ASSEMBLY OF THE US-JAPAN MFE-RB-15J EXPERIMENT FOR IRRADIATION IN THE HFIR

– T. Hirose, M. Ando, H. Tanigawa, N. Okubo (Japan Atomic Energy Agency), J. L. McDuffee, D. W. Heatherly, R. G. Sitterson, R. E. Stoller (Oak Ridge National Laboratory) and T. Yamamoto (University of California, Santa Barbara)

OBJECTIVE

This work is being carried out under the Collaboration on Fusion Materials between the U.S. DOE and the Japan Atomic Energy Agency. The MFE-RB-15J capsule is a part of the Phase-V experimental program with the goal of elucidating the effects of helium generation in fusion structural candidate engineering alloys, and verifying the irradiation response of alloy F82H base metal and welds for ITER-TBM (Test Blanket Module) application. The target dose of this capsule is 6 dpa at the peak and it will introduce 300 appm of transmutation helium in F82H doped with boron-10.

SUMMARY

Assembly of the MFE-RB-15J capsule was completed in April, 2008 and installed in HFIR location RB-1A inside a europia thermal neutron shield.. Irradiation began with cycle 415, starting June 3, 2008. A detailed specimen loading list for the capsule is provided in this report.

PROGRESS AND STATUS

Introduction

This experiment is being carried out within the framework of the US DOE-JAEA Collaboration on Fusion Materials, which is in its fifth phase. The goals of the experiment include the investigation of the effects of helium on fracture properties, and the development of engineering data on the fusion candidate alloy F82H and joints made by welding (TIG and EB) and HIP. The data is needed for ITER-TBM design and alloy qualification. A more detailed description of the experiment will be provided in a subsequent report. This report provides a summary of the specimen preparation for the MFE-RB-15J experiment.

Design Description

The design of the MFE-RB-15J is very similar to that of MFE-RB-17J [1]. The main differences between these two are irradiation temperature and the structural material. The MFE-RB-15J is optimized for irradiation at 300 and 400°C, and the structural material of the capsule is stainless steel, (instead of the molybdenum used in -17J specimen holders.) In the MFE-RB-15J experiment three axially stacked specimen holders are located within a common inner containment housing (top, middle and bottom), which is itself contained in an outer housing. The top and bottom holders are irradiated at 300°C and the middle one at 400°C. The 300°C holder is partitioned into three regions and the 400°C holder into five regions to distribute and locate the specimens. The specimen holders are filled with lithium, to reduce thermal gradients during irradiation. The experiment placed in an annular europium oxide shield and loaded into the RB-1A position. The purpose of the shield is to reduce helium production from ^{10}B transmutation in the initial part of the irradiation [2,3]. The shield used in this experiment had been used previously for several cycles with experiments, MFE-RB-10J and MFE-RB-14J.

Specimen Loading

The specimen materials in this experiment are summarized in Table 1. The specimen types include six types of toughness specimens (0.18”DCT, 0.14”DCT, half-1/3CVN, half-1/3PCCVN, Multi5-PCCVN, DFMB), sheet tensile specimens (SS-J3), pressurized creep tubes (PT), hourglass fatigue specimens (SF-1), atom probe specimens (APFIM), and miniature multipurpose coupons (MMPC). The fatigue specimen, SF-1 is newly employed for this experiment, and is described elsewhere [4]. The overall layout of MFE-RB-15J experiment is summarized in Table 2.

