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Neutron Exposure Parameters For The Dosimetry Capsule in The Heavy-Section Steel Irradiation Program Tenth Irradiation Series

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Abstract

This report describes the computational methodology for the least-squares adjustment of the dosimetry data from the HSSI 10.0D dosimetry capsule with neutronics calculations. It presents exposure rates at each dosimetry location for the neutron fluence greater than 1.0 MeV, fluence greater than 0.1 MeV, and displacements per atom. Exposure parameter distributions are also described in terms of three-dimensional fitting functions. When fitting functions are used it is suggested that an uncertainty of 6% (1 σ) should be associated with the exposure rate values. The specific activity of each dosimeter at the end of irradiation is listed in the Appendix.

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Foreword

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This report is designated HSSI Report 19. Reports in this series are listed below:

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Neutron Exposure Parameters for the Dosimetry Capsule in the Heavy-Section Steel Irradiation Program Tenth Irradiation Series

I. Remec, C. A. Baldwin, and F. B. K. Kam

Introduction

A variety of experiments and analyses for assessing the effects of neutron irradiation on metallurgical test specimens have been sponsored by the U.S. Nuclear Regulatory Commission (NRC). Results from these investigations should provide information that will lead to an improved understanding of the processes of neutron damage to pressure vessels and other structural materials. Thus, the lifetime of many nuclear reactors may be extended through knowledge gained from these experiments, and confidence in the accuracy of information relative to the integrity of reactor pressure vessels and of related components should be enhanced.

A new facility in which to perform the Heavy-Section Steel Irradiation (HSSI) Program irradiations was installed at the University of Michigan's Ford Nuclear Reactor in Ann Arbor, Michigan. Before any metallurgical capsule irradiation, an extensive dosimetry experiment was carried out to assess the neutron irradiation exposure rates and their distributions. The dosimetry experiment HSSI 10.0D included a simulated metallurgical capsule with special holes drilled through a steel block to allow precise positioning of the dosimeter tubes. A comprehensive set of dosimeters was irradiated inside the dosimeter tubes. In addition to the dosimeters inside the simulated capsule, removable dosimeter tube (RDT) dosimeters were irradiated just behind the thermal shield, outside the capsule. The RDT dosimeters can be removed on a cycle-to-cycle basis.

This report describes the computational methodology for the least-squares adjustment of the dosimetry data from the HSSI 10.0D dosimetry capsule with neutronics calculations. It presents exposure parameter rates at each dosimetry location for the neutron fluence rate greater than 1.0 MeV, fluence rate greater than 0.1 MeV, and displacement-per-atom (dpa) rate. Irradiation exposure rates determined should be useful for the estimation of irradiation times and exposure parameters of current and future HSSI irradiation experiments.

Methodology of the Analysis

To determine the neutron irradiation exposure parameters, a neutron spectrum adjustment procedure was used that combines transport calculations of the neutron field and measurements using radiometric monitors.

The input data required in this analysis consisted of the following:

- neutron fluence rate spectrum obtained from transport calculations at each dosimetry location,
- measured activity of each dosimeter,
- cross section for each dosimetry reaction used,
- location of each dosimetry set, and
- response function for each irradiation exposure parameter.

Neutron transport calculations for the HSSI 10.0D capsule were performed by Williams.* The three-dimensional fluence rate spectra for each dosimetry location were obtained by the flux synthesis method, which combines the results of two-dimensional and one-dimensional transport theory calculations. A 47-group neutron spectrum was provided at each of the dosimetry locations in the capsule and for the three fuel cycles.

A comprehensive set of radiometric monitors was irradiated in the dosimetry capsule. It consisted of ^{59}Co and ^{109}Ag thermal dosimeters and ^{54}Fe and ^{63}Cu threshold dosimeters, which were irradiated in the 27 locations inside the capsule. At five locations, ^{58}Ni, ^{46}Ti, ^{237}Np, and ^{238}U dosimeters were also used. At the five locations where fission dosimeters were used, the dosimeters were irradiated under 0.89-mm-thick (35-mil-thick) gadolinium covers; at the other locations, dosimeters were irradiated bare. The arrangement of the irradiation locations inside the capsule, labeled as P1 to P27, and the coordinate system are shown in Fig. 1. These labels and/or location coordinates are used throughout the tables in this report, where activities or irradiation exposure parameters are listed. The relative location of the irradiation capsule with respect to the reactor core is shown in Figs. 2 and 3. The thickness of materials between the core and the dosimetry capsule are shown in Fig. 4. The specific activities of neutron dosimeters at the end of irradiation are given in the Appendix.

The activation cross-section library and covariance information in 640 energy groups were created from the IRDF 90 and ENDF V dosimetry files. To account for the gadolinium cover, a modified set of cross sections was generated, where the 640-group cross sections were multiplied by attenuation factors defined as:

$$AF = \exp\left[- (D \times AV/AT) \times TH \times CS \right] , \quad (1)$$

where

AF = attenuation factor,
D = density of cover material (7.9004 g/cm^3 for Gd),
AV = Avogadros number,
AT = atomic weight (157.25 for Gd),
TH = thickness of the cover (0.89 mm, 35 mil),
CS = total absorption cross section of Gd (taken from the IRDF 90 file).

This formula is, of course, a crude approximation only and does not consider the geometry of the covers and the dosimeters. However, it appears to be reasonably accurate for the current application. The resulting cross sections were then combined with the cross sections for bare dosimeters and were converted to 32 energy groups for use in the adjustment runs. Cross-section covariance matrixes were also converted to the 32-group structure. Computer code FLXPRO from the LSL-M2 code package was used for this purpose.[1]

*M. L. Williams, Louisiana State University, Nuclear Science Center, personal communication to F. B. K. Kam.

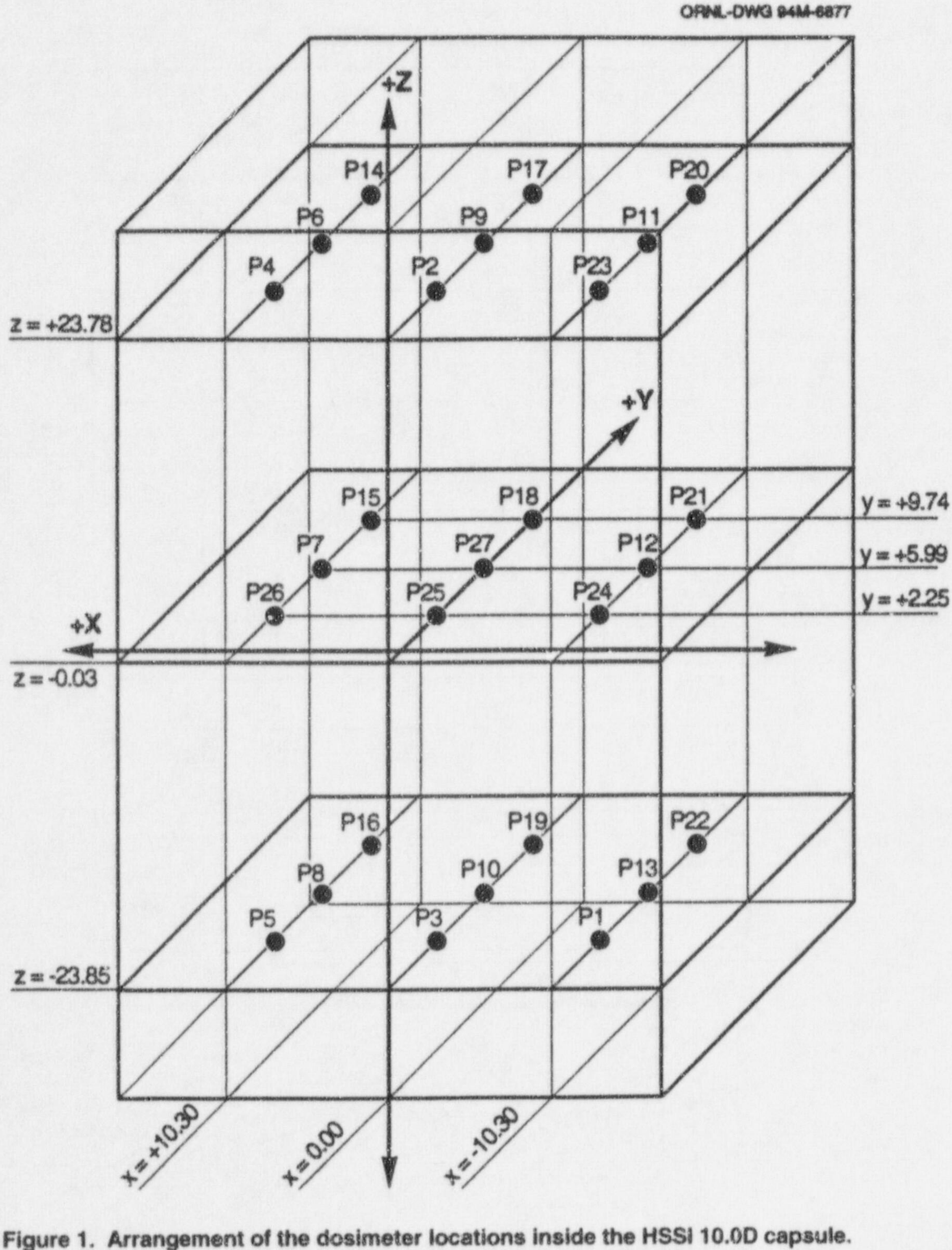


Figure 1. Arrangement of the dosimeter locations inside the HSSI 10.0D capsule. Origin of the coordinate system is in the center of the front face of the capsule.

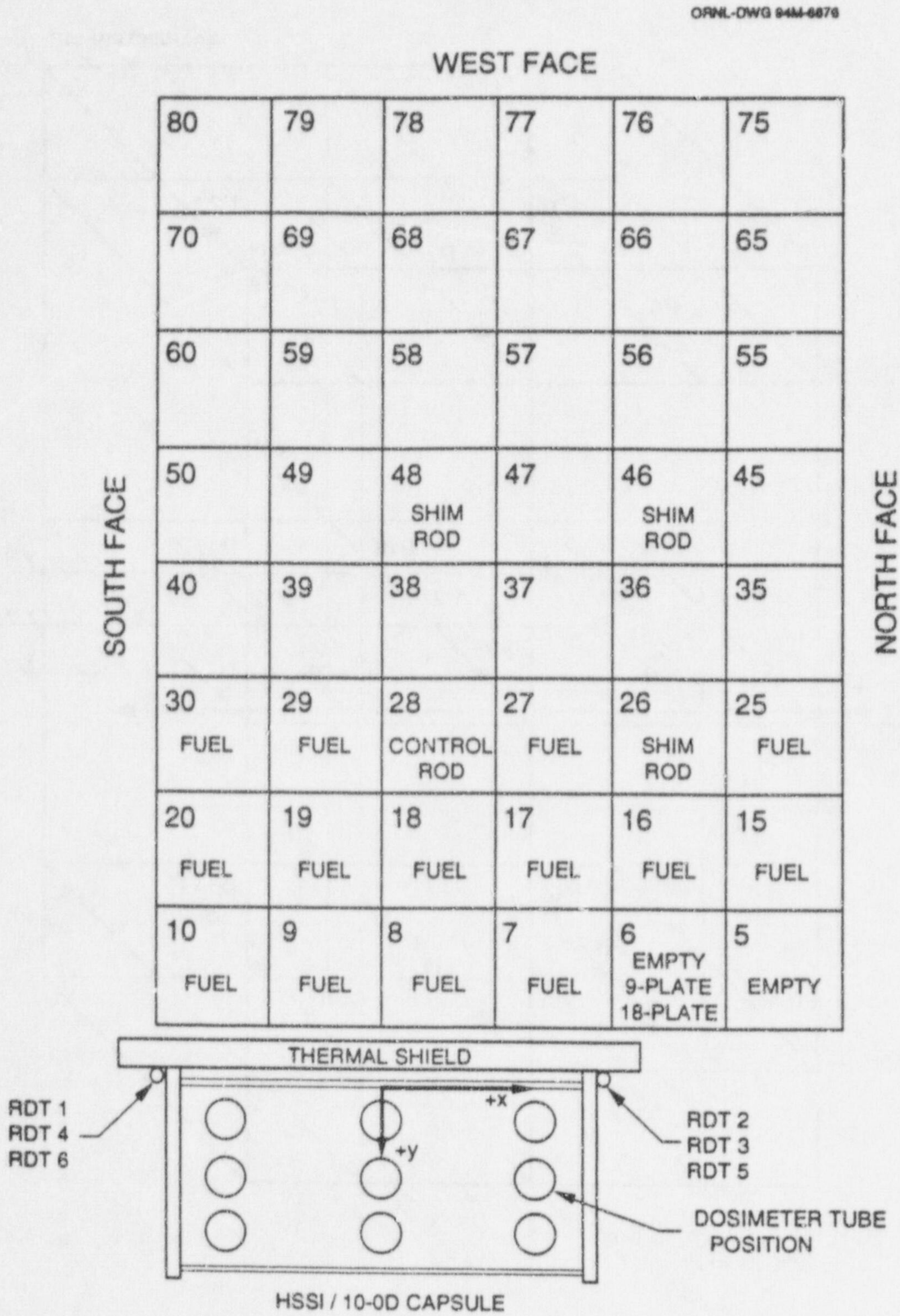


Figure 2. Location of the HSSI 10.0D capsule relative to the reactor core—horizontal cross section.

