STUDY OF IRRADIATION CREEP OF VANADIUM ALLOYS,[1] H. Tsai, R. V. Strain, M. C. Billone, T. S. Bray, and D. L. Smith (Argonne National Laboratory); M. L. Grossbeck (Oak Ridge National Laboratory); K. Fukumoto, and H. Matsui (Tohoku University, Japan)

SUMMARY

Thin-wall tubing produced from the 832665 (500 kg) heat of V-4 wt.% Cr-4 wt.% Ti material was formed into pressurized tube specimens and irradiated in the HFIR RB-12J experiment to study irradiation creep. Irradiation and the required cool-down following irradiation have been completed and disassembly of the vehicle is underway. Calculated dose for the specimens ranged from 5.5 to 6.0 dpa and the calculated irradiation temperatures were 400 to 500°C.

OBJECTIVE

Vanadium alloys are candidate structural materials for fusion first walls and blankets because of their attractive high-temperature properties and low activation. While many alloy properties have been extensively studied, irradiation-induced creep has not. Data on irradiation creep are important because creep may be a principal contributor to deformation and is potentially performance-limiting. The objective of this task is to determine the creep rate at 500°C under a range of loading conditions.

CREEP SPECIMEN FABRICATION

The creep specimens used in the RB-12J experiment are 25.4 mm long x 4.57 mm OD x 0.25 mm wall tubes with welded end plugs, as shown in Fig. 1. The tubes were fabricated by drawing of bar stock,and the end plugs were produced by electric-discharge machining of plate stock[1]. Circumferential plug-to-tube welds were made with an electron-beam welder in vacuum. The specimens were vacuum-annealed at 1000°C for 1.0 h while wrapped in Ti foil, then pressurized, through a 0.25-mm-dia. meter hole in the top end plug, with high-purity helium in a pressure chamber. The final closure weld of the hole was made with a laser through the quartz window in the chamber. Six specimens, with at-temperature hoop stresses ranging from 0 to 200 Mpa, were irradiated in the RB-12J experiment. The specified pressure loading was determined with a code that accounted for thermal expansion of the creep tubing and compressibility of the helium gas. Following the leak check, the dimensions of the assembled creep specimens were measured with a precision laser profilometer at 5 axial (x/L = 0.1, 0.3, 0.5, 0.7, and 0.9) and 19 azimuthal locations to an accuracy of 10^{-4} mm.

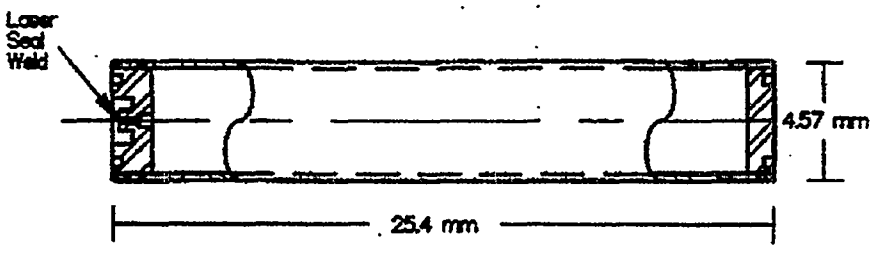

Fig. 1. Schematic Diagram of Creep Specimens

To mitigate gaseous impurity uptake, the six creep specimens were loaded in two sealed thin-wall

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Zircalloy capsules, which acted as an impurity getter. A pinhole was drilled in the end plug of the Zircalloy capsule to prevent pressure buildup in case of an unexpected specimen failure. The inside dimensions of the Zircalloy tubing were 81.3 mm long x 5.05 mm ID and the wall thickness was 0.10 mm.

IRRADIATION SUMMARY

The irradiation of RB-12J was completed in 10 HFIR cycles, from Cycle 352 (Feb. 7, 1997) through Cycle 361 (Jan. 17, 1998). The irradiation location was RB-5B.

Calculated temperatures and neutron damage [2] for the six creep specimens are shown in Table 1. The range of temperatures reflected the impact of several factors: changes in HFIR power levels during operation, 180° capsule rotation at the end of each cycle, movement of the HFIR control plates, uncertainties in the relationship between specimen temperatures and thermocouple temperatures, and variation in individual thermocouples over the course of the 10 cycles.

In Cycle 353, an attempt to recover from a computer failure led to three separate high-temperature excursions; total duration was about 4 min. The peak temperatures during these times were estimated to be ≈40°C above those shown in Table 1 [2].

Table 1. Creep Specimens from HFIR-12J Experiment

Specimen No.	Calculated Temp.(°C)	Calculated Dpa	Nominal Hoop Stress (MPa)
B1	496±22	5.96	0
B12	399±21	5.96	50
B11	496±22	5.75	100
B3	476±22	5.45	150
B9	496±22	5.75	150
B5	476±22	5.45	200

STATUS OF EXPERIMENT

Following the postirradiation cool-down in the HFIR pool, the RB-12J vehicle was moved to the ORNL hot cell in January 1999 for disassembly. At the time of writing, the specimens have been retrieved from the irradiation vehicle but not from the Zircalloy getter tubes.

FUTURE ACTIVITIES

The specimens will be retrieved from the Zircalloy getter tubes and their diameters will be measured with a precision laser profilometer. Stress dependence of the creep strains will be evaluated, and stress-free swelling of the material from the 0-MPa specimens will also be evaluated. These results will be compared with the limited previously published in-reactor creep data on vanadium alloys.

REFERENCES:

1. H. Tsai, R. V. Strain, and D. L. Smith, "Study of Irradiation Creep of Vanadium Alloys," Fusion Materials Semiannual Progress Report, DOE/ER-0313/22, June 1997, pp. 57-60.
2. K. E. Lenox and M. L. Grossbeck, "Operating History of the HFIR MFE-RB-11J and –12J (P3-2 and P3-3) Experiments," Fusion Materials Semiannual Progress Report, DOE/ER-0313-25, December 1998, pp. 307-323.