Table 1 Materials list for MFE-RB-15J experiment

ID	Description
F82H IEA [5]	8Cr-2W RAF/Ms, F82H IEA heat (F82H-mod.)
F82H TIG WM [6]	TIG weld metal of F82H joint
F82H TIG FG HAZ [7]	Fine grained HAZ from TIG weld joint, heated above A_{C1}transformation temperature
F82H TIG OT HAZ [7]	Over tempered HAZ from TIG weld joint, heated below A_{C1} Transformation temperature
F82H HIP [8]	HIP joint of F82H processed at 1100°C followed by heat treatment at 960°C and 750°C
F82H+10BN [9]	F82H with additional 60 wppm Boron-10
F82H+11BN [9]	F82H with additional 60 wppm Boron-11
F82H EB WM [10]	Weld metal of F82H Electron Beam weld joint
F82H EB HAZ [10]	HAZ from F82H Electron Beam weld joint
F82H mod3 [11]	F82H with 0.1% of Tantalum
Eurofer97 [12]	9Cr-1W RAF/Ms
U14YWT1000 [13]	ODS steel consolidated at 1000°C
U14YWT1150 [13]	ODS steel consolidated at 1150°C
US MA957	Commercial ODS steel

Table 2 Layout of the MFE-RB-15J experiment

Region	Specimen Type	Design Temp. (^{o}C)	Distance above HMP* (mm)		
			Top	Middle	Bottom
Top-C	APFIM, 0.14"DCT, MMPC, SJ3	300	180	168	155
Top-B	PT, SF1	300	155	142	129
Top-A	hf-1/3CVN, SJ3, M5PCCVN**	300	129	116	103
Middle-E	0.18"DCT, DFMB, SJ3	400	57.4	48.6	39.8
Middle-D	PT, hf-1/3CVN, hf-1/3PCCVN, SF1,SJ3	400	39.4	26.5	13.7
Middle-C	hf-1/3CVN, SF1,SJ3	400	13.3	0.4	-12.5
Middle-B	PT, hf-1/3CVN, SF1	400	-12.9	-25.8	-38.7
Middle-A	0.18"DCT, M5PCCVN**	400	-39.1	-48.0	-57.0
Bottom-C	0.14"DCT, hf-1/3CVN, SJ3	300	-103	-115	-128
Bottom-B	PT, hf-1/3CVN, SJ3	300	-129	-142	-155
Bottom-A	SF1, SJ3, M5PCCVN**	300	-155	-167	-180

* HMP - Horizontal mid-plane of the HFIR

** M5PCCVNs located over A, B and C regions.

Figure 1 shows the arrangement of the specimen holders. The regions are separated by stainless steel spacers, which are approximately 25 mm in length. As shown in this figure, the M5PCCVN specimens (54 mm in length) span three regions. The total length of the specimen-containing zone is 360 mm, and the fluence fraction, Pf, at the ends of this zone is approximately 0.7 of the mid-plane value.

