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EBR-II DOSIMETRY TEST
REACTION RATE MEASUREMENTS
(REACTOR RUNS 31E AND 31F)

L. S. Kellogg
W. H. Zimmer

June 1970

AEC RESEARCH &
DEVELOPMENT REPORT

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ERRATA

Pages 12 and 13. Power History Figures 5 and 6. Reactor power history data indicated essentially flat power operation during runs 31E and 31F. The plotted elapsed time scale is in error after initial test operating power was reached. The plots should show breaks to represent an elapsed period in order to include the end of irradiation time-date. The irregularity between 11-4-68 and 11-5-68 shown in Figure 5 is in error--the line should be straight. Both tests were terminated in a reactor scram.

Page 20. The last sentence should end: reaction data.

Page 23. Column 2, half life entry number 12 should read Reference 16, not Reference 10.

Page 26.' Standard deviation (among laboratories), standard error (standard deviation of the mean), and biased results as noted on this and subsequent pages are discussed on Page 18, Section VI.

Pages 30 and 31. The headings for the fission foil reaction rate tabulated data should read fissions/sec/nucleus; all nonfissionable foil data is dps/nucleus.

Page 30. Reaction rate data for ^{238}U has been corrected for 0.0023% ^{235}U .

Page 32. $^{46}\text{Ti}(\text{N},\text{P})$ ^{46}Sc data should have the following at the end of the tabulation:

No apparent bias.

$\bar{x}$ $4.94 \times 10^{-15} \pm 5.6\% \text{ S } (2.5\% \text{ SE})$

Page 34. $^{237}\text{Np}(\text{n},\text{f})$ ^{140}Ba should reference note (d). Footnotes should read:

- a. 93.25% enriched ^{235}U . Results corrected for 6.75% ^{238}U .
- b. Alloy - Corrections made for 16.4% enriched ^{235}U content.
- c. Depleted uranium 99.9977% ^{238}U . Results corrected for 0.0023% ^{235}U .
- d. Results corrected for 1000 ppm ^{238}U .

Page 36. Note (b) should read:

- b. Alloy - Corrections made for 16.4% enriched ^{235}U content.

Page 38. The heading over the third column of data ~~tabulations~~ should read:

$^{58}\text{Fe}(\text{n},\gamma)^{59}\text{Fe}$ (contd)

$^{58}\text{Fe}(\text{n},\gamma)^{59}\text{Fe}$ R 5.89, Z +40.04 should read:

R 5.89, Z +46.04

Page 41. $^{24}\text{Mg}(\text{n},\text{p})^{24}\text{Na}$ R 13.14, Z +10.48 should read:

R 13.14, Z +16.48

$^{59}\text{Co}(\text{n},\gamma)^{60}\text{Co}$ R 13.14, Z -14.81 and Z -18.03 should read:

R 13.14, Z +14.81 and Z +18.03

$^{32}\text{MgSO}_4$ should read: $\text{Mg } ^{32}\text{SO}_4$

$^{59}\text{Co}(\text{n},\gamma)^{60}\text{Co}$ Self Shielding heading should stipulate

R = 5.18 cm.

Page 42. $^{54}\text{Fe}(\text{n},\alpha)^{51}\text{Cr}$ R 5.18, Z -5.59 37.0(a) should read: 37.0(b).

$^{197}\text{Au}(\text{n},2\text{n})^{196}\text{Au}$ R 13.14, Z +5.87 should read: Z -5.87.

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UC-80, Reactor
Technology

EBR-II DOSIMETRY TEST REACTION RATE MEASUREMENTS
(REACTOR RUNS 31E AND 31F)

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June 1970

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EBR-II DOSIMETRY TEST REACTION RATE MEASUREMENTS
(REACTOR RUNS 31E AND 31F)

L. S. Kellogg
W. H. Zimmer

ABSTRACT

The data has been analyzed from ~800 foils irradiated during the recent Pacific Northwest Laboratory (PNL) and Argonne National Laboratory (ANL) EBR-II dosimetry test. A standard deviation of +7% has been assigned to the majority of the reaction rate data. In most instances where a rigid statistical evaluation could be made, it indicated a calculated accuracy estimate with errors less than the assigned 7% standard deviation. However, comparisons using other techniques indicated that the 7% value could be reasonably expected to encompass most of the data.

Discrepancies noted in the decay scheme data used by the various participants must be resolved, perhaps by continuation of "Round Robin" interlaboratory comparison programs.

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EBR-II DOSIMETRY TEST-REACTION RATE MEASUREMENTS
(REACTOR RUNS 31E AND 31F)

L. S. Kellogg

W. H. Zimmer

I. INTRODUCTION

A cooperative Pacific Northwest Laboratory (PNL)-Argonne National Laboratory (ANL) dosimetry test was designed and conducted in EBR-II during reactor runs 31E and 31F. (1) One purpose of the test was to provide measured values of energy-dependent integral fluxes as a function of radial and axial positions. (1) To obtain the necessary reaction rates, ~800 foils and some 1200 foil reactions were used. Three separate laboratories analyzed the bulk of the foils: PNL, Atlantic Richfield Hanford Company, and Idaho Nuclear Corporation. ANL-Idaho Falls and two ANL-Chicago Laboratories analyzed extensive experimenter foil packages as well as correlation sets. Two General Electric Company Laboratories (GE-NMPO-Cincinnati and GE-Pleasanton, California) and Oak Ridge National Laboratory also analyzed correlation sets. The core center correlation sets and core center and midplane experimenter's and spectral sets were used for statistical evaluation of the analytical data.

