NEUTRON DOSIMETRY AND DAMAGE CALCULATIONS FOR THE HFIR-CTR-62 and 63 IRRADIATIONS - L. R. Greenwood (Pacific Northwest National Laboratory)* and C. A. Baldwin (Oak Ridge National Laboratory)

OBJECTIVE

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

SUMMARY

Neutron fluence measurements and radiation damage calculations are reported for the CTR-62 and –63 experiments, which were conducted in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). The maximum neutron fluence at midplane was 6.9E+22 n/cm^2 resulting in about 14 dpa in type 316 stainless steel.

PROGRESS AND STATUS

The CTR-62 and -63 experiments were irradiated in the target position of the HFIR during cycles 335 through 341, starting April 13, 1995, and ending December 16, 1995, for a net exposure of 180.45 effective full power days at 85 MW. The two irradiation assemblies were nearly identical and they were co-irradiated in HFIR. The goal of the experiment was to irradiate reduced-activation and conventional ferritic steels at temperatures of 300 and 400°C. A complete description of the specimen matrix and irradiation assembly has been published previously.[1]

Neutron dosimetry capsules were inserted in between the specimen holders, as shown in reference 1. The dosimetry capsules consisted of small, welded aluminum tubes measuring about 1.5 mm in diameter and 6.4 mm in length. Each tube contained small monitor wires of Cu, Fe, Ni, Ti, Nb, 80.2% Mn-Cu alloy, and 0.112% Co-Al alloy. Five dosimetry capsules were irradiated with each of the experiments; however, only six of the capsules were analyzed. Each capsule was opened in a hot cell at ORNL and each individual monitor wire was gamma counted to determine the residual activation. Due to the delay between the end of irradiation and the opening of the capsules for analysis, the shorter-lived isotopes could not be detected. The activation results were then forwarded to PNNL for analysis.

The measured activities were converted to activation rates as listed in Table 1 by correcting for nuclear burnup, gamma self-absorption, decay 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 20-30% for the thermal/epithermal reactions and 5-30% 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 activation rates in Table 1 were fit to a polynomial function of form $f(x) = f(0)\ [\ 1 + a\ x^2\ ]$, where x is the vertical height from reactor centerline in cm. All of the data are reasonably well fit

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by the average polynomial (coefficient a = -1.06 x 10^{-3}). Midplane activation rates were then used in the STAY'SL[2] computer code to adjust the neutron flux spectrum determined in previous spectral measurements in the target position in HFIR.[3] 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 the ENDF/B-V[4] evaluation. The resultant 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 HFIR target position.[3]

Table 1. Activation Rates (at/at-s) - HFIR CTR-62 and -63

Experiment/ Monitor	Ht,cm	$^{54}Fe(n,p)^{54}Mn$ (E-11)	$^{63}Cu(n,\alpha)^{60}Co$ (E-13)	$^{55}Mn(n,2n)^{54}Mn$ (E-13)	$^{59}Co(n,\gamma)^{60}Co$ (E-8)	$^{93}Nb(n,\gamma)^{94}Nb$ (E-9)
62-J1	18.3	3.94	2.45	1.22	5.38	1.74
62-J3	0.0	5.60	3.70	1.81	7.09	2.68
62-J5	-18.3	-	2.32	1.17	4.53	1.68
63-J6	21.3	3.22	1.98	0.97	2.97	1.43
63-J8	6.1	-	3.59	1.76	7.23	2.65
63-J11	-15.2	4.38	2.75	-	-	1.97

Table 2. Midplane Fluence and Damage Values for HFIR CTR-62 and -63

Neutron Fluence,n/cm2		Element	dpa	He,appm
Total	6.91E+22	C	12.1	26.0
Thermal (<.5 eV)	3.15E+22	Al	21.9	9.8
0.5 eV - 0.1 MeV	2.08E+22	V	15.6	0.33
> 0.1 MeV	1.68E+22	Cr	13.7	2.3
> 1 MeV	8.50E+21	Fe	12.1	4.0
		Ni Fast	13.1	53.7
		59-Ni	11.5	6526.5
		Total Ni	24.6	6580.3
		Cu	105	3.6

Neutron damage calculations were performed using the SPECTER computer code[5] at the midplane position of HFIR. 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.[6] Helium production in stainless steel is detailed in Table 3.

FUTURE WORK

Additional experiments are in progress in HFIR.

Table 3. dpa and He Values for 316 SS in HFIR CTR-62 and -63 (Includes ^{59}Ni effect)

Height,cm	dpa	He,appm
0	14.0	820
3	13.9	810
6	13.5	779
9	12.9	729
12	12.0	659
15	10.9	570
18	9.5	464

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

REFERENCES

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