ORNL-DWG 94M-6878

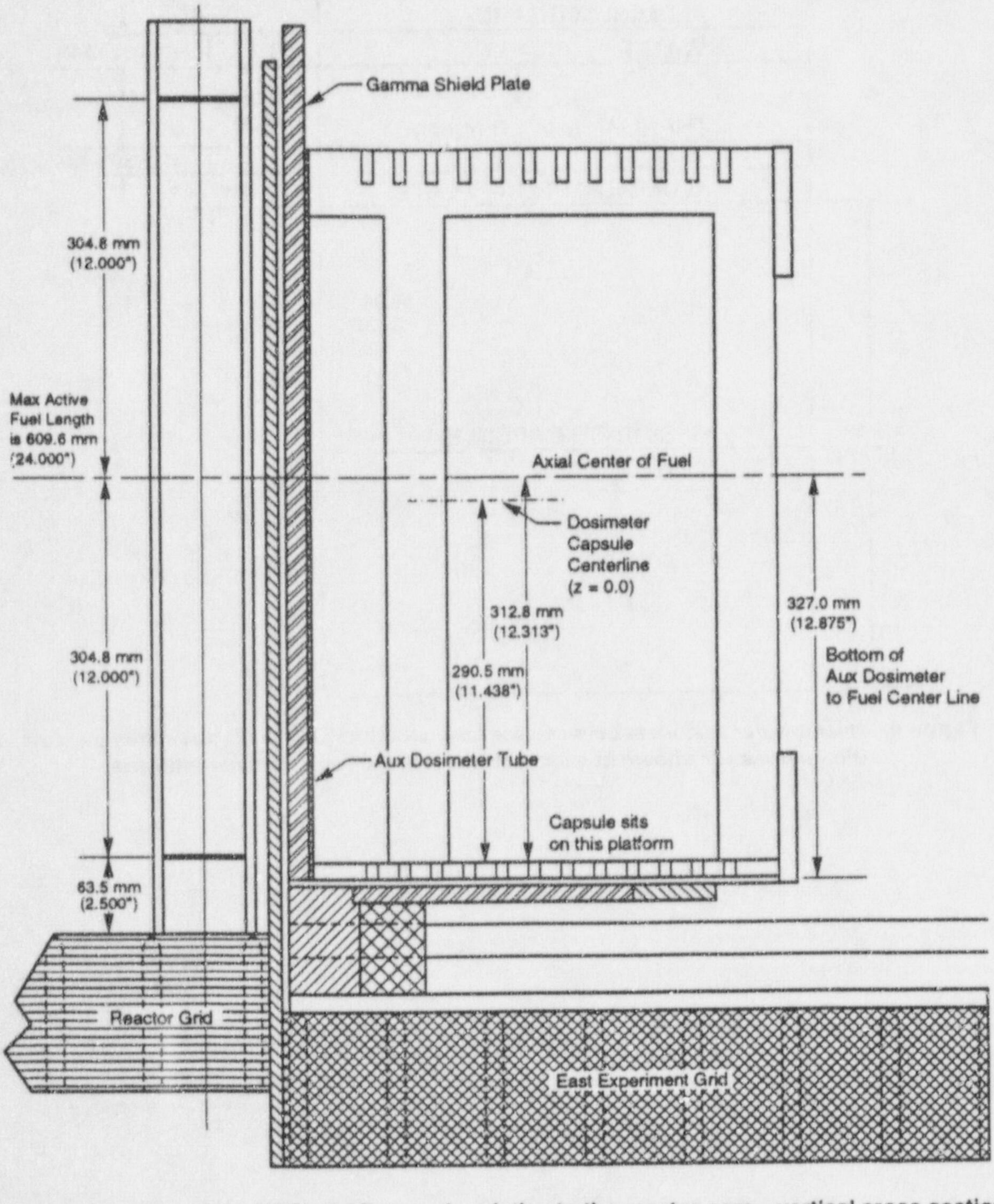


Figure 3. Location of the HSSI 10.0D capsule relative to the reactor core—vertical cross section.

ORNL-DWG 94M-6679

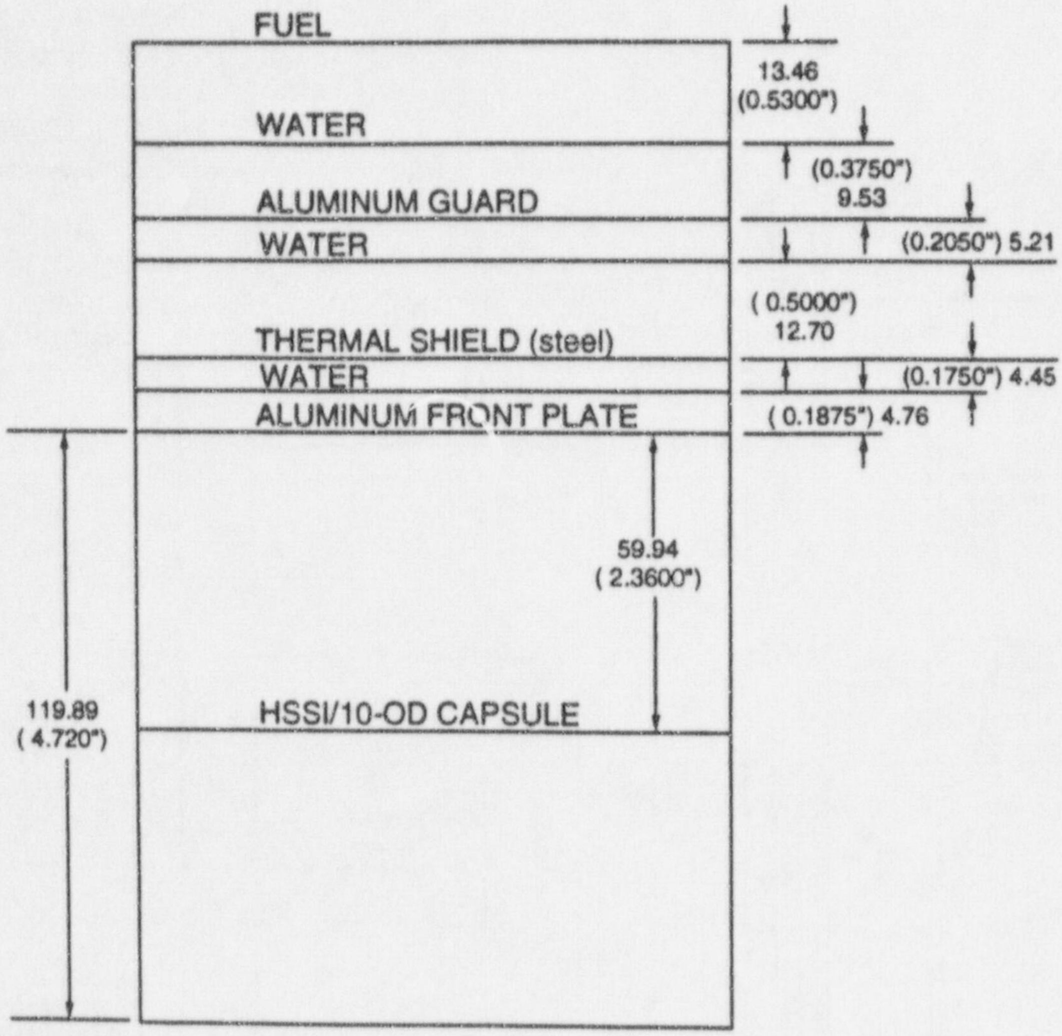


Figure 4. Thickness of materials between the core and the HSSI 10.0D dosimetry capsule. Dimensions are shown in millimeters and in inches within parentheses.

Measured activities were converted to reaction probabilities, taking into account the reactor power history for the cycles of the irradiation. Computer code ACT from the LSL-M2 code package was used for this purpose.[1] The reactor power history for the three cycles considered is shown in Table A.2 of the Appendix.

The spectrum covariance matrix was used, as calculated for the simulated surveillance capsule position for the Oak Ridge Research Reactor Poolside Facility Metallurgical Experiment.[2,3] The original calculation of the fluence variance-covariances covered only the range from 18 to 0.1 MeV. Therefore, two energy groups from 1 E-5 to 0.1 eV and from 0.1 eV to 0.1 MeV were added, with large variances of 150% and 75%, respectively, and small correlations of 0.1 and 0.2. The spectrum covariance matrix was converted in the group structure used in the adjustment with the computer code FLXPRO. Obviously the assumed spectrum variance-covariance information is only approximate. However, it does not appear to be critical for the analysis since comprehensive dosimetry measurements are available, and in such cases the adjustment results are generally not sensitive to the details in the spectrum covariance matrix.

For the least-squares neutron spectrum adjustment calculations, computer code LSL-M2 was used.[1] The adjustment runs provided the adjusted neutron spectrum at each location considered. The neutron irradiation exposure rates selected to characterize the irradiation conditions are neutron fluence rate with energy greater than 1 MeV ($F_{E>1\,MeV}$), neutron fluence rate with energy greater than 0.1 MeV ($F_{E>0.1\,MeV}$), and dpa rate. Fluence rates, $F_{E>1\,MeV}$ and $F_{E>0.1\,MeV}$, are obtained as sums of group fluxes over the corresponding energy range; however, for the dpa rate calculations, the cross sections used were taken from Ref. 4. These exposure parameters were determined for each dosimetry location and are listed in Tables 1 through 3. Listed exposure parameter rates are averages, representative of the three fuel cycles during which the HSSI 10.0D capsule was irradiated. Exposure parameters are given for reactor full-core power of 2 MW.

The exposure parameters obtained from the adjustment runs were fitted to an appropriate three-dimensional function. It is desirable to describe the space variation of irradiation parameters by means of a three-dimensional function because the values of exposure parameters are often needed at locations other than the dosimetry locations. The function, used for fitting the irradiation parameters, was of the form

$$F(x,y,z) = A \cos [B_x (x - x_0)] \cos [B_z (z - z_0)] \exp (-\lambda y) \quad . \qquad (2)$$

The constants A, B_x, x_0, B_z, z_0, and λ were determined with least squares fitting and are listed in Table 4 for each of the three irradiation parameters.

Table 1. Adjusted average fast fluence rates, $F_{E>1 MeV}$, for cycles 338B, 339B, and 340A for all dosimetry locations

Location	Coordinates			$F_{E>1 MeV}$
	X (cm)	Y (cm)	Z (cm)	($cm^{-2}s^{-1}$)
P23	-10.30	2.25	23.78	5.017E+11
P2	0.00	2.25	23.78	7.866E+11
P4	10.30	2.25	23.78	7.862E+11
P11	-10.30	5.99	23.78	2.689E+11
P9	0.00	5.99	23.78	4.250E+11
P6	10.30	5.99	23.78	4.044E+11
P20	-10.30	9.74	23.78	1.392E+11
P17	0.00	9.74	23.78	2.195E+11
P14	10.30	9.74	23.78	2.060E+11
P24	-10.30	2.25	-0.03	7.975E+11
P25	0.00	2.25	-0.03	1.295E+12
P26	10.30	2.25	-0.03	1.320E+12
P12	-10.30	5.99	-0.03	4.391E+11
P27	0.00	5.99	-0.03	7.084E+11
P7	10.30	5.99	-0.03	6.780E+11
P21	-10.30	9.74	-0.03	2.298E+11
P18	0.00	9.74	-0.03	3.678E+11
P15	10.30	9.74	-0.03	3.453E+11
P1	-10.30	2.25	-23.85	3.710E+11
P3	0.00	2.25	-23.85	5.885E+11
P5	10.30	2.25	-23.85	5.933E+11
P13	-10.30	5.99	-23.85	2.024E+11
P10	0.00	5.99	-23.85	3.229E+11
P8	10.30	5.99	-23.85	3.100E+11
P22	-10.30	9.74	-23.85	1.060E+11
P19	0.00	9.74	-23.85	1.689E+11
P16	10.30	9.74	-23.85	1.587E+11

Table 2. Adjusted average fast fluence rates, $F_{E > 0.1\ MeV}$, for cycles 338B, 339B, and 340A for all dosimetry locations