This paper contains a discussion of the general test description, analytical techniques, coordination and correlation of the data from experimenters, and evaluation of the reported data.

II. SUMMARY AND CONCLUSIONS

This document presents results of the reaction rate measurements for the cooperative PNL-ANL EBR-II runs 31E and 31F dosimetry test. The subsequent use of the reaction rate results to obtain flux-spectral data are reported elsewhere. (1)

A standard deviation of $\sim 7\%$ could reasonably be assigned to the remainder of data for 14 foil reactions used in the further calculations. This standard deviation of estimated accuracy is based on the following:

- Statistical evaluation of the spectral, experimenter's, and correlation foil sets located on core center and mid-plane positions.
- Individual precision estimates.
- Axial and radial plot comparisons.
- Previous dosimetry correlation runs.

The number of discrepant foil results as indicated by various techniques were relatively few compared to the bulk of the data. However, several types of errors encountered, such as overall systems calibration errors and laboratory bias, again indicated the need for continuing a "Round Robin" laboratory correlation study. (2-4)

III. TEST DESCRIPTION

FLUX MONITORS

The selection, sizing, and encapsulation of the individual monitor foil materials are thoroughly discussed in another publication.⁽¹⁾ Essentially, the data reported in this document were taken from the following five general types of foil sets:

- Spectral Sets (S) - 16 different high purity foil materials to be used for determining flux, fluence, and spectrum (Table 1).
- Gradient Sets (G) - 20 mil iron and nickel wires located between spectral sets to provide axial flux gradient information.
- Experimenter's Monitors and Correlation Sets - These consisted of at least iron, nickel, and titanium foils but also included other foil materials as supplied or requested by the participant.

TABLE 1. Spectral Set Foils

Reaction	Form	Dimensions ^(a)	Test ^(b)	Approx. Weight, mg	Number/ Location	Encapsulated ^(c)
$^{59}\text{Co}(n,\gamma)^{60}\text{Co}$	Metal-foil	5 mil	L	27	1	
	Metal-foil	0.5 mil	H	3	1	
$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$	Metal-foil	0.5 mil	L	3	1	
	Metal-foil	0.5 mil	H	3	1	
$^{45}\text{Sc}(n,\gamma)^{46}\text{Sc}$	Metal-wire	1 mil	L	2	1	
	Metal-wire	1 mil	H	2	1	
$^{197}\text{Au}(n,\gamma)^{198}\text{Au}$	Metal-foil	0.05 mil	L	0.2	1	
	Metal-foil	0.05 mil	H	0.2	1	
$^{23}\text{Na}(n,\gamma)$ $^{23}\text{Na}(n,2n)$ $^{35}\text{Cl}(n,\alpha)$	NaCl-Pellet	0.08 in. diam, 1/8 in. long	L & H	22	1	
$^{54}\text{Fe}(n,p)$						
$^{58}\text{Fe}(n,\gamma)$						
$^{54}\text{Fe}(n,p)$	Metal-wire	20 mil $\times$ 3 in. R ^(a)	L	121	1	
$^{58}\text{Fe}(n,\gamma)$						
$^{54}\text{Fe}(n,p)$	Metal-wire	20 mil $\times$ 1/2 in. R	H	18	1	
$^{58}\text{Fe}(n,\gamma)$						
$^{58}\text{Ni}(n,p)$	Metal-wire	20 mil $\times$ 1 in. R	L	46	1	
$^{58}\text{Ni}(n,p)$	Metal-wire	20 mil $\times$ 1/2 in. R	H	22	1	
$^{58}\text{Ni}(n,2n)$						
$^{27}\text{Al}(n,\alpha)$	Metal-wire	20 mil $\times$ 3 in. R	L	42	1	
	Metal-wire	20 mil $\times$ 3/16 in. S ^(a)	H	3	1	X
$^{24}\text{Mg}(n,p)$	Metal-foil	5 mil	L	5		
	Metal-piece	5 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	1.4		X

TABLE 1. (Continued)

Reaction	Form	Dimensions ^(a) (g)	Test ^(b)	Approx. Weight, mg	Number/ Location	Encapsulated ^(c)
$^{46}\text{Ti}(\text{n},\text{p})$	Metal-wire	20 mil $\times$ 1/3 in. R ^(a)	L	24	1	
$^{46}\text{Ti}(\text{n},\text{p})$ $^{47}\text{Ti}(\text{n},\text{p})$ $^{48}\text{Ti}(\text{n},\text{p})$	Metal-wire	20 mil $\times$ 1/2 in. R	H	12	1	
$^{127}\text{I}(\text{n},2\text{n})$	KI-Pellet	0.08 in. diam $\times$ 1/8 in.	L	31	1	X
	KI-Pellet	0.08 in. diam $\times$ 1/8 in.	H	31	1	X
$^{238}\text{U}(\text{n},\text{f})$ (e) $^{238}\text{U}(\text{n},\gamma)$ (f)	Metal-piece	1 mil $\times$ 1/8 in. $\times$ 5/8 in.	L	15	1	X
$^{238}\text{U}(\text{n},\text{f})$ (e) $^{238}\text{U}(\text{n},\gamma)$ (f)	Metal-piece	1 mil $\times$ 1/8 in. $\times$ 5/8 in.	H	15	1	X
$^{238}\text{U}(\text{n},\text{f})$ (g)	Metal-piece	1 mil $\times$ 1/8 in. $\times$ 3-3/4 in.	H	100	1	X
$^{235}\text{U}(\text{n},\text{f})$ (e)	Metal-piece	1 mil $\times$ 1/8 in. $\times$ 5/8 in.	L	15	1	X
$^{235}\text{U}(\text{n},\text{f})$ (e,h)	Metal-piece	1 mil $\times$ 1/8 in. $\times$ 5/8 in.	H	15	1	X
$^{235}\text{U}(\text{n},\text{f})$ (g)	Metal-piece	1 mil $\times$ 1/8 in. $\times$ 3/4 in.	H	20	1	X
$^{237}\text{Np}(\text{n},\text{f})$ (e)	Metal-piece	6 mil $\times$ 0.080 in. $\times$ 1/8 in.	L	20	1	X
$^{237}\text{Np}(\text{n},\text{f})$ (e)	Metal-piece	6 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	20	1	X
$^{237}\text{Np}(\text{n},\text{f})$ (g)	Metal-piece	6 mil $\times$ 0.080 in. $\times$ 1/4 in.	H	40	1	X

