STATUS OF DOE/JAERI COLLABORATIVE PROGRAM PHASE II AND PHASE III CAPSULES – J. P. Robertson, K. E. Lenox (Oak Ridge National Laboratory), and Y. Miwa (Japan Atomic Energy Research Institute)

OBJECTIVE

The objective of the High Flux Isotope Reactor (HFIR) irradiations is to determine the response of various U.S. and Japanese structural alloys with different pretreatments and alloy compositions to the combined effects of displacement damage and helium generation.

SUMMARY

Significant progress continues to be made in the post-irradiation examinations (PIE) of the specimens from the DOE ORNL/JAERI collaborative capsules and in the design and fabrication of additional capsules. This report serves as a summary of the irradiation parameters for the capsules and the Fusion Materials progress reports related to the design, loading, operation, and dosimetry.

PROGRESS AND STATUS

Tables 1 and 2 summarize the progress and status of the capsules involved in the Phase II and Phase III irradiation programs. Details of the capsule design, assembly, and operation, specimen matrices and testing, and alloy compositions can be found in previous reports in this series. The locations of some of the more detailed reports are shown in the table, but this is not intended to be an exhaustive list. The dose levels shown in the table are the peak capsule values achieved at the reactor centerline. The dpa values in the HFIR target are estimated by assuming 9.38×10^{-4} dpa/MWd. The dpa values in the hafnium-shielded HFIR RB experiments are estimated by assuming 2.55×10^{-4} dpa/MWd. While a status of "testing complete" is listed for several of the capsules, it should be noted that data analyses and microscopy examinations are still in progress.

The JP series HFIR target capsules (JP9-16, JP20-22) contain primarily transmission electron microscopy disks (TEM) and SS-3 flat tensile specimens. A wide variety of alloys and thermomechanical conditions are included. Many of the TEM disks were made from isotopically tailored alloys to produce a range of He/dpa ratios (<0.1, 10, 20, 70 appm/dpa). The specimen temperatures are 300, 400, 500, and 600°C and the dose levels are 8, 17, 34, and 60 dpa.

The JP17, 18, and 19 capsules each contained miniature fracture toughness specimens, SS-3 tensile specimens, and TEM disk specimens, in order to directly compare fracture toughness, tensile properties, and microstructure of several austenitic and ferritic steel alloys.

The CTR-62 and 63 capsules, containing low activation ferritic steel specimens, were irradiated for 7 cycles to approximately 14 dpa. The tensile, Charpy, and TEM specimens operated at either 300 or 400°C.

The HFIR-JP25 target capsule will be the last of five capsules that compose the ORNL/JAERI Phase III Task I project on low activation ferritic steels (the other capsules are RB-11J, RB-12J, CTR-62, and CTR-63). This capsule is to be irradiated to a peak dose of 20 dpa. The specimens will operate at 300 and 500°C, the same temperatures as the RB-11J and 12J capsules. The capsule will include tensile, Charpy V-notch, pre-cracked Charpy, and TEM specimens of IEA F82H base metal, nickel-doped base metal, weld metal, and weldment.

The RB-60J-1, 200J-1, 330J-1, and 400J-1 experiments are a continuation of the Oak Ridge Research Reactor (ORR) spectrally tailored experiments. The capsules operated in the RB positions of the HFIR surrounded by a hafnium shield to simulate the expected fusion helium to damage (He/dpa) ratio in steel. The doses shown in the table are in addition to the 7 dpa accumulated during the ORR irradiation, bringing the total for the two-stage irradiation to 16-19 dpa. Dosimetry and helium measurements from specimens from the 60J-1 and 330J-1 capsules indicate that this experiment was successful in producing fusion relevant helium/dpa

Table 1. Summary of Target Capsule Irradiation Parameters and Status

Capsule	Primary Research Objectives	Irradiation Start and End; Number of Cycles	Operating Parameters: MWd; dpa; temperature	Status	Most Pertinent Semiannual Report Numbers DOE/ER-0313/xx
JP10 JP11 JP13 JP16	austenitic and ferritic steels; isotopically tailored TEM disks; tensile specimens	start: 7/90 end: 9/91 11 cycles	20161 MWd 17.3 dpa 300-600°C	testing complete	Design: 0313/3 Loading: 0313/5 Operation: 0313/16 Dosimetry: 0313/19
JP14	austenitic and ferritic steels; isotopically tailored TEM disks; tensile specimens	start: 7/90 end: 9/92 21 cycles	38786 MWd 33.9 dpa* 300-600°C	testing complete	Design: 0313/3 Loading: 0313/5 Operation: 0313/16
JP9 JP12 JP15	austenitic and ferritic steels; isotopically tailored TEM disks; tensile specimens	start: 7/90 end: 4/94 35 cycles	64904 MWd 59.6 dpa 300-600°C	testing complete	Design: 0313/3 Loading: 0313/5 Operation: 0313/16 Dosimetry: 0313/23
JP17	austenitic and ferritic steels; fracture toughness, tensile, TEM specimens	start: 12/91 end: 2/92 2 cycles	3702 MWd 2.9 dpa 250-300 °C	testing complete	Design: 0313/12 Loading: 0313/12 Operation: 0313/19 Dosimetry: 0313/19
JP18 JP19	austenitic and ferritic steels; fracture toughness, tensile, TEM specimens	start: 8/91 end: 10/91 2 cycles	3575 MWd 2.9 dpa 60-125°C	testing complete	Design: 0313/11 Loading: 0313/11 Operation: 0313/19 Dosimetry: 0313/19
JP20	austenitic and ferritic steels; isotopically tailored TEM disks; tensile specimens	start: 12/93 end: 6/94 5 cycles	9367 MWd 8.4 dpa 300-600°C	testing in progress	Design: 0313/12 Loading: 0313/15 Operation: 0313/18 Dosimetry: 0313/23
JP21	austenitic and ferritic steels; isotopically tailored TEM disks; tensile specimens	start: 12/93 end: 4/95 11 cycles	21337 MWd 18.6 dpa* 300-600°C	disassembly complete	Design: 0313/12 Loading: 0313/15 Operation: 0313/18
JP22	austenitic and ferritic steels; isotopically tailored TEM disks; tensile specimens	start: 12/93 end: 1/96 19 cycles	38880 MWd 34 dpa* 300-600°C	testing in progress	Design: 0313/12 Loading: 0313/15 Operation: 0313/18
CTR-62 CTR-63	ferritic steels; tensile, CVN, and TEM specimens	start: 4/95 end: 12/95 7 cycles	14 dpa* 300, 400°C	testing in progress	Design: 0313/18 Loading: 0313/18
JP25	ferritic steels; tensile, CVN, and TEM specimens	10 cycles	20 dpa* 300, 500°C	design in progress	