Location	Coordinates			$F_{E > 0.1\ MeV}$
	X	Y	Z	
	(cm)	(cm)	(cm)	($cm^{-2}s^{-1}$)
P23	-10.30	2.25	23.78	1.254E+12
P2	0.00	2.25	23.78	2.027E+12
P4	10.30	2.25	23.78	1.885E+12
P11	-10.30	5.99	23.78	8.018E+11
P9	0.00	5.99	23.78	1.315E+12
P6	10.30	5.99	23.78	1.124E+12
P20	-10.30	9.74	23.78	4.734E+11
P17	0.00	9.74	23.78	7.770E+11
P14	10.30	9.74	23.78	6.372E+11
P24	-10.30	2.25	-0.03	2.089E+12
P25	0.00	2.25	-0.03	3.483E+12
P26	10.30	2.25	-0.03	3.297E+12
P12	-10.30	5.99	-0.03	1.378E+12
P27	0.00	5.99	-0.03	2.302E+12
P7	10.30	5.99	-0.03	1.981E+12
P21	-10.30	9.74	-0.03	8.248E+11
P18	0.00	9.74	-0.03	1.371E+12
P15	10.30	9.74	-0.03	1.126E+12
P1	-10.30	2.25	-23.85	9.556E+11
P3	0.00	2.25	-23.85	1.559E+12
P5	10.30	2.25	-23.85	1.461E+12
P13	-10.30	5.99	-23.85	6.202E+11
P10	0.00	5.99	-23.85	1.027E+12
P8	10.30	5.99	-23.85	8.852E+11
P22	-10.30	9.74	-23.85	3.707E+11
P19	0.00	9.74	-23.85	6.142E+11
P16	10.30	9.74	-23.85	5.047E+11

Table 3. Adjusted average displacement-per-atom (dpa) rates for cycles 338B, 339B, and 340A for all dosimetry locations

Location	Coordinates			dpa
	X (cm)	Y (cm)	Z (cm)	(s^{-1})
P23	-10.30	2.25	23.78	7.410E-10
P2	0.00	2.25	23.78	1.174E-09
P4	10.30	2.25	23.78	1.143E-09
P11	-10.30	5.99	23.78	4.244E-10
P9	0.00	5.99	23.78	6.797E-10
P6	10.30	5.99	23.78	6.163E-10
P20	-10.30	9.74	23.78	2.340E-10
P17	0.00	9.74	23.78	3.746E-10
P14	10.30	9.74	23.78	3.304E-10
P24	-10.30	2.25	-0.03	1.187E-09
P25	0.00	2.25	-0.03	1.936E-09
P26	10.30	2.25	-0.03	1.921E-09
P12	-10.30	5.99	-0.03	7.002E-10
P27	0.00	5.99	-0.03	1.142E-09
P7	10.30	5.99	-0.03	1.046E-09
P21	-10.30	9.74	-0.03	3.917E-10
P18	0.00	9.74	-0.03	6.363E-10
P15	10.30	9.74	-0.03	5.616E-10
P1	-10.30	2.25	-23.85	5.499E-10
P3	0.00	2.25	-23.85	8.791E-10
P5	10.30	2.25	-23.85	8.622E-10
P13	-10.30	5.99	-23.85	3.201E-10
P10	0.00	5.99	-23.85	5.182E-10
P8	10.30	5.99	-23.85	4.747E-10
P22	-10.30	9.74	-23.85	1.791E-10
P19	0.00	9.74	-23.85	2.898E-10
P16	10.30	9.74	-23.85	2.561E-10

Table 4. Parameters from the three-dimensional fits of the exposure parameter rates*

(A) Fitting parameters for $F_{E>1\,MeV}$

	A ($cm^{-2}s^{-1}$)	B_x (cm^{-1})	x_0 (cm)	B_z (cm^{-1})	z_0 (cm)	λ (cm^{-1})
Average†	2.021E+12	0.06082	5.071	0.04252	2.030	0.1707

(B) Fitting parameters for $F_{E>0.1\,MeV}$

	A ($cm^{-2}s^{-1}$)	B_x (cm^{-1})	x_0 (cm)	B_z (cm^{-1})	z_0 (cm)	λ (cm^{-1})
Average†	4.887E+12	0.06920	3.303	0.04337	1.706	0.1286

(C) Fitting parameters for dpa rate

	A (s^{-1})	B_x (cm^{-1})	x_0 (cm)	B_z (cm^{-1})	z_0 (cm)	λ (cm^{-1})
Average†	2.890E-09	0.06404	4.272	0.04262	1.998	0.1535

*The fitting function is of the form

$$F(x,y,z) = A \cos[B_x(x - x_0)] \cos[B_z(z - z_0)] \exp(-\lambda y),$$

and the coordinate system is as shown in Figs. 2 and 3.

†Average exposure parameter rates for cycles 338B, 339B, and 340A were used to calculate three-dimensional fitting parameters.

Results

Information presented herein consists of the following:

1. The fluence rates, $F_{E>1\,MeV}$ and $F_{E>0.1\,MeV}$, and the dpa rates for each dosimetry location are listed in Tables 1 through 3. Values given were obtained from the least-squares adjustment procedure and are the averages of the exposure parameters for the cycles 338B, 339B, and 340A.

2. Constants derived for the fitting function (Eq. 2) for each exposure parameter are given in Table 4.

Exposure parameter rates at any location (*x*, *y*, or *z*) can be readily calculated using Eq. 2 and the constants listed in Table 4. The coordinates of the point where exposure parameter rates are needed must be given in the coordinate system, as shown in Figs. 2 and 3. Time-integrated exposure parameters can be obtained by multiplying the exposure rates by the time of irradiation expressed in effective full-power seconds.

Uncertainties are not accurately propagated through all the computational sequences, and there may be biases that are not recognized. However, uncertainties obtained from the least-squares adjustment procedure take into account estimated uncertainties of neutronics calculations and measured activities. Uncertainties of the exposure parameter rates obtained from the adjustment calculations are ~5% (1 σ). When irradiation exposure rates are calculated from Eq. 2, uncertainty arising from the three-dimensional fitting should be also considered. Differences between the exposure parameter rates at the dosimetry locations as obtained from the adjustment and as calculated from the fitting function are on the order of 3% (average), as illustrated in Tables A.5 through A.7 in the Appendix. Therefore, for the irradiation exposure rates obtained from Eq. 2, an uncertainty of 6% (1 σ) is considered to be a good estimate.

Conclusion

The irradiation exposure parameter rate distributions in the HSSI 10.0D dosimetry capsule were determined. Exposure rate distributions are described in terms of values at dosimetry locations and in terms of three-dimensional fitting functions. When fitting functions are used, it is suggested that an uncertainty of 6% (1 σ) be associated with the exposure rate values. Irradiation exposure rates determined should be useful for the estimation of irradiation times and exposure parameters of current and future HSSI metallurgical irradiation experiments.

References

1. F. W. Stallmann, Lockheed Martin Energy Research Corporation, Oak Ridge Natl. Lab., Oak Ridge, Tenn., *LSL-M2: A Computer Program for Least-Squares Logarithmic Adjustment of Neutron Spectra*, USNRC Report NUREG/CR-4349 (ORNL/TM-9933), March 1986.

2. R. E. Maerker et al., Electric Power Research Institute, Palo Alto, Calif., *Revision and Extension of the Data Base in the LEPRICON Dosimetry Methodology*, EPRI NP-3841, January 1985.

3. F. W. Stallmann, Lockheed Martin Energy Research Corporation, Oak Ridge Natl. Lab., Oak Ridge, Tenn., *Determination of the Damage Exposure Parameter Values in the PSF Metallurgical Irradiation Experiment,* USNRC Report NUREG/CR-3841 (ORNL/TM-9166), October 1984.

4. American Society for Testing and Materials (ASTM), E-693, *Standard Practice for Characterizing Neutron Exposures in Ferritic Steels in Terms of Displacements Per Atom (DPA)*, Annual Book of ASTM Standards.

Appendix

The data included in this Appendix should be sufficient for another organization to recalculate the exposure parameters if fluence rate spectra are available or if neutronics calculations are performed. In particular, the data included herein are (1) specific activities of each dosimeter at the end of irradiation (EOI), (2) coordinates of each dosimeter relative to the coordinate system shown in Figs. 2 and 3, and (3) the irradiation history of the capsule. In addition, cycle-to-cycle variations caused by changes in the core configuration are discussed through a comparison of the specific activities of the removable dosimeter tube (RDT) dosimeters. Finally, the suitability of the three-dimensional fitting function for determination of the irradiation parameters is accessed.

The specific activity of each dosimeter at the end of irradiation is listed in Table A.1. The in-capsule dosimetry was irradiated for three fuel cycles. The irradiation history is given in Table A.2. Additional dosimetry in the form of Co/Al and Fe wires was located in RDTs just behind the thermal shield (Fig. 2). RDT dosimeters were changed after each fuel cycle to allow the assessment of cycle-to-cycle variations in fluence rate magnitude and spatial distribution. Because the lengths of fuel cycles did not vary significantly, a comparison of the measured specific activities can be used directly to monitor relative cycle-to-cycle changes in fluence rate. The ^{54}Mn and ^{60}Co activities provide information about the fast and thermal fluence rates, respectively. Measured specific activities of the RDT dosimeters are listed in Table A.3. Table A.4 gives a comparison of the activities for the three cycles analyzed; values given are relative to the activities measured for cycle 338B. Maximum cycle-to-cycle variations in the ^{54}Mn specific activities are on the order of 10% and 30% for the RDT at the south and north sides of the capsule, respectively. Higher variations in the RDT dosimeter activities at the north side were caused by using three different types of fuel elements in core position 6 (see Fig 2). For cycle 338B, an unfueled plug was put in position 6. For cycle 339B, a 9-plate element occasionally used for adjusting core reactivity was used. Finally, for cycle 340B, a normal 18-plate element was used in position 6. Using different types of fuel elements in core position 6 also affected the side-to-side gradient (in the direction of X axis) of the neutron field across the capsule. For the three cycles analyzed, the specific ^{54}Mn activities from the RDT on the north side of the capsule were approximately 2.0, 2.3, and 2.7 times higher, respectively, than the activities from the RDT on the south side of the capsule. However, most of the north-to-south decrease in the neutron field is because of the capsule location near the southeast core corner. The side-to-side (X axis direction) and axial (Z axis direction) variations in the specific activities of the RDT dosimeters are illustrated in Figs. A.1 through A.3. In the axial direction the ratio of maximum to minimum specific activity of ^{54}Mn is around 1.7 at both sides of the capsule and does not vary with the cycles. Figures A.4 through A.6 show that the shapes of the axial distributions of specific activities are almost the same on both sides of the capsule even though the magnitudes are different.

Tables A.5 through A.7 show the suitability of the three-dimensional fitting function for the irradiation parameters determination. The irradiation parameters $F_{E>1\,MeV}$, $F_{E>0.1\,MeV}$, and dpa rate at the dosimetry locations obtained from the adjustment procedure are compared with the values calculated using Eq. 2 and the fitting parameters from Table 4. It can be seen that the agreement between the adjusted and fitted values is good, with the average difference ranging from 2 to 3%.

