NEUTRON DOSIMETRY AND DAMAGE CALCULATIONS FOR THE JP-17, 18, and 19 EXPERIMENTS IN HFIR

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OBJECTIVE

To provide dosimetry and damage analysis for fusion materials irradiation experiments.

SUMMARY

Neutron fluence measurements and radiation damage calculations are reported for the joint U.S.-Japanese experiments JP-17, 18, and 19 in the target of the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). These experiments were irradiated at 85 MW for two cycles resulting in 43.55 EFPD for JP-17 and 42.06 EFPD for JP-18 and 19. The maximum fast neutron fluence >0.1MeV was about 3.7E+21 n/cm^2 for all three irradiations, resulting in about 3 dpa in 316 stainless steel.

PROGRESS AND STATUS

The fabrication and irradiation of the JP-17, 18, and 19 experiments have been described previously.[1,2] The JP-17 irradiation was conducted from December 31, 1991 to February 27, 1992 for an exposure of 43.553 EFPD at 85 MW. The JP-18 and -19 irradiations were in the reactor for the same exposure of 42.058 EFPD from August 28, 1991 to October 19, 1991.

Small dosimetry capsules measuring about 0.05" in diameter by 0.25" in length were located at 8 different positions in the JP-18 and -19 assemblies and at 7 positions in JP-17. Each dosimetry capsule contained milligram quantities of Fe, Ni, Ti, Nb, 0.1% Co-Al, and 80.2% Mn-Cu. Following the irradiation, selected capsules from each irradiation were disassembled in hot cells and subsequently gamma counted at ORNL.

The gamma-counting results were forwarded to Pacific Northwest Laboratory (PNL) for analysis. The measured activities were converted to activation rates, as listed in Table 1, by correcting for burnup of the reacting and product atoms, gamma self-absorption, decay of the product isotopes during and after irradiation, isotopic abundance, and atomic weight. Burnup corrections are based on an iterative procedure for the thermal/epithermal monitor reactions. The resultant estimates of the thermal/epithermal neutron fluences were then used to calculate burnup corrections for the threshold fast neutron monitor reactions. Burnup corrections averaged 5-10% for the thermal/epithermal reactions and only a few percent for the threshold reaction rates. The activation rates listed in Table 1 are normalized to full reactor power of 85 MW and have a net absolute uncertainty of about 5%.

The fast neutron reactions, ^{54}Fe(n,p)^{54}Mn and ^{55}Mn(n,2n)^{54}Mn, for all three irradiations appear to fall on a smooth curve when plotted versus the height relative to the HFIR midplane. The thermal neutron activities for the ^{59}Co and ^{93}Nb capture reactions also fall on a very similar curve for the JP-18 and -19 reactions. The best fit to all four reactions results in a global equation $A(X) = A(0)\ (1 - 9.31E\text{-}4\, X^2)$ where A(0) is the midplane value and X is the height in cm.

For the JP-17 irradiation, the thermal neutron activities for the ^{59}Co and ^{93}Nb capture reactions were about 25% lower than for the JP-18 and 19 irradiations, although the fast neutron reaction rates were about the same for all three experiments. The reason for this difference is not known but may be due to a thermal neutron flux depression effect due to other materials that were co-irradiated in the target region.

Midplane activation rates were used as input to the STAY'SL computer code[3] to adjust the neutron flux spectrum determined previously in HFIR.[4] STAY'SL performs a generalized least-squares adjustment of all measured and calculated values including the measured activities, calculated spectra, and neutron cross sections. Neutron cross sections and their uncertainties were generally taken from ENDF/B-V.[5] The adjusted neutron fluence values are listed in Table 2. The activation rates and the derived neutron spectra and fluences are in excellent agreement with previous measurements in the target position of HFIR,[4,6] except for the thermal flux depression noted for JP-17.

Neutron damage calculations with the SPECTER computer code[7] were performed for the midplane position. Midplane dpa and helium (appm) values are also listed in Table 2. The fluence and damage values at other experimental positions can be calculated by the gradient equation given above. Damage parameters for other elements or compounds have been calculated and are readily available on request.

Helium production in nickel and nickel alloys requires a more complicated non-linear calculation.[8] Helium production in 316 stainless steel is listed as a function of height in Table 3.

FUTURE WORK

Dosimeters have been received from the HFIR-JP-23 irradiation and for the COBRA-1A1 irradiation in the Experimental Breeder Reactor II.

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TABLE 1 - Activation Rates (at/at-s) - HFIR-MFE-JP-17, 18, 19

Sample Ht,cm	$^{54}Fe(n,p)^{54}Mn$ (x10^{-11})	$^{93}Nb(n,\gamma)^{94}Nb$ (x10^{-9})	$^{59}Co(n,\gamma)^{60}Co$ (x10^{-8})	55Mn(n,2n)^{54}Mn (x10^{-13}O
17-23 24.1	2.60	1.03	2.43	0.76
17-50 -0.9	-	-	4.57	1.77
17-54 -10.5	5.12	1.79	4.15	1.47
17-55 -18.2	3.89	1.30	2.76	1.11
17-57 -24.3	2.41	-	2.24	-
18-22 22.9	2.66	1.27	3.05	0.81
18-32 -4.6	5.34	2.40	5.64	1.49
18-34 -16.8	3.87	1.77	4.24	1.11
19-65 3.1	5.41	2.50	6.10	1.56
19-72 -4.6	5.27	2.48	6.07	1.52

TABLE 2 - Midplane Fluence and Damage Values for HFIR-MFE-JP-17, 18, 19

	JP-17	JP-18,19		JP-17		JP-18/19	
	Neutron Fluence .x10^{21}n/cm2		Element	dpa	He.appm	dpa	He.appm
Total	12.60	14.78	C	2.65	6.5	2.69	6.2
Therma(<.5eV)	4.78	6.44	Al	4.91	2.5	4.89	2.4
0.5eV - 0.1MeV	4.09	4.60	V	3.50	0.1	3.48	0.1
>0.1MeV	3.73	3.74	Cr	3.11	0.6	3.07	0.5
>1MeV	1.96	1.90	Fe	2.75	1.0	2.71	1.0

Ni Fast	2.93	13.6	2.93	12.7
59-Ni	<u>0.50</u>	<u>283.5</u>	<u>0.85</u>	<u>483.9</u>
Total	3.43	297.1	3.78	496.6
Cu	3.56	0.9	3.53	0.9

TABLE 3 - DPA and He Values for 316 SS in HFIR-MFE-JP-17, 18, 19
(includes ^{59}Ni effect)

JP-17			JP-18/19	
Ht (+cm)	dpa	He (appm)	dpa	He (appm)
0	2.90	39.4	2.91	65.3
3	2.87	38.8	2.89	64.3
6	2.80	37.0	2.82	61.4
9	2.69	34.2	2.70	56.6
12	2.52	30.3	2.53	50.2
15	2.30	25.6	2.30	42.4
18	2.03	20.4	2.03	33.7
21	1.71	14.9	1.71	24.5
24	1.35	9.6	1.35	15.6

316SS = Fe(0.645), Ni(0.13), Cr(0.18), Mn(0.019), Mo(0.026) wt%