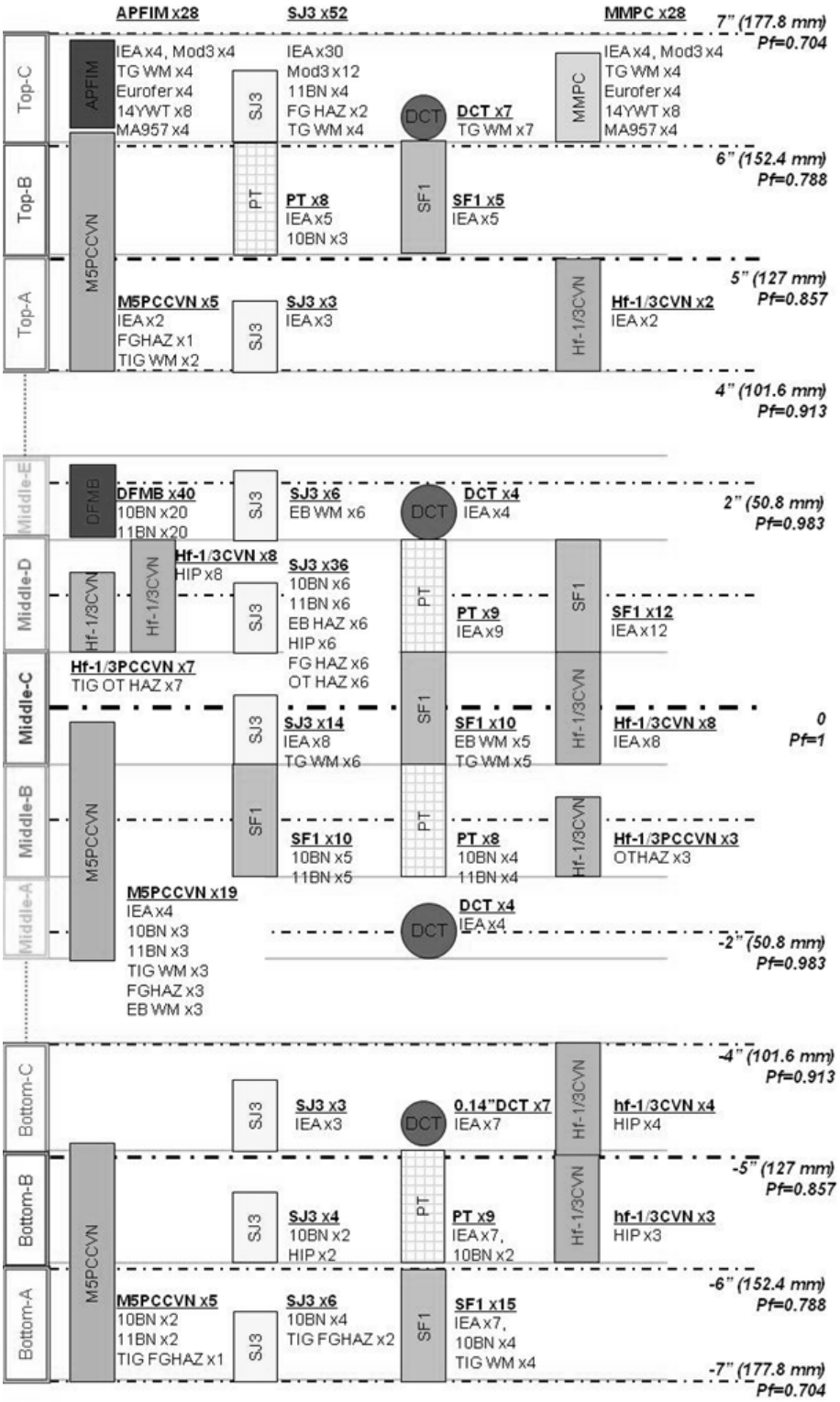

Figure 1 Schematic view of the MFE-RB-15J experiment, showing specimen holders and loading.

The detailed specimen loading is given in Table 3.

Future Work

The MFE-RB-15J capsule will be irradiated to a peak fluence of 6 dpa and 4.2 dpa at ends of the specimen zone, which will take approximately ten HFIR cycles. This will introduce 300 appm of transmutation helium in F82H+10BN. The irradiation will be completed with cycle 424.

Table 3. MFE-RB-15J Loading List, Identifying each specimen by specimen number, type, material, and location in the experiment.

MFE-RB-15J, 300°C top-C region (~ 155 ~ 180 mm above reactor mid plane)

-APFIM (28 pieces)

EUROFER 97:	RA, RB, RC, RD
F82H IEA:	1A, 1B, 1C, 1D
F82H mod3:	HA, HB, HC, HD
F82H TIG WM:	2A, 2B, 2C, 2D
U14YWT1000:	ZUA, ZUB, ZUC, ZUD
U14YWT1150:	ZTA, ZTB, ZTC, ZTD
US MA957:	ZSA, ZSB, ZSC, ZSD

-0.14”DCT (7 pieces)

F82H IEA:	1VXA, 1VXB, 1VXC, 1VXD, 1VXE, 1VXF, 1VXG

-MMPC (28 pieces)

EUROFER 97:	RA, RB, RC, RD
F82H IEA:	1A, 1B, 1C, 1D
F82H mod3:	HA, HB, HC, HD
F82H TIG WM:	2A, 2B, 2C, 2D
U14YWT1000:	ZUA, ZUB, ZUC, ZUD
U14YWT1150:	ZTA, ZTB, ZTC, ZTD
US MA957:	ZSA, ZSB, ZSC, ZSD