Table A.1. Activities of the dosimeters in the HSSI 10.0D dosimetry capsule

Monitor ID	Reaction	Coordinates X (cm)	Y (cm)	Z (cm)	Activity* at EOI† (Bq/mg)
GS01-Co	Co-59 (n,g) Co-60	-10.300	2.250	-23.850	7.98E+02
GS01-Ag	Ag-109 (n,g) Ag-110m	-10.300	2.250	-23.850	1.26E+03
GS01-Fe	Fe-54 (n,p) Mn-54	-10.300	2.250	-23.850	1.02E+03
GS01-Cu	Cu-63 (n,a) Co-60	-10.300	2.250	-23.850	1.21E+01
GS02-Co	Co-59 (n,g) Co-60	0.000	2.250	23.780	1.63E+03
GS02-Ag	Ag-109 (n,g) Ag-110m	0.000	2.250	23.780	3.09E+03
GS02-Fe	Fe-54 (n,p) Mn-54	0.000	2.250	23.780	2.18E+03
GS02-Cu	Cu-63 (n,a) Co-60	0.000	2.250	23.780	2.55E+01
GS03-Co	Co-59 (n,g) Co-60	0.000	2.250	-23.850	1.07E+03
GS03-Ag	Ag-109 (n,g) Ag-110m	0.000	2.250	-23.850	1.99E+03
GS03-Fe	Fe-54 (n,p) Mn-54	0.000	2.250	-23.850	1.50E+03
GS03-Cu	Cu-63 (n,a) Co-60	0.000	2.250	-23.850	1.81E+01
GS04-Co	Co-59 (n,g) Co-60	10.300	2.250	23.780	1.83E+03
GS04-Ag	Ag-109 (n,g) Ag-110m	10.300	2.250	23.780	3.09E+03
GS04-Fe	Fe-54 (n,p) Mn-54	10.300	2.250	23.780	2.24E+03
GS04-Cu	Cu-63 (n,a) Co-60	10.300	2.250	23.780	2.69E+01
GS05-Co	Co-59 (n,g) Co-60	10.300	2.250	-23.850	1.25E+03
GS05-Ag	Ag-109 (n,g) Ag-110m	10.300	2.250	-23.850	1.98E+03
GS05-Fe	Fe-54 (n,p) Mn-54	10.300	2.250	-23.850	1.60E+03
GS05-Cu	Cu-63 (n,a) Co-60	10.300	2.250	-23.850	1.92E+01
GS06-Co	Co-59 (n,g) Co-60	10.300	5.990	23.780	6.05E+02
GS06-Ag	Ag-109 (n,g) Ag-110m	10.300	5.990	23.780	1.28E+03
GS06-Fe	Fe-54 (n,p) Mn-54	10.300	5.990	23.780	1.02E+03
GS06-Cu	Cu-63 (n,a) Co-60	10.300	5.990	23.780	1.13E+01
GS07-Co	Co-59 (n,g) Co-60	10.300	5.990	-0.030	1.14E+03
GS07-Ag	Ag-109 (n,g) Ag-110m	10.300	5.990	-0.030	2.22E+03
GS07-Fe	Fe-54 (n,p) Mn-54	10.300	5.990	-0.030	1.51E+03
GS07-Cu	Cu-63 (n,a) Co-60	10.300	5.990	-0.030	1.76E+01
GS08-Co	Co-59 (n,g) Co-60	10.300	5.990	-23.850	5.50E+02
GS08-Ag	Ag-109 (n,g) Ag-110m	10.300	5.990	-23.850	9.66E+02
GS08-Fe	Fe-54 (n,p) Mn-54	10.300	5.990	-23.850	7.21E+02
GS08-Cu	Cu-63 (n,a) Co-60	10.300	5.990	-23.850	8.57E+00
GS09-Co	Co-59 (n,g) Co-60	0.000	5.990	23.780	6.62E+02
GS09-Ag	Ag-109 (n,g) Ag-110m	0.000	5.990	23.780	1.41E+03
GS09-Fe	Fe-54 (n,p) Mn-54	0.000	5.990	23.780	9.73E+02
GS09-Cu	Cu-63 (n,a) Co-60	0.000	5.990	23.780	1.36E+01
GS10-Co	Co-59 (n,g) Co-60	0.000	5.990	-23.850	4.29E+02
GS10-Ag	Ag-109 (n,g) Ag-110m	0.000	5.990	-23.850	9.48E+02
GS10-Fe	Fe-54 (n,p) Mn-54	0.000	5.990	-23.850	6.95E+02
GS10-Cu	Cu-63 (n,a) Co-60	0.000	5.990	-23.850	8.01E+00

Table A.1 (continued)

Monitor ID	Reaction	Coordinates X (cm)	Y (cm)	Z (cm)	Activity* at EOI† (Bq/mg)
GS11-Co	Co-59 (n,g) Co-60	-10.300	5.990	23.780	5.33E+02
GS11-Ag	Ag-109 (n,g) Ag-110m	-10.300	5.990	23.780	9.84E+02
GS11-Fe	Fe-54 (n,p) Mn-54	-10.300	5.990	23.780	6.51E+02
GS11-Cu	Cu-63 (n,a) Co-60	-10.300	5.990	23.780	8.01E+00
GS12-Co	Co-59 (n,g) Co-60	-10.300	5.990	-0.030	7.37E+02
GS12-Ag	Ag-109 (n,g) Ag-110m	-10.300	5.990	-0.030	1.44E+03
GS12-Fe	Fe-54 (n,p) Mn-54	-10.300	5.990	-0.030	9.63E+02
GS12-Cu	Cu-63 (n,a) Co-60	-10.300	5.990	-0.030	1.11E+01
GS13-Co	Co-59 (n,g) Co-60	-10.300	5.990	-23.850	3.63E+02
GS13-Ag	Ag-109 (n,g) Ag-110m	-10.300	5.990	-23.850	6.32E+02
GS13-Fe	Fe-54 (n,p) Mn-54	-10.300	5.990	-23.850	4.65E+02
GS13-Cu	Cu-63 (n,a) Co-60	-10.300	5.990	-23.850	5.56E+00
GS14-Co	Co-59 (n,g) Co-60	10.300	9.740	23.780	5.81E+02
GS14-Ag	Ag-109 (n,g) Ag-110m	10.300	9.740	23.780	8.11E+02
GS14-Fe	Fe-54 (n,p) Mn-54	10.300	9.740	23.780	4.72E+02
GS14-Cu	Cu-63 (n,a) Co-60	10.300	9.740	23.780	5.56E+00
GS15-Co	Co-59 (n,g) Co-60	10.300	9.740	-0.030	0.00E+00**
GS15-Ag	Ag-109 (n,g) Ag-110m	10.300	9.740	-0.030	1.27E+03
GS15-Fe	Fe-54 (n,p) Mn-54	10.300	9.740	-0.030	7.13E+02
GS15-Cu	Cu-63 (n,a) Co-60	10.300	9.740	-0.030	8.33E+00
GS16-Co	Co-59 (n,g) Co-60	10.300	9.740	-23.850	4.34E+02
GS16-Ag	Ag-109 (n,g) Ag-110m	10.300	9.740	-23.850	5.96E+02
GS16-Fe	Fe-54 (n,p) Mn-54	10.300	9.740	-23.850	3.48E+02
GS16-Cu	Cu-63 (n,a) Co-60	10.300	9.740	-23.850	4.11E+00
GS17-Co	Co-59 (n,g) Co-60	0.000	9.740	23.780	4.71E+02
GS17-Ag	Ag-109 (n,g) Ag-110m	0.000	9.740	23.780	8.32E+02
GS17-Fe	Fe-54 (n,p) Mn-54	0.000	9.740	23.780	4.44E+02
GS17-Cu	Cu-63 (n,a) Co-60	0.000	9.740	23.780	5.13E+00
GS18-Co	Co-59 (n,g) Co-60	0.000	9.740	-0.030	6.90E+02
GS18-Ag	Ag-109 (n,g) Ag-110m	0.000	9.740	-0.030	1.19E+03
GS18-Fe	Fe-54 (n,p) Mn-54	0.000	9.740	-0.030	6.71E+02
GS18-Cu	Cu-63 (n,a) Co-60	0.000	9.740	-0.030	7.57E+00
GS19-Co	Co-59 (n,g) Co-60	0.000	9.740	-23.850	3.45E+02
GS19-Ag	Ag-109 (n,g) Ag-110m	0.000	9.740	-23.850	5.74E+02
GS19-Fe	Fe-54 (n,p) Mn-54	0.000	9.740	-23.850	3.27E+02
GS19-Cu	Cu-63 (n,a) Co-60	0.000	9.740	-23.85	3.75E+00
GS20-Co	Co-59 (n,g) Co-60	-10.300	9.740	23.780	3.93E+02
GS20-Ag	Ag-109 (n,g) Ag-110m	-10.300	9.740	23.780	6.05E+02
GS20-Fe	Fe-54 (n,p) Mn-54	-10.300	9.740	23.780	3.04E+02
GS20-Cu	Cu-63 (n,a) Co-60	-10.300	9.740	23.780	3.65E+00

Table A.1 (continued)

Monitor ID	Reaction	Coordinates X (cm)	Y (cm)	Z (cm)	Activity* at EOI† (Bq/mg)
GS21-Co	Co-59 (n,g) Co-60	-10.300	9.740	-0.030	5.88E+02
GS21-Ag	Ag-109 (n,g) Ag-110m	-10.300	9.740	-0.030	8.92E+02
GS21-Fe	Fe-54 (n,p) Mn-54	-10.300	9.740	-0.030	4.41E+02
GS21-Cu	Cu-63 (n,a) Co-60	-10.300	9.740	-0.030	5.29E+00
GS22-Co	Co-59 (n,g) Co-60	-10.300	9.740	-23.850	2.98E+02
GS22-Ag	Ag-109 (n,g) Ag-110m	-10.300	9.740	-23.850	4.21E+02
GS22-Fe	Fe-54 (n,p) Mn-54	-10.300	9.740	-23.850	2.19E+02
GS22-Cu	Cu-63 (n,a) Co-60	-10.300	9.740	-23.850	2.62E+00
FRDS-A-Co	Co-59 (n,g) Co-60	-10.300	2.250	23.780	5.10E+02
FRDS-A-Ag	Ag-109 (n,g) Ag-110m	-10.300	2.250	23.780	1.67E+03
FRDS-A-Np	Np-237 (n,f) Zr-95	-10.300	2.250	23.780	3.16E+04
FRDS-A-Np	Np-237 (n,f) Ru-103	-10.300	2.250	23.780	4.60E+04
FRDS-A-Np	Np-237 (n,f) Ru-106	-10.300	2.250	23.780	2.55E+03
FRDS-A-Np	Np-237 (n,f) Cs-137	-10.300	2.250	23.780	2.76E+02
FRDS-A-Np	Np-237 (n,f) Ce-144	-10.300	2.250	23.780	6.14E+03
FRDS-A-U	U-238 (n,f) Zr-95	-10.300	2.250	23.780	5.91E+03
FRDS-A-U	U-238 (n,f) Ru-103	-10.300	2.250	23.780	1.02E+04
FRDS-A-U	U-238 (n,f) Ru-106	-10.300	2.250	23.780	7.04E+02
FRDS-A-U	U-238 (n,f) Cs-137	-10.300	2.250	23.780	5.53E+01
FRDS-A-U	U-238 (n,f) Ce-144	-10.300	2.250	23.780	1.59E+03
FRDS-A-Ni	Ni-58 (n,p) Co-58	-10.300	2.250	23.780	8.10E+04
FRDS-A-Fe	Fe-54 (n,p) Mn-54	-10.300	2.250	23.780	1.45E+03
FRDS-A-Ti	Ti-46 (n,p) Sc-46	-10.300	2.250	23.780	1.07E+03
FRDS-A-Cu	Cu-63 (n,a) Co-60	-10.300	2.250	23.780	1.68E+01
FRDS-B-Co	Co-59 (n,g) Co-60	-10.300	2.250	-0.030	7.70E+02
FRDS-B-Ag	Ag-109 (n,g) Ag-110m	-10.300	2.250	-0.030	2.54E+03
FRDS-B-Np	Np-237 (n,f) Zr-95	-10.300	2.250	-0.030	5.62E+04
FRDS-B-Np	Np-237 (n,f) Ru-103	-10.300	2.250	-0.030	8.12E+04
FRDS-B-Np	Np-237 (n,f) Ru-106	-10.300	2.250	-0.030	4.67E+03
FRDS-B-Np	Np-237 (n,f) Cs-137	-10.300	2.250	-0.030	5.06E+02
FRDS-B-Np	Np-237 (n,f) Ce-144	-10.300	2.250	-0.030	1.08E+04
FRDS-B-U	U-238 (n,f) Zr-95	-10.300	2.250	-0.030	8.33E+03
FRDS-B-U	U-238 (n,f) Ru-103	-10.300	2.250	-0.030	1.43E+04
FRDS-B-U	U-238 (n,f) Ru-106	-10.300	2.250	-0.030	9.92E+02
FRDS-B-U	U-238 (n,f) Cs-137	-10.300	2.250	-0.030	7.94E+01
FRDS-B-U	U-238 (n,f) Ce-144	-10.300	2.250	-0.030	2.16E+03
FRDS-B-Ni	Ni-58 (n,p) Co-58	-10.300	2.250	-0.030	1.18E+05
FRDS-B-Fe	Fe-54 (n,p) Mn-54	-10.300	2.250	-0.030	2.08E+03
FRDS-B-Ti	Ti-46 (n,p) Sc-46	-10.300	2.250	-0.030	1.54E+03
FRDS-B-Cu	Cu-63 (n,a) Co-60	-10.300	2.250	-0.030	2.42E+01
FRDS-C-Co	Co-59 (n,g) Co-60	0.000	2.250	-0.030	1.23E+03
FRDS-C-Ag	Ag-109 (n,g) Ag-110m	0.000	2.250	-0.030	4.00E+03
FRDS-C-Np	Np-237 (n,f) Zr-95	0.000	2.250	-0.030	9.90E+04
FRDS-C-Np	Np-237 (n,f) Ru-103	0.000	2.250	-0.030	1.44E+05
FRDS-C-Np	Np-237 (n,f) Ru-106	0.000	2.250	-0.030	7.87E+03
FRDS-C-Np	Np-237 (n,f) Cs-137	0.000	2.250	-0.030	9.02E+02
FRDS-C-Np	Np-237 (n,f) Ce-144	0.000	2.250	-0.030	2.01E+04