TABLE 1. (Continued)

<u>Reaction</u>	<u>Form</u>	<u>Dimensions^(a)</u>	<u>Test^(b)</u>	<u>Approx. Weight, mg</u>	<u>Number/ Location</u>	<u>Encapsulated^(c)</u>
$^{232}\text{Th}(n,f)$ ^(d)	Metal-piece	5 mil $\times$ 0.080 in. $\times$ 5/8 in.	L	80	1	X
	Metal-piece	5 mil $\times$ 0.080 in. $\times$ 1/16 in.	H	9	1	X
$^{232}\text{Th}(n,f)$ ^(e)	Metal-piece	5 mil $\times$ 1/8 in. $\times$ 5/8 in.	H	80		

a. Foils shall be a small flat washer $\sim 1/4$ in. OD $\times$ 1/8 in. ID, thickness will vary as noted. Wire shall be referenced by OD and approximate length with S - straight and R - formed round.

b. L refers to Low Power (86 KW)⁽⁶⁾ Run 31E
H refers to High Power (50 MW)⁽⁶⁾ Run 31F

c. Check indicates material contained in stainless steel tubes $\sim 3/4$ in. long $\times$ 0.093 OD with 2.3 mil wall, welded closed, see Figure 1.

d. All fission foils except ^{237}Np and ^{232}Th were formed into rolls. If direct counting cannot be made, both capsule and foil should be dissolved to eliminate fission fragment loss. All fission foils shall be less than 100 mg for burnup.

e. Analyze for ^{140}Ba .

f. Analyzed for ^{239}Np .

g. Analyze for $^{137}\text{Cs}/^{148}\text{Nd}$. These will be included only in the spectral sets in Rows 4, 6, and 7 at midplane. One capsule containing 3 each of ^{235}U and ^{238}U will be in Row 4 below midplane only.

h. Analyze for ^{137}Cs .

- Self-shielding Sets (SS) - Various thicknesses of copper, cobalt, and scandium used to determine the effect of the monitor thickness on its activation in different spectral environments (Table 2).
- Statistical Sets - Three 20 mil iron wires packaged together. These are used to help determine the overall precision of individual analyses.

A sixth set, Stable Product Fissionable Material (SPF), was included. This set consisted of ^{235}U and ^{238}U for ^{137}Cs and ^{148}Nd measurements to determine burnup; however, this set will not be discussed at this time because analysis is not complete.

ENCAPSULATION OF FOIL SETS

The previously-described foil sets were assembled in Type 304 SS capsules (see Tables 1 and 2 and Figures 1, 2, and 3).⁽¹⁾ The assembled capsules were then placed in a standard 19-pin structural subassembly. Any subassembly pin position not used for dosimetry foils was filled with solid stainless steel rods for positioning purposes. Figure 4 shows the foil set locations. Low Power run 31E dosimetry test involved a single pin (X045) located in subassembly 2B1 while High Power run 31F dosimetry test involved five pins located in four sub-assemblies: two (X046) in 2B1 and one (X047) in 4E2, one (X048) in 6D2 and one (X049) in 7A3. The general loading pattern can be seen in Reference 1.

IRRADIATION TIME HISTORY

Figures 5 and 6 provide relative power-time history curves⁽⁵⁾ for EBR-II runs 31E (Low Power) and 31F (High Power), respectively. Analysis of these curves indicated that foil activation results could be converted to saturated activities (reaction rates) by assuming effective constant-power run-times of 62 min for run 31E and 8 days and 6 hr for run 31F. The

TABLE 2. Self-shielding Sets

Reaction	Form	Dimensions ^(a)	Test ^(b)	Approx. Weight, mg	Number/ Location	Encapsulated ^(c)
$^{59}\text{Co}(n,\gamma)^{60}\text{Co}$	Al-Co-wire 0.483%	30 mil $\times$ 1/8 in.	H	4	3	X
	Metal-piece	0.5 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	0.7	3	X
	Metal-wire	20 mil $\times$ 1/8 in.	H	6	3	X
	Metal-piece	5 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	7	3	X
$^{45}\text{Sc}(n,\gamma)^{46}\text{Sc}$	Metal-wire	20 mil $\times$ 3/16 in.	H	2	3	X
	Metal-strip	1 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	0.5	3	X
	Metal-strip	5 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	2	3	X
	Metal-strip	10 mil $\times$ 0.080 in. $\times$ 1/8 in.	H	3	3	X
$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$	Metal-piece	0.5 mil $\times$ 0.080 in. $\times$ 1/8 in.	L	1	6	X
	Metal-piece	5 mil $\times$ 0.080 in. $\times$ 1/8 in.	L	5	3	X
	Metal-wire	20 mil $\times$ 1/8 in.	L	6	3	X

a. Foils shall be a small flat washer $\sim 1/4$ in. OD $\times$ 1/8 in. ID, thickness will vary as noted. Wire shall be referenced by OD and approximate length with S - straight and R - formed round.