-SSJ3 tensile (52 pieces)

F82H+11BN:	EX0, EX1, EX2, EX3
F82H TIG FG	HAZ:21V0, 21V1
F82H TIG WM:	1V0, 1V1, 1V2, 1V3
F82H mod3:	HX0, HX1, HX2, HX3, HX4, HX5, HY0, HY1, HY2, HY3, HY4, HY5
F82H IEA:	0VAa, 0VAb, 0VAc, 0VAd, 0VAe, 0VAf, 0VAg, 0Vah, 0VAj, 0VAk, 0VAm, 0VAn, 0VAp, 0VAq, 0VAr, 0VAs, 0VAt, 0VAu, 0VAv, 0VAw, 0WAa,0WAb, 0WAc, 0WAd, 0WAe, 0WAf, 0Wag, 0WAh,0WAj, 0WAk

MFE-RB-15J, 300°C top -B region (~ 129 ~ 155 mm above reactor mid plane

-Pressurized creep tube (8 pieces)

F82H+10BN:	DXP0, DXP1, DZP2
F82H IEA:	0XP0, 0XP3, 0XP5, 0XP9, 0ZP4

-SF-1 fatigue (5 pieces)

F82H IEA:	0X6, 0X7, 0X8, 0X9, 0XA

MFE-RB-15J, 300°C top-A region (~ 103 ~ 129 mm above reactor mid plane)

-hf-1/3CVN (2 pieces)

F82H IEA:	0XS, 0XT

-SS-J3 tensile (3 pieces)

F82H IEA:	0X0, 0X1, 0X2

MFE-RB-15J, 300°C spanning top-A, B and C regions (~ 103 ~ 157 mm above mid plane)

-M5PCCVN (5 pieces)

F82H IEA: 0VB, 0VC
F82H TIG FG HAZ: 21V4
F82H TIG WM: 1V4, 1V5

MFE-RB-15J, 400°C middle holder, E-zone (~ 39.8 ~ 57.4 mm above reactor mid plane)

-0.18”DCT (4 pieces)

F82H IEA: 0WEa, 0WEb, 0WEc, 0WEd

-DFMB (40 pieces)

F82H+10BN: DXHa, DXHb, DXHc, DXHd, DXHe, DXHf, DXHg, DXHh, DXHi, DXHk, DYHa, DYHb, DYHc, DYHd, DYHe, DYHf, DYHg, DYHh, DYHi, DYHk
F82H+11BN: EXHa, EXHb, EXHc, EXHd, EXHe, EXHf, EXHg, EXHh, EXHi, EXHk, EYHa, EYHb, EYHc, EYHd, EYHe, EYHf, EYHg, EYHh, EYHi, EYHk

-SSJ3 tensile (6 pieces)

F82H EB WM: 27W0, 27W1, 27W2, 27W3, 27W4, 27W5

MFE-RB-15J, 400°C middle holder, D-zone (~ 13.7 ~ 19.4 mm above reactor mid plane)

-hf-1/3CVN (8 pieces)

F82H HIP: BAY6, BAY7, BAY8, BAY9, BAYA, BAYC, BAYE, BAYH

-hf-1/3PCCVN (7pcs)

F82H TIG OT HAZ: 22W7, 22W8, 22W9, 22WA, 22WB, 22WC, 22WD

-Pressurized creep tube (9 pieces)

F82H IEA: 0XPA, 0YPA, 0YPB, 0YP7, 0YP9, 0XP8, 0YP5, 0YP3, 0ZP2

-SF-1 fatigue (12 pieces)

F82H IEA: 0XJ, 0Y6, 0Y7, 0Y8, 0Y9, 0YA, 0YB, 0YC, 0YD, 0YE, 0YF, 0YG

-SSJ3 tensile (36 pieces)