Table A.1 (continued)

Monitor ID	Reaction	Coordinates			Activity* at EOI†
		X (cm)	Y (cm)	Z (cm)	(Bq/mg)
FRDS-C-U	U-238 (n,f) Zr-95	0.000	2.250	-0.030	1.31E+04
FRDS-C-U	U-238 (n,f) Ru-103	0.000	2.250	-0.030	2.29E+04
FRDS-C-U	U-238 (n,f) Ru-106	0.000	2.250	-0.030	1.51E+03
FRDS-C-U	U-238 (n,f) Cs-137	0.000	2.250	-0.030	1.22E+02
FRDS-C-U	U-238 (n,f) Ce-144	0.000	2.250	-0.030	3.35E+03
FRDS-C-Ni	Ni-58 (n,p) Co-58	0.000	2.250	-0.030	1.79E+05
FRDS-C-Fe	Fe-54 (n,p) Mn-54	0.000	2.250	-0.030	3.15E+03
FRDS-C-Ti	Ti-46 (n,p) Sc-46	0.000	2.250	-0.030	2.33E+03
FRDS-C-Cu	Cu-63 (n,a) Co-60	0.000	2.250	-0.030	3.65E+01
FRDS-D-Co	Co-59 (n,g) Co-60	10.300	2.250	-0.030	1.19E+03
FRDS-D-Ag	Ag-109 (n,g) Ag-110m	10.300	2.250	-0.030	3.93E+03
FRDS-D-Np	Np-237 (n,f) Zr-95	10.300	2.250	-0.030	1.00E+05
FRDS-D-Np	Np-237 (n,f) Ru-103	10.300	2.250	-0.030	1.46E+05
FRDS-D-Np	Np-237 (n,f) Ru-106	10.300	2.250	-0.030	8.06E+03
FRDS-D-Np	Np-237 (n,f) Cs-137	10.300	2.250	-0.030	8.84E+02
FRDS-D-Np	Np-237 (n,f) Ce-144	10.300	2.250	-0.030	1.86E+04
FRDS-D-U	U-238 (n,f) Zr-95	10.300	2.250	-0.030	1.36E+04
FRDS-D-U	U-238 (n,f) Ru-103	10.300	2.250	-0.030	2.37E+04
FRDS-D-U	U-238 (n,f) Ru-106	10.300	2.250	-0.030	1.60E+03
FRDS-D-U	U-238 (n,f) Cs-137	10.300	2.250	-0.030	1.28E+02
FRDS-D-U	U-238 (n,f) Ce-144	10.300	2.250	-0.030	3.55E+03
FRDS-D-Ni	Ni-58 (n,p) Co-58	10.300	2.250	-0.030	1.92E+05
FRDS-D-Fe	Fe-54 (n,p) Mn-54	10.300	2.250	-0.030	3.41E+03
FRDS-D-Ti	Ti-46 (n,p) Sc-46	10.300	2.250	-0.030	2.51E+03
FRDS-D-Cu	Cu-63 (n,a) Co-60	10.300	2.250	-0.030	3.90E+01
FRDS-E-Co	Co-59 (n,g) Co-60	0.000	5.990	-0.030	6.64E+02
FRDS-E-Ag	Ag-109 (n,g) Ag-110m	0.000	5.990	-0.030	2.02E+03
FRDS-E-Np	Np-237 (n,f) Zr-95	0.000	5.990	-0.030	6.11E+04
FRDS-E-Np	Np-237 (n,f) Ru-103	0.000	5.990	-0.030	8.73E+04
FRDS-E-Np	Np-237 (n,f) Ru-106	0.000	5.990	-0.030	4.78E+03
FRDS-E-Np	Np-237 (n,f) Cs-137	0.000	5.990	-0.030	5.39E+02
FRDS-E-Np	Np-237 (n,f) Ce-144	0.000	5.990	-0.030	1.08E+04
FRDS-E-U	U-238 (n,f) Zr-95	0.000	5.990	-0.030	6.63E+03
FRDS-E-U	U-238 (n,f) Ru-103	0.000	5.990	-0.030	1.17E+04
FRDS-E-U	U-238 (n,f) Ru-106	0.000	5.990	-0.030	7.78E+02
FRDS-E-U	U-238 (n,f) Cs-137	0.000	5.990	-0.030	6.25E+01
FRDS-E-U	U-238 (n,f) Ce-144	0.000	5.990	-0.030	1.69E+03
FRDS-E-Ni	Ni-58 (n,p) Co-58	0.000	5.990	-0.030	8.35E+04
FRDS-E-Fe	Fe-54 (n,p) Mn-54	0.000	5.990	-0.030	1.44E+03
FRDS-E-Ti	Ti-46 (n,p) Sc-46	0.000	5.990	-0.030	1.03E+03
FRDS-E-Cu	Cu-63 (n,a) Co-60	0.000	5.990	-0.030	1.54E+01

*For the Co and Ag monitors, diluted materials in form of Al alloys were used. Co (Al) was with Co content of 0.1% by weight, and Ag (Al) alloy was with Ag content of 0.173% by weight. Activities listed are per milligram of alloy. The fission product activities in ^{237}Np and ^{238}U monitors are given per milligram of ^{237}Np and ^{238}U, respectively. Activities of all other monitors are given per milligram of chemically pure target material.

†EOI = end of irradiation.

**Monitor lost.

Table A.2. Irradiation history for HSSI 10.0D dosimetry capsule

Beginning		End		Fraction of
date	time	date	time	full power*
		Cycle 338B†		
02/18/92	16:03	02/18/92	16:23	0.005
02/18/92	16:23	02/19/92	10:51	0.0
02/19/92	10:51	02/28/92	13:05	1.0
02/28/92	13:05	03/17/92	14:46	0.0
		*Cycle 339B***		
03/17/92	14:46	03/18/92	10:05	1.0
03/18/92	10:05	03/18/92	10:25	0.0
03/18/92	10:25	03/26/92	08:49	1.0
03/26/92	08:49	03/31/92	12:16	0.0
		Cycle 340A††		
03/31/92	12:16	04/07/92	08:45	1.0
04/07/92	08:45	04/07/92	15:47	0.0
04/07/92	15:47	04/08/92	07:55	1.0
04/08/92	07:55	04/08/92	16:47	0.0
04/08/92	16:47	04/09/92	23:45	1.0
04/09/92	23:45			0.0

*Full power is 2 MW.

†Cycle 338B effective full-power time: 7.85646 E+5 s.

**Cycle 339B effective full-power time: 7.54980 E+5 s.

††Cycle 340A effective full-power time: 7.61700 E+5 s.

Table A.3. Specific activities of the removable dosimeter tube (RDT) dosimeters in the HSSI 10.0D experiment at the end of irradiation (EOI)

Reaction	Coordinates			Specific activity at EOI		
	X (cm)	Y (cm)	Z (cm)	Cy 338B	Cy 339B (Bq/mg)	Cy 340A
				RDT1	RDT4	RDT6
Fe-54 (n,p) Mn-54	-17.14	-0.96	24.13	450	423	439
Fe-54 (n,p) Mn-54	-17.14	-0.96	13.97	622	601	606
Fe-54 (n,p) Mn-54	-17.14	-0.96	3.81	723	665	670
Fe-54 (n,p) Mn-54	-17.14	-0.96	-3.81	707	672	658
Fe-54 (n,p) Mn-54	-17.14	-0.96	-13.97	595	556	574
Fe-54 (n,p) Mn-54	-17.14	-0.96	-24.13	386	344	364
Co-59 (n,g) Co-60	-17.14	-0.96	24.13	2060	1880	1980
Co-59 (n,g) Co-60	-17.14	-0.96	13.97	3720	3490	3500
Co-59 (n,g) Co-60	-17.14	-0.96	3.81	4180	3890	3980
Co-59 (n,g) Co-60	-17.14	-0.96	-3.81	4110	3890	3970
Co-59 (n,g) Co-60	-17.14	-0.96	-13.97	3420	3260	3280
Co-59 (n,g) Co-60	-17.14	-0.96	-24.13	2220	2070	2140
				RDT2	RDT3	RDT5
Fe-54 (n,p) Mn-54	17.14	-0.96	24.13	856	983	1100
Fe-54 (n,p) Mn-54	17.14	-0.96	13.97	1250	1410	1600
Fe-54 (n,p) Mn-54	17.14	-0.96	3.81	1410	1560	1810
Fe-54 (n,p) Mn-54	17.14	-0.96	-3.81	1390	1540	1780
Fe-54 (n,p) Mn-54	17.14	-0.96	-13.97	1180	1340	1550
Fe-54 (n,p) Mn-54	17.14	-0.96	-24.13	753	851	975
Co-59 (n,g) Co-60	17.14	-0.96	24.13	2620	2860	3060
Co-59 (n,g) Co-60	17.14	-0.96	13.97	4740	5070	5580
Co-59 (n,g) Co-60	17.14	-0.96	3.81	5510	5990	6570
Co-59 (n,g) Co-60	17.14	-0.96	-3.81	5480	5960	6660
Co-59 (n,g) Co-60	17.14	-0.96	-13.97	4630	4960	5540
Co-59 (n,g) Co-60	17.14	-0.96	-24.13	2830	3170	3310

Table A.4. Cycle-to-cycle comparison of specific activities of the removable dosimeter tube (RDT) dosimeters in the HSSI 10.0D experiment at the end of irradiation (EOI)

Reaction	Coordinates			Normalized specific activity at EOI*		
	X (cm)	Y (cm)	Z (cm)	Cy 338B	Cy 339B	Cy 340A
				RDT1	RDT4	RDT6
Fe-54 (n,p) Mn-54	-17.1	-0.96	24.13	1.00	0.94	0.98
Fe-54 (n,p) Mn-54	-17.1	-0.96	13.97	1.00	0.97	0.97
Fe-54 (n,p) Mn-54	-17.1	-0.96	3.81	1.00	0.92	0.93
Fe-54 (n,p) Mn-54	-17.1	-0.96	-3.81	1.00	0.95	0.93
Fe-54 (n,p) Mn-54	-17.1	-0.96	-13.97	1.00	0.93	0.96
Fe-54 (n,p) Mn-54	-17.1	-0.96	-24.13	1.00	0.89	0.94
Co-59 (n,g) Co-60	-17.1	-0.96	24.13	1.00	0.91	0.96
Co-59 (n,g) Co-60	-17.1	-0.96	13.97	1.00	0.94	0.94
Co-59 (n,g) Co-60	-17.1	-0.96	3.81	1.00	0.93	0.95
Co-59 (n,g) Co-60	-17.1	-0.96	-3.81	1.00	0.95	0.97
Co-59 (n,g) Co-60	-17.1	-0.96	-13.97	1.00	0.95	0.96
Co-59 (n,g) Co-60	-17.1	-0.96	-24.13	1.00	0.93	0.96
				RDT2	RDT3	RDT5
Fe-54 (n,p) Mn-54	17.14	-0.96	24.13	1.00	1.15	1.29
Fe-54 (n,p) Mn-54	17.14	-0.96	13.97	1.00	1.13	1.28
Fe-54 (n,p) Mn-54	17.14	-0.96	3.81	1.00	1.11	1.28
Fe-54 (n,p) Mn-54	17.14	-0.96	-3.81	1.00	1.11	1.28
Fe-54 (n,p) Mn-54	17.14	-0.96	-13.97	1.00	1.14	1.31
Fe-54 (n,p) Mn-54	17.14	-0.96	-24.13	1.00	1.13	1.29
Co-59 (n,g) Co-60	17.14	-0.96	24.13	1.00	1.09	1.17
Co-59 (n,g) Co-60	17.14	-0.96	13.97	1.00	1.07	1.18
Co-59 (n,g) Co-60	17.14	-0.96	3.81	1.00	1.09	1.19
Co-59 (n,g) Co-60	17.14	-0.96	-3.81	1.00	1.09	1.22
Co-59 (n,g) Co-60	17.14	-0.96	-13.97	1.00	1.07	1.20
Co-59 (n,g) Co-60	17.14	-0.96	-24.13	1.00	1.12	1.17

*At each location and for each reaction, the specific activities are divided by the specific activity in cycle 338B.