b. L refers to Low Power (86 KW)⁽⁶⁾ Run 31E
H refers to High Power (50 MW)⁽⁶⁾ Run 31F

c. Check indicates material contained in stainless steel tubes $\sim 3/4$ in. long $\times$ 0.093 OD with ~ 3 mil wall, welded closed, see Figure 1.

Neg 701853-16

FIGURE 1. Spectral Set-Foil and Capsule Assembly

FIGURE 2. Typical Experimenter and Correlation Set

POSITION	MATERIAL	DIMENSIONS, ^(a) in.
1	Co	0.0005 × 0.080 × 1/8
2	Co	0.005 × 0.080 × 1/8
3	SAME AS 1	
4	SAME AS 2	
5	SAME AS 1	
6	SAME AS 2	
7	Co	0.020 OD × 1/8
8	Al-Co ^(b)	0.030 OD × 1/8
9	Co	SAME AS 7
10	Al-Co	SAME AS 8
11	Co	SAME AS 7
12	Al-Co	SAME AS 8

- a. Dimensions will vary with materials,
b. Al-Co wire 0.483% Co.*

FIGURE 3. Typical Self-shielding Set for Copper, Cobalt, and Scandium

Neg 701853-11

FIGURE 4. Dosimetry Tests 31E and 31F Capsule Locations

FIGURE 5 Time History for EBR-II Run 31E (Low Power Test)

FIGURE 6. Time History for EBR-II Run 31F (High Power Test)

dates, actual times at power, and shutdown times are also shown in Figure 5 and 6.⁽⁶⁾ The error introduced by using these effective constant-power time histories as opposed to the actual power time histories, shown in Figures 5 and 6, should be less than ~0.5% for all foil reactions used in the EBR-II test.⁽¹⁾

IV. METHODS OF ANALYSIS

ANALYTICAL TECHNIQUES

*

The extreme range of activities encountered, the complexity of the gamma spectra encountered, and the facilities available to the experimenter required the use of a wide variety of analytical techniques and/or tools. No attempt was made prior to the test to request uniform analytical procedures, although some interlaboratory comparison tests had been made prior to this run.^(2-4,7-9) Most participants dissolved the foil materials and counted a suitable aliquot directly. Where fission foils were dissolved, it was requested that both the foil and encapsulating material be dissolved to eliminate the possibility of fragment loss. One laboratory was able to count nondestructively. Separations were made by several laboratories for fission foil products ^{140}Ba , ^{137}Cs and ^{99}Mo .

General Separation Procedures

- ^{140}Ba - Barium carrier was added and several $\text{Fe}(\text{OH})_3$ scavenges made, with final precipitation as BaSO_4 . The ^{140}La was allowed to reach transient equilibrium for gamma counting.⁽¹⁰⁾
- ^{137}Cs - Cesium carrier is added and cesium perchlorate is precipitated from alcohol. The precipitate is dissolved and several $\text{Fe}(\text{OH})_3$ scavenges made. Final precipitation of cesium perchlorate is again made from alcohol.⁽¹¹⁾

* From 6 disintegrations per second (dps) to 10^{12} dps of the measured nuclide in the total foil. Dose rates were as high as 240 rad/hr at 2 in.

- ^{137}Cs - Cesium carrier is added, and several $\text{Fe}(\text{OH})_3$ scavenges are made. Final precipitation of cesium chloroplatinate is made from alcohol. (11)
- ^{99}Mo - Molybdenum and iron carriers are added, and the molybdenum extracted from HCl solution into ether. The molybdenum is back extracted into water and two $\text{Fe}(\text{OH})_3$ scavenges made. Final precipitation as molybdenum 8-hydroxyquinolate is made from a slightly acid solution. (12)

COUNTING SYSTEMS

- The most widely used gamma spectrometry system was the 3×3 in. solid $\text{NaI}(\text{Tl})$ detector with a 400 or 512 channel pulse height analyzer. However, 2×2 in. solid and 4×5 in. well $\text{NaI}(\text{Tl})$ detectors were also used. Counting positions ranged from within the well to 100 cm above the detector.
- Several laboratories used $\text{Ge}(\text{Li})$ detectors in conjunction with 4096 channel pulse height analyzers. The sizes of the $\text{Ge}(\text{Li})$ detectors used ranged from 10 cm^3 to 25 cm^3 and were of true or trapizoidal coaxial configuration.
- Other counting systems used by some participants for various specific analyses included liquid scintillation counters, gas flow beta proportional counters, X-ray spectrometers and ionization chambers (IC).
- Calibration of the $\text{NaI}(\text{Tl})$ systems was accomplished by either counting standard sources corresponding to those isotopes observed, or by correlating the system with Heath's data⁽¹³⁾ and subsequent use of the so-called "Heath Curves."⁽¹⁴⁾ The $\text{Ge}(\text{Li})$ systems were calibrated using standard sources of the isotope in question or standards covering the gamma energy regions in question. All other counting systems used were calibrated using standard sources of the isotope being analyzed.