F82H+10BN: DY0, DY1, DY2, DY3, DY4, DY5
F82H+11BN: EY0, EY1, EY2, EY3, EY4, EY5
F82H EB HAZ: 28W0, 28W1, 28W2, 28W3, 28W4, 28W5
F82H HIP: BAY0, BAY1, BAY2, BAY3, BAY4, BAY5
F82H TIG FG HAZ: 21W0, 21W1, 21W2, 21W3, 21W4, 21W5
F82H TIG OT HAZ: 22W0, 22W1, 22W2, 22W3, 22W4, 22W5

MFE-RB-15J, 400°C middle-C region (~12.5 ~ 13.3 mm above reactor mid plane)

-hf-1/3CVN (8 pieces)

F82H IEA: 0YS, 0YT, 0YV, 0YW, 0WG, 0WH, 0WJ, 0WK

-SF-1 fatigue (10 pieces)

F82H EB WM: 27W9, 27WA, 27WC, 27WE, 27WH
F82H TIG WM: 1W8, 1W9, 1WA, 1WB, 1WC

-SSJ3 tensile (14 pieces)

F82H IEA: 0Y0, 0Y1, 0Y2, 0Y3, 0Y4, 0Y5, 0YM, 0YN
F82H TIG WM: 1W0, 1W1, 1W2, 1W3, 1W4, 1W5

MFE-RB-15J, 400°C middle-B region (~ 12.9 ~ 38.7 mm below reactor mid plane)

-hf-1/3PCCVN (3 pieces)

F82H TIG OT HAZ: 22WE, 22WF, 22W6

-Pressurized creep tube (8 pieces)

F82H+10BN: DYP9, DYP8, DYP7, DYP6
F82H+11BN: EXP0, EZP0, EYP9, EYP8

-SF-1 fatigue (10 pieces)

F82H+10BN: DYJ, DYK, DYM, DYN, DYP
F82H+11BN: EYJ, EYK, EYM, EYN, EYP

MFE-RB-15J, 400°C middle-A region (~ 39.1 ~ 57 mm below reactor mid plane)

-0.18" DCT (4 pieces)

F82H IEA: 0WEe, 0WEf, 0WEg, 0WEh

MFE-RB-15J, 400°C spanning middle-A, B and C regions (~ 3 ~ 57 mm below mid plane)

-M5PCCVN (19 pieces)

F82H+10BN: DY6, DY7, DY8
F82H+11BN: EY6, EY7, EY8
F82H EB WM: 27W6, 27W7, 27W8
F82H IEA: 0YK, 0WB, 0WC, 0WD
F82H TIG FG HAZ: 21W6, 21W7, 21W8
F82H TIG WM: 1W6, 1W7, 1WC

MFE-RB-15J, 300°C bottom-c region (~ 103 ~ 128 mm below reactor mid plane)

-0.14"DCT (7 pieces)

F82H IEA: 0VXA, 0VXB, 0VXC, 0VXD, 0VXE, 0VXF, 0VXG

-hf-1/3CVN (4 pieces)

F82H HIP: BAX6, BAX7, BAX8, BAX9

-SSJ3 tensile (3 pieces)

F82H IEA: 0X3, 0X4, 0X5

MFE-RB-15J, 300°C bottom-B region (~ 129 ~ 155 mm below mid plane)

-hf-1/3CVN (3 pieces)

F82H HIP: BAXA, BAXC, BAXE

-Pressurized creep tube (9 pieces)

F82H+10BN: DXP2, DXP3
F82H IEA: 0VP1, 0WP1, 0XP2, 0XP6, 0XP7, 0ZP0, 0ZP1

-SSJ3 tensile (4 pieces)

F82H+10BN: DX4, DX5
F82H HIP: BAX0, BAX1

MFE-RB-15J, 300°C bottom-A (~ 155 ~ 180 below reactor mid plane)

-SF-1 fatigue (15 pieces)

F82H+10BN: DXJ, DXK, DXM, DXN
F82H IEA: 0XB, 0XC, 0XD, 0XE, 0XF, 0XG, 0XH
F82H TIG WM: 1V6, 1V7, 1V8, 1V9

-SSJ3 tensile (6 pieces)