ORNL-DWG 98-3491

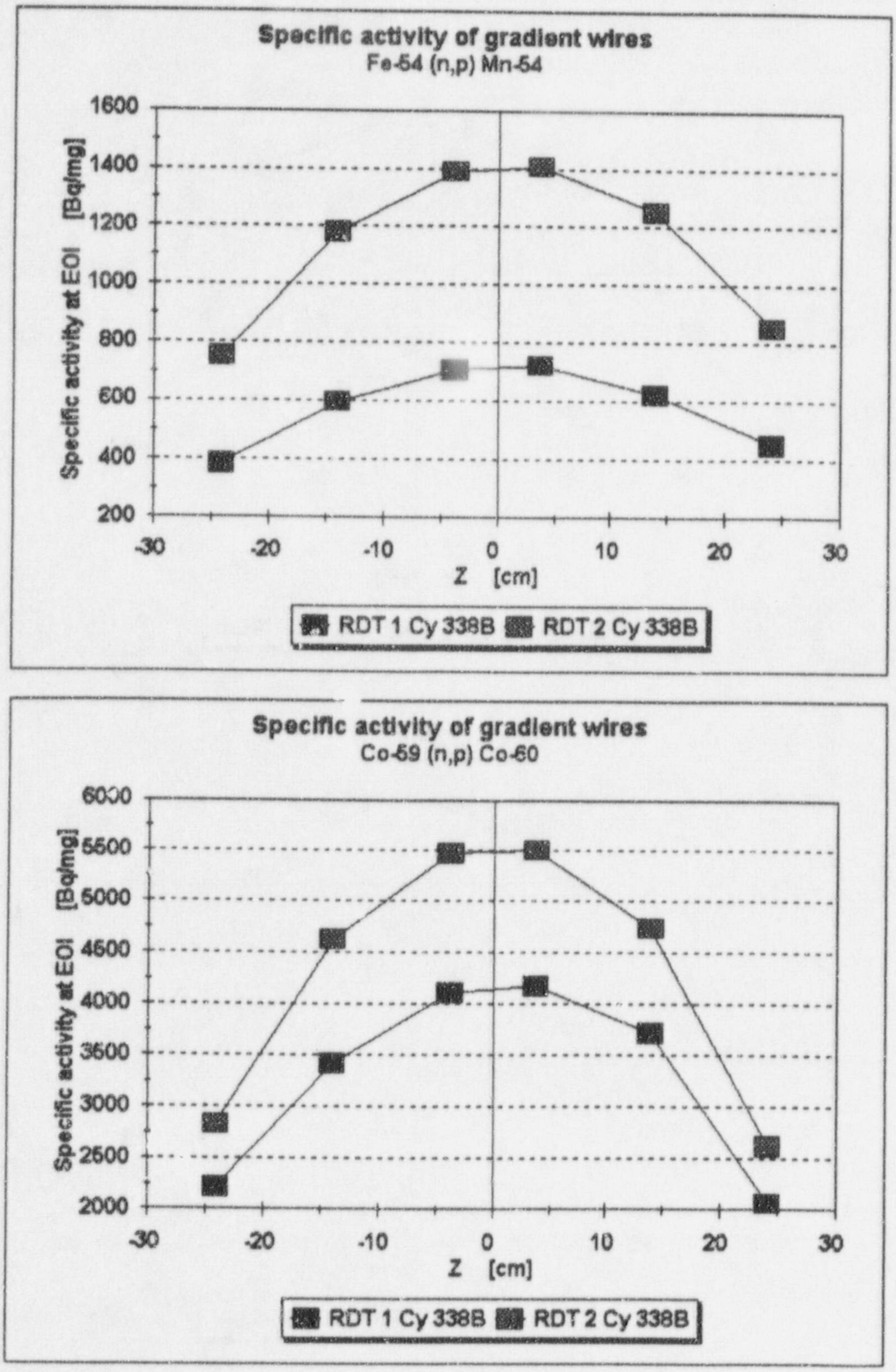
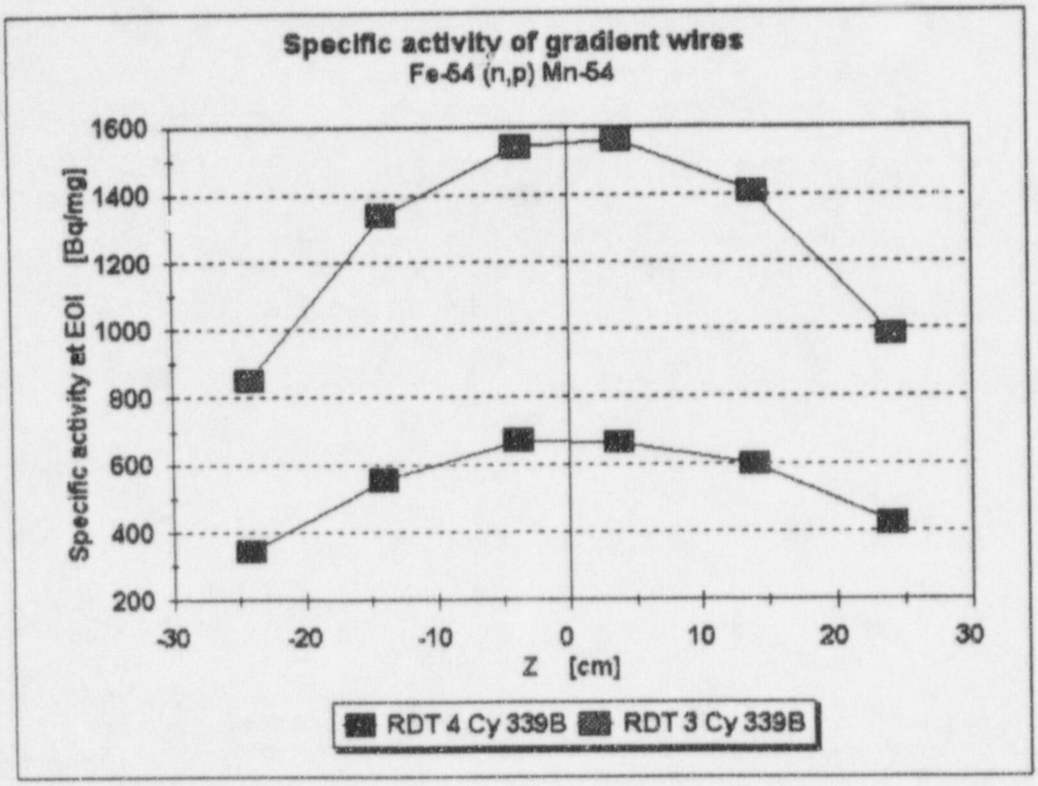


Figure A.1. Measured specific activities of the RDT dosimetry for the cycle 338B vs Z coordinate for (top) iron gradient wires and (bottom) cobalt gradient wires.

ORNL-DWG 98-3492



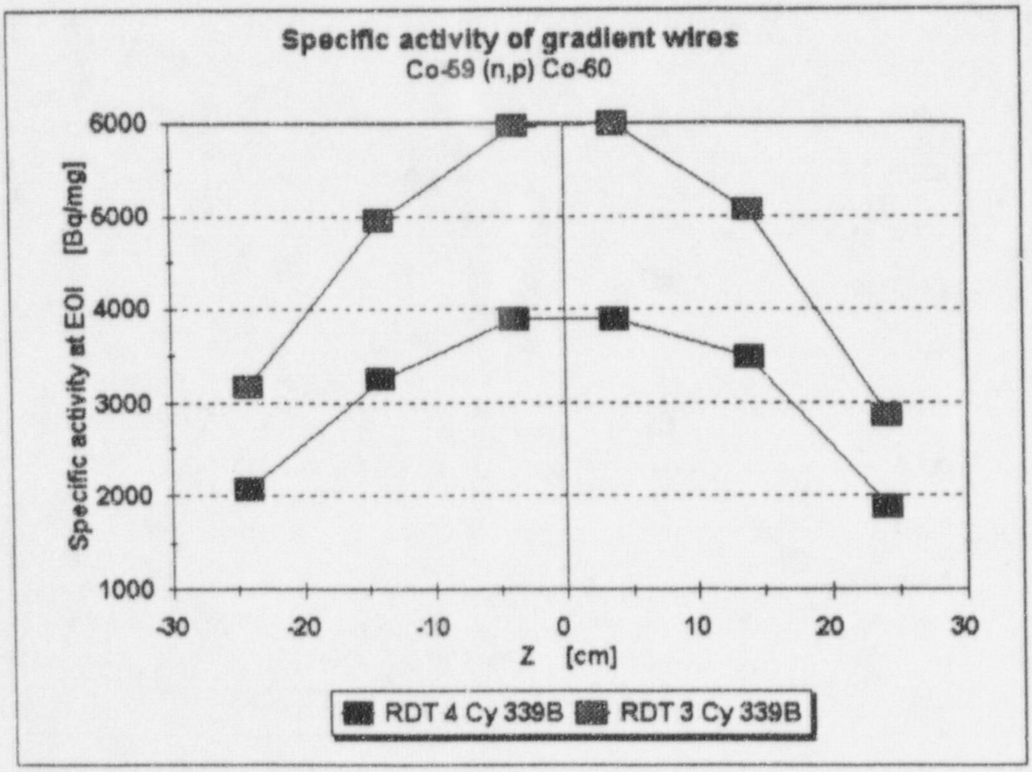
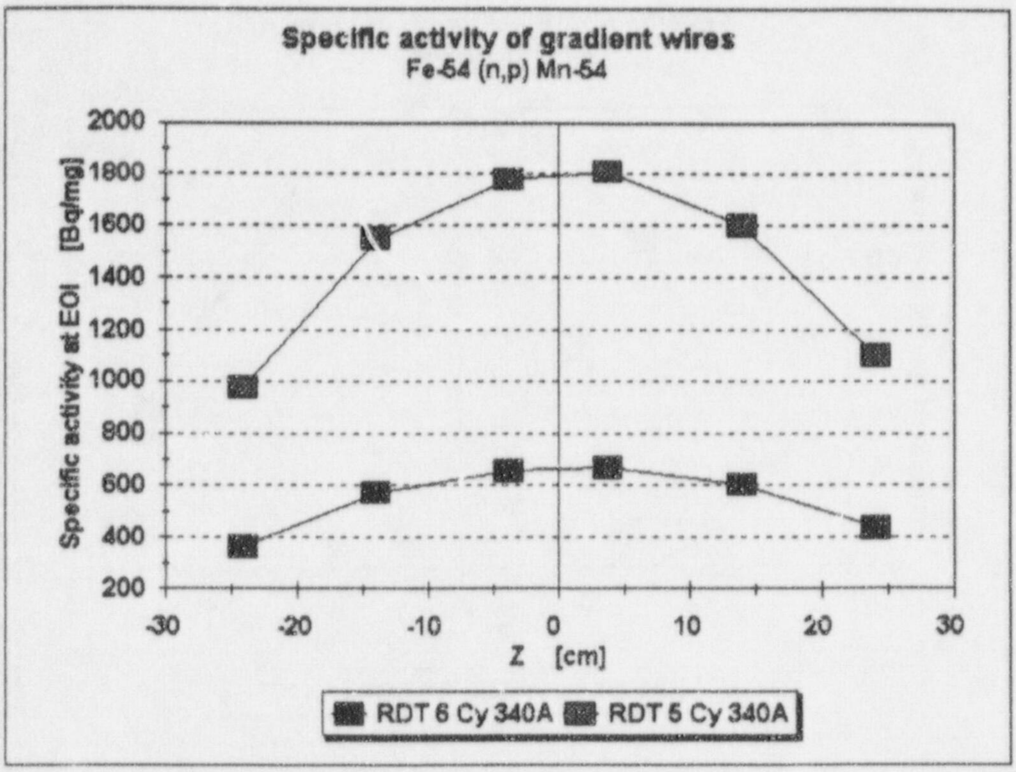


Figure A.2. Measured specific activities of the RDT dosimetry for the cycle 339B vs Z coordinate for (top) iron gradient wires and (bottom) cobalt gradient wires.