Calculation Techniques

Procedures used to convert the raw counting data to disintegration rate varied considerably and depended upon the detection system used and complexity of the γ spectra encountered. The majority of the data obtained by using Ge(Li) detectors were calculated using total peak areas with direct comparison to reference sources or using Efficiency versus Energy Curves and Branching Intensities. Data obtained using the NaI(Tl) detectors were handled using a number of techniques. In the case of a relatively simple spectra, direct comparison with a calibrated reference source or use of the detector-correlated "Heath Curves" with appropriate decay scheme data were generally used. Where the spectra were more complicated, such techniques as calibrated reference source and spectrum stripping were used, as well as solution of simultaneous linear equations or least squares fitting techniques using computer programs. Table 3 lists the systems and techniques used by the individual laboratories.

V. DATA CORRELATION

REPORTING

All participants were requested to report to PNL their foil activity measurements in units of count rate per unit weight with estimated precision and accuracy. Methods of analysis were also requested, such as: destructive or nondestructive; separation techniques if used; types of counting system involved; decay scheme data used to convert count rates to disintegration rates, half lives, and calculation techniques. Upon receipt of data, axial and radial plots were made in order to detect anomalous results as quickly as possible in order that re-evaluation of the data and re-analysis of the foil could be made. Where anomalous results were noted, the participant was notified, although the degree of apparent error was not given.

TABLE 3. Comparison of Techniques Used by Individual Laboratories

Isotope ^(a) Analyzed:		¹⁹⁸ Au	¹⁴⁰ Ba	¹³⁷ Cs	⁹⁹ Mo	⁶⁴ Cu	⁶⁰ Co	⁵⁹ Fe	⁵⁸ Co	⁵⁴ Mn	⁴⁸ Sc	⁴⁷ Sc	⁴⁶ Sc
Technique	Nondestructive	A ^(b)	A				A, H	A	A	A	A, H	A, H	A, H
	Destructive-dc	G	B, D			B, G, H	B, D, G H	B, C, D F, G, I	B, C, D E, F, G	B, C, D E, F, G, I	B, G	B, G	B, C, E F, G
Destructive Separation ^(c)			B(a)	B(b), C(c)	B(b), C(c)								
Detector	NaI(Tl)		B, D	B, C	B, C	B, H	B, D, H	B, C, C F, I	B, C, D E, F	B, C, D E, F, I	B, H	B, H	B, C, E F, H
	Ge(Li)	A, G ^(d)	A			G,	A, G	A, G	A, G, E	A, G, E	A, G	A, G	A, G
	IC						D						
Calibration	Calibrated Ref. Stds.	A, G	D	C	C	H, G	A, D G, H	A, D F, G, I	A, D, E F, G	A, D F, G, I	A, G, H	A, G, H	A, F, G
	"Heath" curves		B	B	B	B	B	B, C	B, C	B, C	B	B	B, C
Calculation	Direct comparison or spectrum strip		D	C	C	H	D, H	D, F	D, E F	D, E F	H	H	F, H
	Total peak or edge corrected	A, G	A, B	B	B	B, G	A, B, G	A, B, C, G	A, B, C, G	A, B, C G	A, B, G H	A, B, G H	A, B, C G
	Computer					H	H	I		I			

a. Isotopes listed are the reaction products analyzed. ⁶⁰Co could be from either ⁵⁹Co(n, γ) ⁶⁰Co or ⁶³Cu(n, α) ⁶⁰Co

b. Laboratory designations A, B, C, etc. are also used for their respective results listed in Tables 7 and 8.

c. Destructive separation. The designation B(a) represents Laboratory B-separation "a" as discussed previously.

d. More than one detector, calibration method, and calculation technique were used by several of the laboratories

Calculation or counting errors were usually found to exist, and the results were adjusted accordingly. In the case of serious discrepancy in decay constants, the participants concurred with the PNL-accepted values and adjusted their data. Where minor differences here noted, the participant was notified and asked to review the constants in question. However, no corrections were requested unless the participant was satisfied as to the validity of the PNL-accepted data. Table I indicates the data used by the individual laboratories as compared to that presently used at PNL.

REACTION RATE CALCULATION

Conversion of the activity data to reaction rates for further Multiple Foil Data Reduction was made at this laboratory. All factors used in this conversion can be found in Tables 5 and 6.

VI. RESULTS

CORRELATION MEASUREMENTS

Correlation and statistical evaluation of the 14 foil reactions⁽¹⁾ used at this time from spectral, experimenter and correlation sets located at core center are shown in Tables 7 and 8. In order to normalize all foils to midplane, gradient factors were used which were obtained from best-fit plots of the measured reaction rates plus 2 db calculations.⁽²¹⁾ Corrections for foil impurity were also made on the ^{235}U , ^{238}U and ^{237}Np fission foils. Analysis of variance using F statistics⁽²²⁾ and Scheffe's Contrast Test⁽²³⁾ were used to determine whether an individual result or a laboratory bias existed. If bias was indicated, the data was eliminated before calculation of a weighted sample mean, standard deviation, and standard error. Where only two laboratories reported values, a weighted mean and deviation is given, since possible bias could not be statistically evaluated. An exception to the latter is the

$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$ reaction. Axial and radial plots of all the measured ^{64}Cu results along with apparent consistency with the SAND-II reduction of the overlapping 14 foil reaction set(20) indicated that a possible bias existed in the results from Laboratory B. Some variation may exist between the results listed here and those previously reported(1,24,25) due to refinements in determination of the gradient factors used.