F82H+10BN: DX0, DX1, DX2, DX3
F82H TIG FG HAZ: 21V2, 21V3

MFE-RB-15J, 300°C spanning bottom-A, B and C regions (~ 155 ~ 180 mm below mid plane)

-M5PCCVN (5 pieces)

F82H+10BN: DX6, DX7
F82H+11BN: EX6, EX7
F82H TIG FG HAZ: 21V5

References

[1] A. L. Qualls, K. R. Thoms, D. W. Heatherly, and R. G. Sitterson, "Assembly of the MFE-RB-17J Experiment," Fusion Materials Semi-annual Progress Report DOE/ER/0313/35, (December 2003) 242.

[2] J. P. Robertson, K. E.Lenox, M. L. Grossbeck, A. F. Rowcliffe, S. Jitsukawa, and K. Shiba, Fusion Materials Semi-annual Progress Report DOE/ER/0313/23, (December 1997) 345.

[3] A. L. Qualls, Fusion Materials Semi-annual Progress Report DOE/ER/0313/28, (June 2000) 266.

[4] T. Hirose, H. Tanigawa, M. Ando, A. Kohyama, Y. Katoh and M. Narui, "SF-1 Radiation effects on low cycle fatigue properties of reduced activation ferritic/martensitic steels, " Journal of Nuclear Materials, 307-311 (2002) 304.

[5] K. Shiba, A. Hishinuma, A. Tohyama and K. Masamura, "Properties of Low Activation Ferritic Steel F82H IEA Heat -Interim Report of IEA Round-robin Tests (1)-," JAERI-Tech 97-038 (1997).

[6] T. Sawai, K. Shiba and A. Hishinuma, “Microstructure of welded and thermal-aged low activation steel F82H IEA heat,” Journal of Nuclear Materials, 283-287 (2000) 657.

[7] H. Tanigawa, T. Hirose, K. Shiba, R. Kasada, E.Wakai, H. Serizawa, Y. Kawahito, S. Jitsukawa, A. Kimura, Y. Kohno, A. Kohyama, S. Katayama, H. Mori, K. Nishimoto, R.L. Klueh, M.A. Sokolov, R.E. Stoller, S.J. Zinkle, " Technical issues of reduced activation ferritic/martensitic steels for fabrication of ITER test blanket modules," Fusion Engineering and Design 83 (2008) 1471.

[8] H. Ogiwara, H. Tanigawa, T. Hirose, M. Enoeda and M. Akiba, "Impact Properties of Reduced Activation Ferritic/Martensitic Steel, F82H Jointed by Hot Isostatic Pressing," to be published in Journal of Nuclear Materials.

[9] E. Wakai, M. Sato, T. Sawai, K. Shiba and S. Jitsukawa, “Mechanical properties and microstructure of F82H steel doped with boron or boron and nitrogen as a function of heat treatment,” Materials Transactions. Vol. 45, no. 2, (2004) 407.

[10] T. Sawai, K. Shiba and A. Hishinuma "Microstructure of welded and thermal-aged low activation steel, F82H IEA heat," Journal of Nuclear Materials, 283-287 (2000) 657.

[11] K. Shiba, M. Enoeda and S. Jitsukawa, "Reduced activation martensitic steels as a structural material for ITER test blanket," Journal of Nuclear Materials, 329-333 (2004) 243.

[12] B. van der Schaaf, D.S. Gelles, S. Jitsukawa, A. Kimura, R.L. Klueh, A. Möslang, G.R. Odette, "Progress and critical issues of reduced activation ferritic/martensitic steel development," Journal of Nuclear Materials 283-287 (2000) 52.

[13] P. Miao, G.R. Odette, T. Yamamoto, M. Alinger, D. Hoelzer and D. Gragg, "Effects of consolidation temperature, strength and microstructure on fracture toughness of nanostructure ferritic alloys," Journal of Nuclear Materials, 367–370 (2007) 208.