ORNL-DWG 98-3493



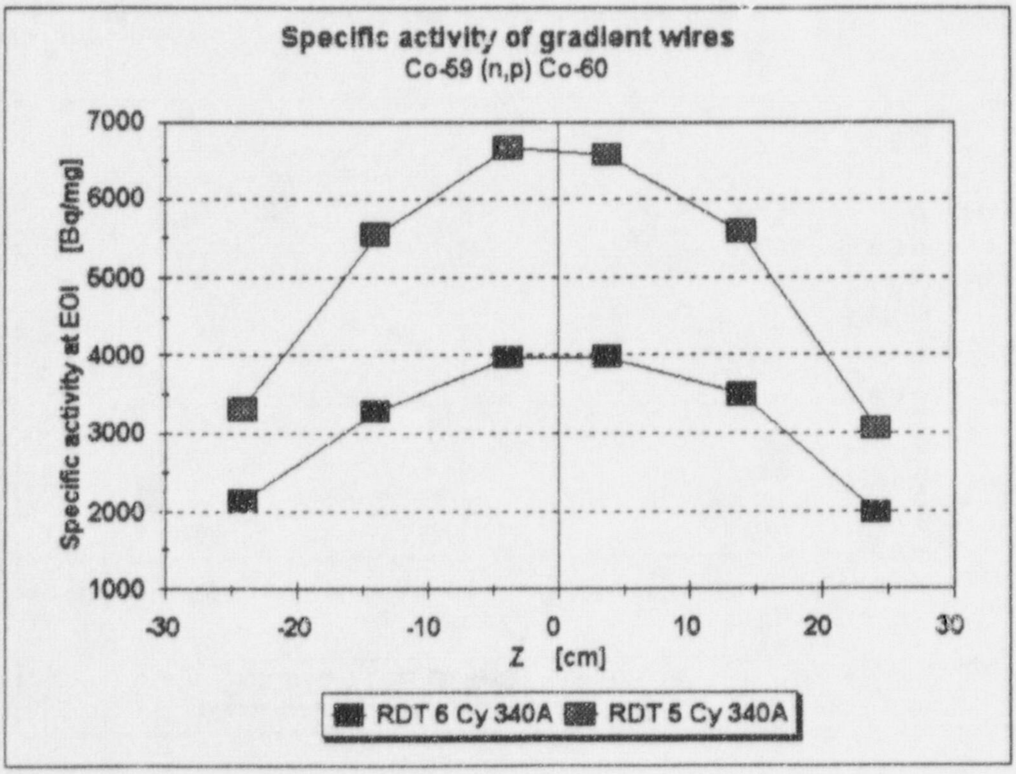


Figure A.3. Measured specific activities of the RDT dosimetry for the cycle 340A vs Z coordinate for (top) iron gradient wires and (bottom) cobalt gradient wires.

ORNL-DWG 98-3494

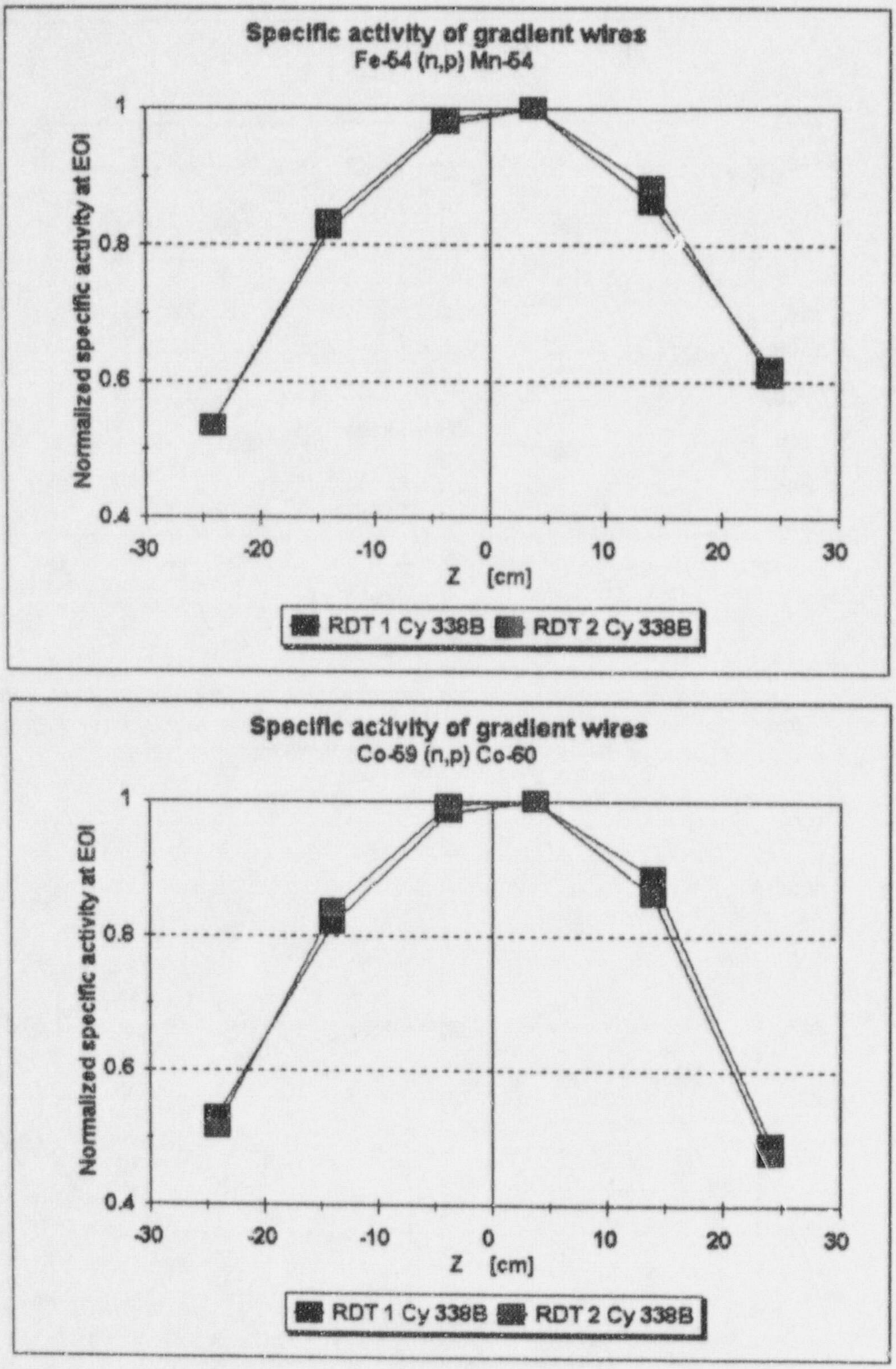
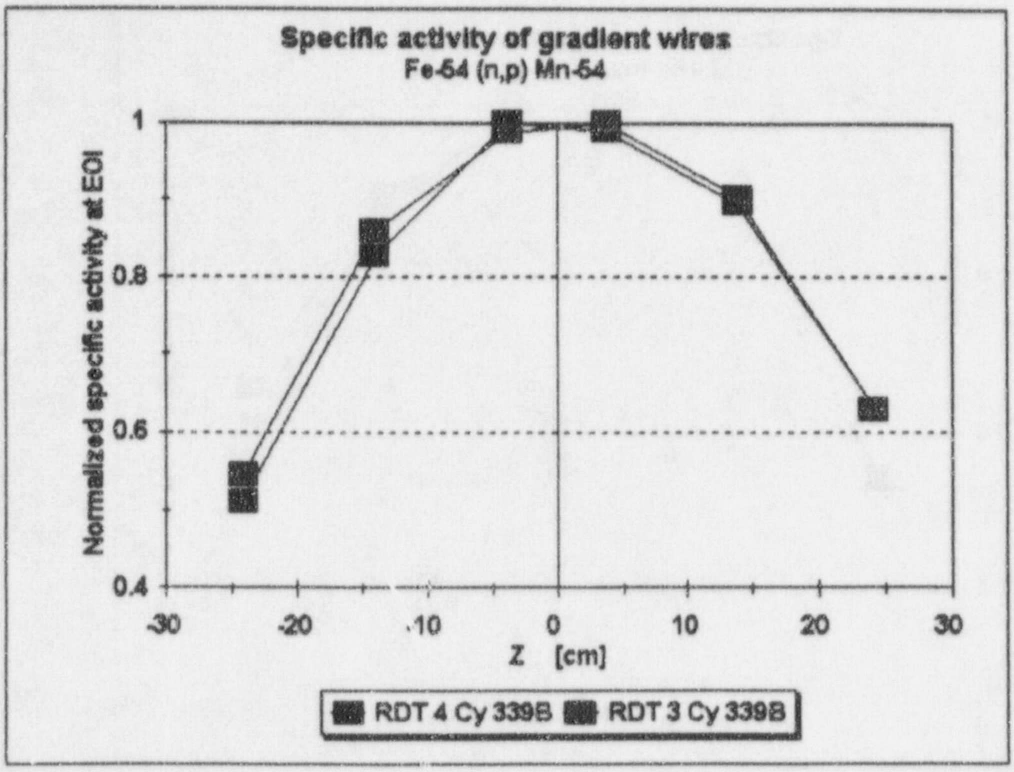


Figure A.4. Normalized measured specific activities of the RDT dosimetry for the cycle 338B vs Z coordinate for (top) iron gradient wires and (bottom) cobalt gradient wires. Normalization is to the maximum value of 1.0 for each reaction and each RDT.

ORNL-DWG 98-3495



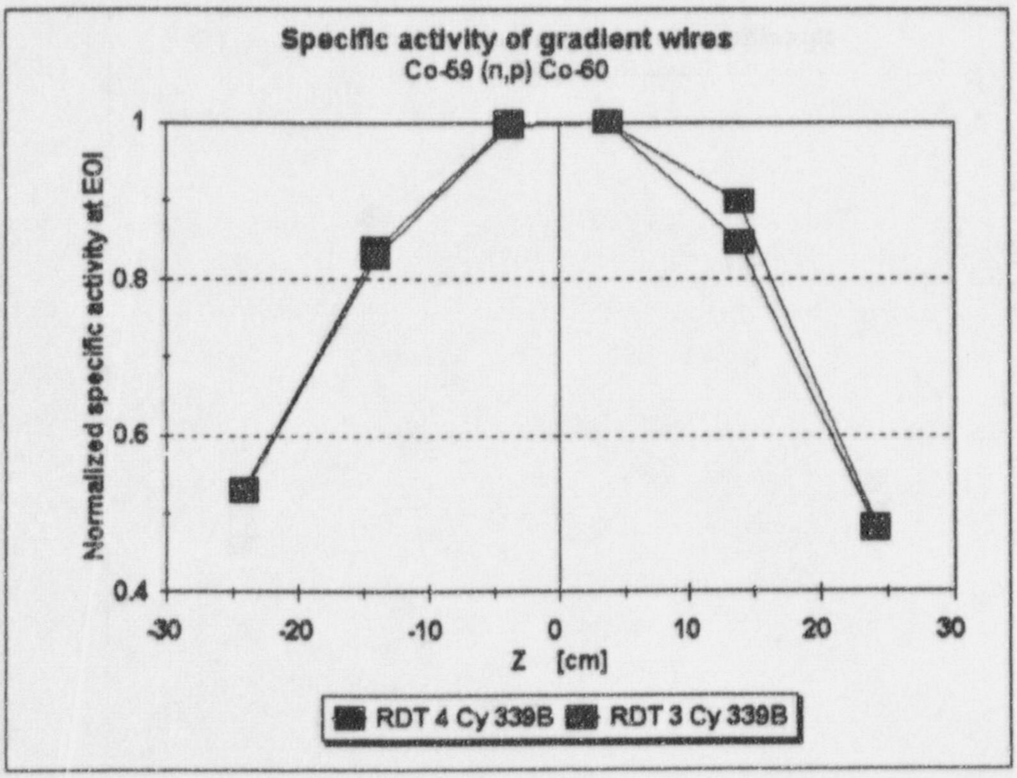


Figure A.5. Normalized measured specific activities of the RDT dosimetry for the cycle 339B vs Z coordinate for (top) iron gradient wires and (bottom) cobalt gradient wires. Values are normalized to the maximum value of 1.0 for each reaction and each RDT.