The evaluation measurements (shown in Tables 7 and 8), evaluation of the axial and radial plot data, and laboratory evaluation of previous dosimetry correlation runs indicated that a standard deviation of +7% could reasonably be assigned the remainder of the 14 foil reactions.

REACTION RATES

Reaction rates for most of the reported analytical data can be found in Tables 9 and 10. The listed values reflect impurity corrections on the ^{235}U , ^{238}U and ^{237}Np but do not include any gradient corrections. Results for the $^{35}\text{Cl}(n,\alpha)^{32}\text{P}$ reaction are not included due to analytical difficulties and inconsistency within the data itself.

Not all foils were analyzed. Both the KI and a large number of the Sc foils lost their integrity in the High Power run, as the environmental effects had been underestimated.

ANALYTICAL DIFFICULTIES

The major difficulties encountered in the foil analysis were:

- Extreme range of activities; that is, 6 dps to 10^{12} dps/foil of the isotope in question.
- High gross foil activities and dose rates as high as 240 rad/hr at 2 in.

- The complex gamma spectra encountered in many of the foils; that is, fission foils included not only the fission product activities but also activation products from the encapsulation material.

One laboratory encountered extreme difficulty in dissolving the encapsulated ^{237}Np foils. Another laboratory encountered problems in ^{140}Ba separation and requested all results be omitted. Two other laboratories incurred difficulties in both handling the NaCl pellets and subsequent analysis of the product ^{32}P , thereby compromising the $^{37}\text{Cl}(n,\alpha)^{32}\text{P}$ reaction.

TABLE 4. Comparison of Decay Scheme Data Used by Experimenters

<u>Isotope</u>	<u>Lab</u>	<u>Gamma Energy, MeV</u>	<u>Gamma per Disintegration</u>	<u>Half Life, d</u>
^{46}Sc	A	1.120	0.996	83.8
	B	1.12	1.0	83.9
	C	1.12	1.0	84.0
	F	1.12	1.0	84.1
	G	1.1206	1.0	83.9
	PNL	1.12	1.0	84.0
^{47}Sc	A	0.159	0.60	3.43
	B	0.16	0.73	3.43
	G	0.16	0.73	3.43
	PNL	0.16	0.73	3.43
^{48}Sc	A	1.314	1.0	1.83
	B	1.31	1.0	1.83
	G	1.314	1.0	1.83
	PNL	1.31	1.0	1.83
^{54}Mn	A	0.835	1.0	313.02
	B	0.84	1.0	313
	C	0.835	1.0	313
	D	0.835	1.0	313
	E	0.8348	1.0	303
	F	0.845	1.0	314
	G	0.835	1.0	313
	PNL	0.835	1.0	313.5
^{58}Co	A	0.8105	0.995	71.3
	B	0.81	0.99	71.3
	C	0.81 + 0.85	1.01	71.3
	E	0.81 + 0.85	1.01	71.3
	F	0.81 + 0.85	1.01	71.3
	G	0.81	0.99	71.3
	PNL	0.81	0.99	71.3

TABLE 4. (Continued)

Isotope	Lab	Gamma Energy, MeV	Gamma per Disintegration	Half Life, d
^{59}Fe	A	1.291	0.441	45.0
	B	1.29	0.44	
	C	1.29	0.43	45
	F	1.29	0.44	45.1
	G	1.29	0.44	
	PNL	1.292	0.44	45
^{60}Co	A	1.3325	1.0	1914.6
	G	1.332	1.0	1921
	PNL	1.332	1.0	1922.8
^{64}Cu	B	0.511 ^(a)	0.38 ^(a)	0.535
	G	0.511	0.38	0.535
	PNL	0.511	0.38	0.535
	PNL	1.346	0.0048	0.535
^{99}Mo	B	β count		2.779
	C	β count		2.779
	PNL			2.779
^{137}Cs	B	0.662	0.85	10950
	C	0.662	0.85	10950
	PNL	0.662		10994
^{140}Ba	A	1.5916	0.9619	12.8
	B	1.6		12.8
	D	1.6		12.8
	PNL	1.592		12.8
^{198}Au	A	0.4118	0.956	2.698
	G	0.412	0.95	
	PNL	0.412	0.95	2.698
^{24}Na	PNL	1.38		0.625
	I	1.38	--	0.625

