STATUS OF DOE/JAERI COLLABORATIVE PROGRAM PHASE II AND PHASE III CAPSULES – J. P. Robertson, K. E. Lenox (Oak Ridge National Laboratory), I. Ioka and and E. Wakai (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 has been made during the last year in the post-irradiation examinations (PIE) of the specimens from nine DOE ORNL/JAERI collaborative capsules and in the design and fabrication of four additional capsules. JP21, JP22, CTR-62, and CTR-63 were disassembled, JP20 tensile specimens were tested, and a variety of specimens from the RB-60J-1, 200J-1, 330J-1, and 400J-1 capsules were tested. Fabrication of RB-11J and 12J was completed and progress made in the matrix finalization and design of RB-10J and JP25.

PROGRESS AND STATUS

Post-Irradiation Examination

Significant progress has been made during the last year in the post-irradiation examinations (PIE) of the specimens from nine DOE ORNL/JAERI collaborative capsules. 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 8.73×10^{-4} dpa/MWd. The dpa values in the hafnium-shielded HFIR RB experiments are estimated by assuming 2.45×10^{-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, 18, 34, and 57 dpa.

During this reporting period, 17 of the 24 SS-3 tensile specimens from HFIR-JP20 (8 dpa peak) were tested at the respective irradiation temperatures. Four of the tensile specimens (V-5Cr-5Ti) were shipped to Argonne National Laboratory (ANL) for testing and the other three (TiAl alloys) are scheduled to be shipped to the Japan Atomic Energy Research Institute for testing. Analyses of these data are still in progress and will be discussed in future reports in this series. Three of the five TEM disk packets were opened and sorted (JP20, Position 6, 300°C; JP20, Position 7, 500°C; and JP20, Position 9, 400°C). Of these disks (approximately 120 disks per packet), 12 of the Ti-Al disks were identified to be shipped to JAERI for microscopy, 12 isotopically tailored ferritic disks were identified to be shipped to Pacific Northwest National Laboratory (PNNL) for microscopy, and 24 isotopically tailored ferritic disks were selected for microscopy at ORNL.

The HFIR-JP21 and JP22 capsules, which were irradiated to a peak damage level of 18 and 34 dpa, respectively, were disassembled in August 1996. All of the specimens and all but one of the 12 flux monitors were recovered without incident. The lost flux monitor was Monitor #48 from the topmost position in the JP21 capsule. These specimens are now in storage in the Irradiated Materials Examination and Testing (IMET) Facility and are scheduled for PIE during the next reporting period. One TEM disk

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 56.7 dpa* 300-600°C	disassembly complete	Design: 0313/3 Loading: 0313/5 Operation: 0313/16
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 8.2 dpa* 300-600°C	testing in progress	Design: 0313/12 Loading: 0313/15 Operation: 0313/18
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	disassembly complete	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	disassembly complete	Design: 0313/18 Loading: 0313/18
JP25	ferritic steels; tensile, CVN, and TEM specimens	12 cycles	20 dpa* 300, 500°C	design in progress	

*estimated

Table 2. Summary of RB Capsule Irradiation Parameters and Status

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 9.2 dpa* 200°C	testing in progress	Design: 0313/3, 6 Loading: 0313/14 Operation: 0313/15, 18
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	irradiation complete	Design: 0313/19, 20 Loading: 0313/19 Operation: 0313/20
RB-10J	austenitic steels and V alloys; spectrally tailored (Eu_2O_3-shielded); tensile, fracture, TEM specimens	start: 1/98* end: 12/98* 10 cycles	5 dpa* steel: 250°C V: 400-500°C	design in progress	
RB-11J RB-12J	ferritic steels and V alloys; spectrally tailored (Eu_2O_3-shielded); tensile, fracture, TEM specimens	start: 2/97 end: 12/97* 10 cycles	5 dpa* 300, 500°C	fabrication complete	

*estimated

packet (JP22 Position 7, 34 dpa, 500°C) has been opened and the disks sorted and cleaned in preparation for density measurements.

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 levels (approximately 11 appm He/dpa). The irradiation temperatures in these experiments were actively controlled at 60, 200, 330, and 400°C. Pressurized creep tube measurements and analyses were completed on the specimens from the 200J and 400J capsules [e.g., 1] and the data reported along with those from 60J and 330J. In addition, several of the pressurized tubes from the 60J and 400J capsules were punctured and the released pressure measured in order to verify the creep measurements. A number of Grodzinski fatigue specimens were separated out from each of the four capsule sets and set aside for shipping to JAERI. These specimens will be used in slow strain rate tests (SSRT) as part of the investigation of irradiation assisted stress corrosion cracking. Tensile testing was also conducted on specimens from each of these four capsules. In some cases, analyses of the data and

integration into the existing databases are still in progress. Optical photographs of the fracture areas have been made on most of the tested specimens and reduction in area measurements completed. An experimental plan to complete the test matrix during the next year has been developed. Twenty-nine SS-3 tensile specimens made from low activation ferritic steels were collected for eventual shipment to PNNL for testing. Sixteen vanadium alloys specimens were collected and shipped to ANL. Sixty-two SS-1 and SS-3 specimens were tested at ORNL. Transmission electron microscopy disk packets from 200J and 400J were also identified for eventual shipment to PNNL and ANL.

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. These capsules were successfully disassembled in August 1996 and the specimens are awaiting testing in the IMET storage facility.

Pre-Irradiation Progress

The RB-11J and 12J capsules are the first of the spectrally tailored capsules scheduled for irradiation in the Phase III program. These capsules will operate in the HFIR removable beryllium (RB) positions with a europium oxide (Eu_2O_3) thermal neutron shield in place. They will achieve approximately 5 dpa at 300 and 500°C, respectively. The capsules will contain primarily low activation ferritic steel and vanadium alloy specimens in the form of tensile, fracture, creep, and TEM specimens. Fabrication and assembly of the capsules are complete, and the Eu_2O_3 shields have been approved by the Research Reactor Division. The capsules are scheduled to begin irradiation with the start of HFIR cycle 352 (February 1997).

The RB-10J capsule will be irradiated to 5 dpa in a Eu_2O_3-shielded RB position. It will be composed of two distinct sections separated at the reactor centerline. The upper portion will contain vanadium alloy specimens tentatively operating at 420 and 480°C. Bend bars, fracture toughness specimens, tensile specimens, and TEM disks will be included at each temperature. The specimens will be surrounded by lithium in order to prevent oxygen contamination and to provide good thermal contact to the specimens. The lower portion will contain primarily austenitic stainless steels and will operate at approximately 250°C. Tensile specimens, Charpy V-notch specimens, and TEM disks will be included. Some weld and joint specimens may be included also. This capsule is scheduled to be fabricated during the next year and is to be ready for irradiation in January 1998.

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.

REFERENCES

1. M. L. Grossbeck, L. T. Gibson, S. Jitsukawa, L. K. Mansur, and L. J. Turner, in Effects of Radiation on Materials: 18th International Symposium, ASTM STP 1325, R. K. Nanstad, Ed., American Society for Testing and Materials, 1997, in press.