. L. Raby, D. W. Sparks and T. Muroga, "Progress Report on the Varying Temperature, "Fusion Materials Semiannual Progress Report for Period Ending June 30, 1997, p. 243.