a. Positron annihilation photons

TABLE 5. Calculation Factors for EBR-II Dosimetry Test

Reaction	Product Half Life ^(a)	Target Isotope Abundance	Atomic Wt. ^(b)	K ₁ (10 ⁻¹⁹) ^(c)	High Power (H) $\lambda \cdot e^{-\lambda t}$	Low Power (L) $\lambda \cdot e^{-\lambda t}$	
²³ NaCl (n,γ) ²⁴ Na	15.0 h	(1.000)(0.39337)	22.9898	0.970396	9.99894×10^{-1}	4.66282×10^{-2}	2
²⁴ Mg (n,p) ²⁴ Na	15.0 h	0.7860	24.3047	0.513590	9.99894×10^{-1}	4.66282×10^{-2}	2
²⁷ Al (n,α) ²⁴ Na	15.0 h	1.000	26.9815	0.448006	9.99894×10^{-1}	4.66282×10^{-2}	2
Na ³⁵ Cl (n,α) ³² P	14.3 d	(0.7553)(0.60663)	35.453	1.28478	3.29609×10^{-1}	2.08481×10^{-3}	3
⁴⁵ Sc (n,γ) ⁴⁶ Sc	84.0 d	1.000	44.956	0.746459	6.58117×10^{-2}	3.15522×10^{-4}	4
⁴⁶ Ti (n,p) ⁴⁶ Sc	84.0 d	0.0799	47.90	9.95421	6.58117×10^{-2}	3.15522×10^{-4}	4
⁴⁷ Ti (n,p) ⁴⁷ Sc	3.43 d	0.0732	47.90	10.8653	8.11225×10^{-1}	8.66312×10^{-3}	3
⁴⁸ Ti (n,p) ⁴⁸ Sc	44.0 h	0.7399	47.90	1.07493	9.55806×10^{-1}	1.61467×10^{-2}	2
⁵⁴ Fe (n,α) ⁵¹ Cr	27.8 d	0.0584	55.847	15.8783	1.85924×10^{-1}	2.32884×10^{-3}	3
⁵⁴ Fe (n,p) ⁵⁴ Mn	313.5 d ⁽¹⁶⁾	0.0584	55.847	15.8783	1.80754×10^{-2}	9.51915×10^{-5}	5
⁵⁴ Fe ₂ O ₃ (n,α) ⁵¹ Cr (d)	27.8 d	(0.9712)(0.6923)	53.9979	1.33350	1.85924×10^{-1}	2.32884×10^{-3}	3
⁵⁴ Fe ₂ O ₃ (n,p) ⁵⁴ Mn (d)	313.5 d ⁽¹⁰⁾	(0.9712)(0.6923)	53.9979	1.33350	1.80754×10^{-2}	9.51915×10^{-5}	5
⁵⁸ Ni (n,p) ⁵⁸ Co	71.3 d	0.6788	58.71	1.43611	7.70712×10^{-2}	4.18481×10^{-4}	4
⁵⁸ Ni (n,p) ⁵⁸ Co (e)	71.3 d	0.9989	57.9380	0.963074	7.70712×10^{-2}	4.18481×10^{-4}	4
⁵⁸ Fe (n,γ) ⁵⁹ Fe (g)	45 d	0.0000	55.847	280.999	1.19335×10^{-1}	6.62979×10^{-4}	4
⁵⁹ Co (n,2n) ⁵⁸ Co	71.3 d	1.000	58.9332	0.978539	7.70712×10^{-2}	4.18481×10^{-4}	4
⁵⁹ Co (n,p) ⁵⁹ Fe (g)	45 d	1.000	58.9332	0.978539	1.19335×10^{-1}	6.62979×10^{-4}	4
⁵⁹ Co (n,γ) ⁶⁰ Co	5.268 y	1.000	58.9332	0.978539	2.96959×10^{-3}	1.55208×10^{-5}	5
⁶³ Cu (n,α) ⁶⁰ Co	5.268 y	0.6909	63.546	1.52718	2.96959×10^{-3}	1.55208×10^{-5}	5
⁶³ Cu (n,γ) ⁶⁴ Cu	12.84 h	0.6909	63.546	1.52718	9.99977×10^{-1}	5.42558×10^{-2}	2

TABLE 5. (Continued)

Reaction	Product	Target Isotope	Atomic Wt. ^(b)	K_1 (10^{-19}) ^(c)	High Power (H)	Low Power (L)
	Half Life (a)	Abundance			$1-e^{-At}$	$1-e^{-At}$
^{197}Au (n,2n) ^{196}Au	6.18 d	1.000	196.967	3.27048	6.03596×10^{-1}	4.81748×10^{-3}
^{197}Au (n, γ) ^{198}Au	2.698 d	1.000	196.967	3.27048	8.79912×10^{-1}	1.10006×10^{-2}
^{232}Th (n,f) ^{99}Mo	66.7 h (12)	1.000	232.038	3.85281	8.72243×10^{-1}	1.06810×10^{-2}
^{232}Th (n,f) ^{140}Ba	12.80 d	1.000	232.038	3.85281	3.60301×10^{-1}	2.32884×10^{-3}
^{235}U (n,f) ^{99}Mo	66.7 h (12)	1.000 (f)	235.0439	3.90272	8.72243×10^{-1}	1.06810×10^{-2}
^{235}U (n,f) ^{137}Cs	30.12 y (18)	1.000 (f)	235.0439	3.90272	5.20020×10^{-4}	2.71423×10^{-6}
^{235}U (n,f) ^{140}Ba	12.80 d	1.000 (f)	235.0439	3.90272	3.60301×10^{-1}	2.32884×10^{-3}
^{237}Np (n,f) ^{140}Ba	12.80 d	1.000	237.048 ⁽ⁱ⁹⁾	3.93599	3.60301×10^{-1}	2.32884×10^{-3}
^{238}U (n,f) ^{99}Mo	66.7 h (12)	1.000 (f)	238.03	3.95264	8.72243×10^{-1}	1.06810×10^{-2}
^{238}U (n,f) ^{137}Cs	30.12 y (18)	1.000 (f)	238.03	3.95264	5.20020×10^{-4}	2.71423×10^{-6}
^{238}U (n,f) ^{140}Ba	12.80 d	1.000 (f)	238.03	3.95264	3.60301×10^{-1}	2.32884×10^{-3}
^{238}U (n, γ) ^{239}Np	2.35 d	1.000 (f)	238.03	3.95264	9.12262×10^{-1}	1.26193×10^{-2}

a. Unless otherwise noted, all half-life values are from Reference 15.