*estimated

levels (approximately 11 appm He/dpa). The irradiation temperatures in these experiments were actively controlled at 60, 200, 330, and 400°C.

The RB-11J and 12J capsules are the first of the spectrally tailored capsules in the Phase III program. These capsules operated in the HFIR removable beryllium (RB) positions with a europium oxide (Eu_2O_3) thermal neutron shield in place. They achieved approximately 5 dpa at 300 and 500°C, respectively. The capsules contained primarily low activation ferritic steel and

vanadium alloy specimens in the form of tensile, fracture, creep, and TEM specimens. The capsules began irradiation with the start of HFIR fuel cycle 352 (February 1997) and achieved their goal fluence at the end of cycle 361 (July 1998).

The RB-10J capsule will be irradiated to 5 dpa in a Eu_2O_3-shielded RB position. It is composed of two distinct sections separated at the reactor centerline. The upper portion contains vanadium alloy specimens operating at 420 and 480°C. Bend bars, fracture toughness specimens, tensile specimens, and TEM disks are included at each temperature. The specimens are surrounded by lithium in order to prevent oxygen contamination and to provide good thermal contact to the specimens. The lower portion contains primarily austenitic stainless steels and operates at approximately 250°C. Tensile specimens, Charpy V-notch specimens, and TEM disks are included. Fabrication of this capsule was completed in August 1998 and irradiation began in October. The irradiation was suspended after 10 days due to a change in the operating conditions. More details can be found in a companion report in this volume [1].

REFERENCES

1. K. E. Lenox, "As-Built Condition and Operating History of the U.S./JAERI HFIR-MFE-RB-10J Capsule," Fusion Materials Semiannual Progress Report for the Period Ending December 31, 1998, DOE/ER-0313/25.

Table 2. Summary of RB Capsule Irradiation Parameters and Status

Capsule	Primary Research Objectives	Irradiation Start and End; Number of Cycles	Operating Parameters: MWd; dpa; temperature	Status	Most Pertinent Semiannual Report Numbers DOE/ER-0313/xx
RB-60J-1	spectrally tailored (Hf-shielded); tensile, creep, TEM specimens	start: 7/90 end: 11/92 24 cycles	44450 MWd 11.6 dpa 60°C	testing in progress	Design: 0313/3, 4 Loading: 0313/4 Operation: 0313/13 Dosimetry: 0313/17
RB-200J-1	spectrally tailored (Hf-shielded); tensile, creep, TEM specimens	start: 11/92 end: 1/95 20 cycles	37450 MWd 11.6 dpa 200°C	testing in progress	Design: 0313/3, 6 Loading: 0313/14 Operation: 0313/15, 18 Dosimetry: 0313/23
RB-330J-1	spectrally tailored (Hf-shielded); tensile, creep, TEM specimens	start: 7/90 end: 11/92 24 cycles	44450 MWd 11.6 dpa 330°C	testing in progress	Design: 0313/3, 5 Loading: 0313/5 Operation: 0313/11, 13 Dosimetry: 0313/17
RB-400J-1	spectrally tailored (Hf-shielded); tensile, creep, TEM specimens	start: 11/92 end: 1/95 20 cycles	37450 MWd 9.2 dpa* 400°C	testing in progress	Design: 0313/3, 6 Loading: 0313/14 Operation: 0313/15, 18
TRIST-ER1	alumina; in-situ measurement of electrical conductivity	start: 3/96 end: 6/96 3 cycles	3 dpa* 450°C	testing complete	Design: 0313/19, 20 Loading: 0313/19 Operation: 0313/20, 22
RB-10J	austenitic steels and V alloys; spectrally tailored (Eu_2O_3-shielded); tensile, fracture, TEM specimens	start: 10/98 end: 4/00* 10 cycles	5 dpa* steel: 250°C V: 420, 480°C	irradiation in progress	Design: 0313/23, 24 Loading: 0313/25 Operation: 0313/25
RB-11J RB-12J	ferritic steels and V alloys; spectrally tailored (Eu_2O_3-shielded); tensile, fracture, TEM specimens	start: 2/97 end: 7/98 10 cycles	5 dpa* 300, 500°C	irradiation complete; disassembly in progress	Design: 0313/22 Loading: 0313/22 Operation: 0313/22

*estimated