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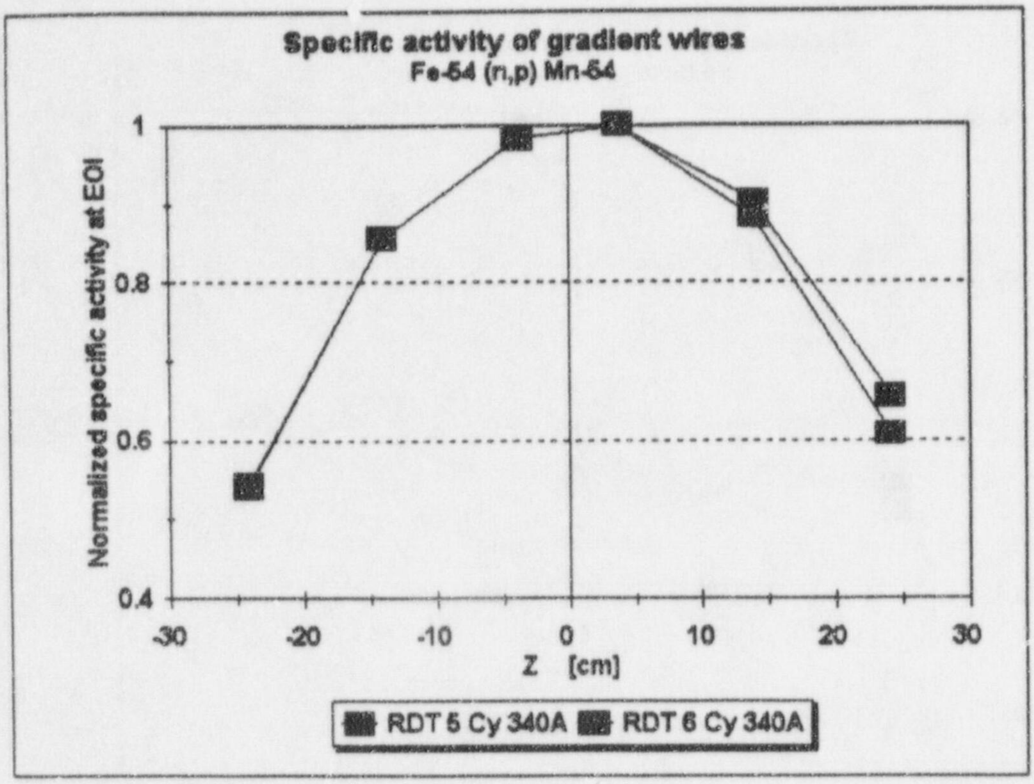

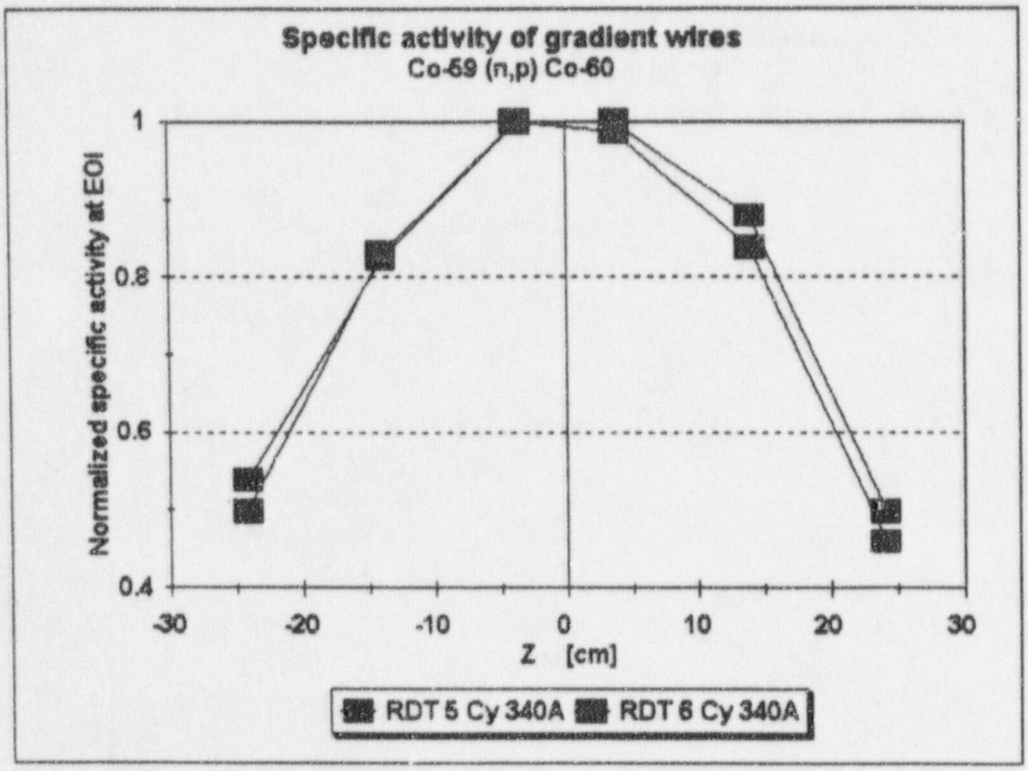

Figure A.6. Normalized measured specific activities of the RDT dosimetry for the cycle 340A vs Z coordinate for (top) iron gradient wires and (bottom) cobalt gradient wires. Values are normalized to the maximum value of 1.0 for each reaction and each RDT.

Table A.5. Comparison of the adjusted fast fluence rates, $F_{E>1\,MeV}$, with values obtained from three-dimensional (3-D) fit. Adjusted flux values are averages of the cycles 338B, 339B, and 340A

Location	Coordinates			$F_{E>1\,MeV}$		Difference
	X (cm)	Y (cm)	Z (cm)	Adjusted ($cm^{-2}s^{-1}$)	3-D fitted ($cm^{-2}s^{-1}$)	(%)
P23	-10.30	2.25	23.78	5.017E+11	4.921E+11	1.9
P2	0.00	2.25	23.78	7.866E+11	7.894E+11	-0.4
P4	10.30	2.25	23.78	7.862E+11	7.870E+11	-0.1
P11	-10.30	5.99	23.78	2.689E+11	2.598E+11	3.4
P9	0.00	5.99	23.78	4.250E+11	4.168E+11	1.9
P6	10.30	5.99	23.78	4.044E+11	4.155E+11	-2.7
P20	-10.30	9.74	23.78	1.392E+11	1.369E+11	1.6
P17	0.00	9.74	23.78	2.195E+11	2.197E+11	-0.1
P14	10.30	9.74	23.78	2.060E+11	2.190E+11	-6.3
P24	-10.30	2.25	-0.03	7.975E+11	8.142E+11	-2.1
P25	0.00	2.25	-0.03	1.295E+12	1.306E+12	-0.9
P26	10.30	2.25	-0.03	1.320E+12	1.302E+12	1.3
P12	-10.30	5.99	-0.03	4.391E+11	4.299E+11	2.1
P27	0.00	5.99	-0.03	7.084E+11	6.897E+11	2.6
P7	10.30	5.99	-0.03	6.780E+11	6.876E+11	-1.4
P21	-10.30	9.74	-0.03	2.298E+11	2.266E+11	1.4
P18	0.00	9.74	-0.03	3.678E+11	3.636E+11	1.2
P15	10.30	9.74	-0.03	3.453E+11	3.624E+11	-4.9
P1	-10.30	2.25	-23.85	3.710E+11	3.705E+11	0.1
P3	0.00	2.25	-23.85	5.885E+11	5.944E+11	-1.0
P 5	10.30	2.25	-23.85	5.933E+11	5.926E+11	0.1
P13	-10.30	5.99	-23.85	2.024E+11	1.956E+11	3.3
P10	0.00	5.99	-23.85	3.229E+11	3.138E+11	2.8
P 8	10.30	5.99	-23.85	3.100E+11	3.129E+11	-0.9
P22	-10.30	9.74	-23.85	1.060E+11	1.031E+11	2.7
P19	0.00	9.74	-23.85	1.689E+11	1.654E+11	2.1
P16	10.30	9.74	-23.85	1.587E+11	1.649E+11	-3.9

Note: average deviation between adjusted and fitted value is 2.0%; maximum deviation observed (at P14) is –6.3%.

Table A.6. Comparison of the adjusted fast fluence rates, $F_{E > 0.1 MeV}$, with values obtained from three-dimensional (3-D) fit. Adjusted flux values are averages of the cycles 338B, 339B, and 340A

Location	Coordinates			$F_{E > 0.1 MeV}$		Difference
	X (cm)	Y (cm)	Z (cm)	Adjusted ($cm^{-2}s^{-1}$)	3-D fitted ($cm^{-2}s^{-1}$)	(%)
P23	-10.30	2.25	23.78	1.254E+12	1.240E+12	1.1
P2	0.00	2.25	23.78	2.027E+12	2.052E+12	-1.2
P4	10.30	2.25	23.78	1.885E+12	1.864E+12	1.1
P11	-10.30	5.99	23.78	8.018E+11	7.664E+11	4.4
P9	0.00	5.99	23.78	1.315E+12	1.268E+12	3.6
P6	10.30	5.99	23.78	1.124E+12	1.152E+12	-2.5
P20	-10.30	9.74	23.78	4.734E+11	4.731E+11	0.1
P17	0.00	9.74	23.78	7.770E+11	7.828E+11	-0.7
P14	10.30	9.74	23.78	6.372E+11	7.113E+11	-11.6
P24	-10.30	2.25	-0.03	2.089E+12	2.148E+12	-2.8
P25	0.00	2.25	-0.03	3.483E+12	3.553E+12	-2.0
P26	10.30	2.25	-0.03	3.297E+12	3.229E+12	2.1
P12	-10.30	5.99	-0.03	1.378E+12	1.327E+12	3.7
P27	0.00	5.99	-0.03	2.302E+12	2.196E+12	4.6
P7	10.30	5.99	-0.03	1.981E+12	1.996E+12	-0.7
P21	-10.30	9.74	-0.03	8.248E+11	8.195E+11	0.6
P18	0.00	9.74	-0.03	1.371E+12	1.356E+12	1.1
P15	10.30	9.74	-0.03	1.126E+12	1.232E+12	-9.4
P1	-10.30	2.25	-23.85	9.556E+11	9.610E+11	-0.6
P3	0.00	2.25	-23.85	1.559E+12	1.590E+12	-2.0
P5	10.30	2.25	-23.85	1.461E+12	1.445E+12	1.1
P13	-10.30	5.99	-23.85	6.202E+11	5.940E+11	4.2
P10	0.00	5.99	-23.85	1.027E+12	9.828E+11	4.3
P8	10.30	5.99	-23.85	8.852E+11	8.930E+11	-0.9
P22	-10.30	9.74	-23.85	3.707E+11	3.667E+11	1.1
P19	0.00	9.74	-23.85	6.142E+11	6.067E+11	1.2
P16	10.30	9.74	-23.85	5.047E+11	5.513E+11	-9.2

Note: average deviation between adjusted and fitted value is 2.9%; maximum deviation observed (at P14) is –11.6%.

Table A.7. Comparison of the adjusted displacement-per-atom (dpa) rates with values obtained from three-dimensional (3-D) fit. Adjusted dpa rates are averages of the cycles 338B, 339B, and 340A

Location	Coordinates			dpa rate		Difference
	X (cm)	Y (cm)	Z (cm)	Adjusted (s^{-1})	3-D fitted (s^{-1})	(%)
P23	-10.30	2.25	23.78	7.410E-10	7.298E-10	1.5
P2	0.00	2.25	23.78	1.174E-09	1.180E-09	-0.6
P4	10.30	2.25	23.78	1.143E-09	1.136E-09	0.6
P11	-10.30	5.99	23.78	4.244E-10	4.111E-10	3.1
P9	0.00	5.99	23.78	6.797E-10	6.650E-10	2.2
P6	10.30	5.99	23.78	6.163E-10	6.398E-10	-3.8
P20	-10.30	9.74	23.78	2.340E-10	2.312E-10	1.2
P17	0.00	9.74	23.78	3.746E-10	3.740E-10	0.2
P14	10.30	9.74	23.78	3.304E-10	3.599E-10	-8.9
P24	-10.30	2.25	-0.03	1.187E-09	1.214E-09	-2.2
P25	0.00	2.25	-0.03	1.936E-09	1.963E-09	-1.4
P26	10.30	2.25	-0.03	1.921E-09	1.889E-09	1.7
P12	-10.30	5.99	-0.03	7.002E-10	6.837E-10	2.4
P27	0.00	5.99	-0.03	1.142E-09	1.106E-09	3.2
P7	10.30	5.99	-0.03	1.046E-09	1.064E-09	-1.7
P21	-10.30	9.74	-0.03	3.917E-10	3.845E-10	1.8
P18	0.00	9.74	-0.03	6.363E-10	6.220E-10	2.3
P15	10.30	9.74	-0.03	5.616E-10	5.984E-10	-6.6
P1	-10.30	2.25	-23.85	5.499E-10	5.508E-10	-0.2
P3	0.00	2.25	-23.85	8.791E-10	8.908E-10	-1.3
P5	10.30	2.25	-23.85	8.622E-10	8.571E-10	0.6
P13	-10.30	5.99	-23.85	3.201E-10	3.103E-10	3.1
P10	0.00	5.99	-23.85	5.182E-10	5.018E-10	3.2
P8	10.30	5.99	-23.85	4.747E-10	4.828E-10	-1.7
P22	-10.30	9.74	-23.85	1.791E-10	1.745E-10	2.6
P19	0.00	9.74	-23.85	2.898E-10	2.823E-10	2.6
P16	10.30	9.74	-23.85	2.561E-10	2.716E-10	-6.0

Note: average deviation between adjusted and fitted value is 2.5%; maximum deviation observed (at P14) is –8.9%.

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11. ABSTRACT *(200 words or less)*

This report describes the computational methodology for the least-squares adjustment of the dosimetry data from the HSSI 10.0D dosimetry capsule with neutronics calculations. It presents exposure rates at each dosimetry location for the neutron fluence greater than 1.0 MeV, fluence greater than 0.1 MeV, and displacements per atom. Exposure parameter distributions are also described in terms of three-dimensional fitting functions. When fitting functions are used it is suggested that an uncertainty of 6% (1 σ) should be associated with the exposure rate values. The specific activity of each dosimeter at the end of irradiation is listed in the Appendix.

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