b. Atomic weights are from the 1966 International Atomic Weight Tables unless otherwise noted.

c. $K_1 = \text{Atomic weight} \div (\text{abundance})(A)(10^{-3})$ where the value used for Avodadro Number (A) is 6.02257×10^{23} .
(dps/mg)(K_1) = dps/nucleus.

d. 97.12% enriched ^{54}Fe . Abundance and weight were calculated for the enriched isotopic mixture.

e. 99.89% enriched ^{58}Ni . Abundance and weight were calculated for the enriched isotopic mixture.

f. Abundances of 100% with respective isotopic weights were used for the " K_1 " calculations. Correction for percent of foil composition and/or enrichment were made elsewhere in the calculation.

g. The ^{59}Fe $t_{1/2}$ of 44.5 d from Reference 17 was inadvertently used for the initial calculation and comparisons. Since the maximum error introduced was <1.02% with negligible error in the HP/LP ratio, corrections were not made.

TABLE 6. Fission Foil Reactions, Half Lives **and** Fission Yield
Values for Fast Reactor Flux-Spectral Measurements

<u>Reaction</u>	<u>Reaction Product</u>	<u>Half Life</u>	<u>Yield %</u>
$^{237}\text{Np}(\text{n},\text{f})$	^{140}Ba	12.80 d	5.8
$^{238}\text{U}(\text{n},\text{f})$	^{140}Ba	12.80 d	6.0
$^{238}\text{U}(\text{n},\text{f})$	^{99}Mo	66.7 h	6.3
$^{238}\text{U}(\text{n},\text{f})$	^{137}Cs	30.12 y	6.3
$^{235}\text{U}(\text{n},\text{f})$	^{140}Ba	12.80 d	6.1
$^{235}\text{U}(\text{n},\text{f})$	^{99}Mo	66.7 h	6.1
$^{235}\text{U}(\text{n},\text{f})$	^{137}Cs	30.12 y	6.2
$^{232}\text{Th}(\text{n},\text{f})$	^{140}Ba	12.80 d	7.6
$^{232}\text{Th}(\text{n},\text{f})$	^{99}Mo	66.7 h	3.1

Fission Yield Data from Reference 20.

TABLE 7. Low Power Run 31E Measured Fission and Reaction Rates
Radial Distance from Core Center 5.2 cm

Foil Reaction	Lab.	Axial Distance	Gradient Factor	Fissions/ nucleus
$^{235}\text{U}(\text{n},\text{f})^{140}\text{Ba}$	A	0.23 cm	1.000	4.99×10^{-12}
	B	-1.70	1.005	5.22×10^{-12}
$^{235}\text{U}/\text{Al}(\text{n},\text{f})^{140}\text{Ba}$	A	-2.74	1.011	5.75×10^{-12}
	A	+3.51	1.018	5.63×10^{-12}
	B	-1.70	1.005	5.16×10^{-12}
$^{235}\text{U}(\text{n},\text{f})^{99}\text{Mo}$	C	+4.47	1.029	5.10×10^{-12}
$^{235}\text{U}/\text{Al}(\text{n},\text{f})^{99}\text{Mo}$	B	-1.70	1.005	5.10×10^{-12}
	C	+4.47	1.029	5.37×10^{-12}
Corrected for 6.75% ^{238}U and where necessary 16.4% Alloy Content. No apparent bias. $\bar{x} \ 5.29 \times 10^{-12} \pm 5.2\% \text{ S } (1.8\% \text{ SE})$				
$^{238}\text{U}(\text{n},\text{f})^{140}\text{Ba}$ ^{99}Mo	A	+0.23	1.000	3.22×10^{-13}
	B	-1.70	1.007	3.30×10^{-13}
	C	+4.47	1.038	3.24×10^{-13}
No apparent bias. $\bar{x} \ 3.26 \times 10^{-13} \pm 1.3\% \text{ S } (0.8\% \text{ SE})$				
$^{237}\text{Np}(\text{n},\text{f})^{140}\text{Ba}$	A	+0.23	1.000	2.15×10^{-12}
	B	-1.70	1.006	2.29×10^{-12}
	D	-2.74	1.014	2.36×10^{-12}
	D	-2.74	1.014	2.36×10^{-12}
Corrected for 1000 ppm ^{238}Pu . No apparent bias. $\bar{x} \ 2.27 \times 10^{-12} \pm 4.2\% \text{ S } (2.7\% \text{ SE})$				

S - Standard deviation
SE - Standard error

TABLE 7. (Continued)

Foil Reaction	Lab.	Axial Distance	Gradient Factor	Fissions or dps/nucleus
$^{232}\text{Th}(n, f) ^{140}\text{Ba}$	A	+0.23 cm	1.000	8.29×10^{-14}
	B	-2.05	1.004	8.43×10^{-14}
		$\bar{x} \ 8.36 \times 10^{-14} \pm \mathbf{1.1\%S}$		
$^{54}\text{Fe}(n, p) ^{54}\text{Mn}$	A	-3.58	1.027	6.35×10^{-14}
		-0.37	1.002	6.23×10^{-14}
		+2.79	1.018	6.17×10^{-14}
	B	-3.00	1.021	7.32×10^{-14} (a)
	C	+2.79	1.018	6.51×10^{-14}
	D	-3.40	1.025	6.67×10^{-14}
		$\bar{x} \ 6.49 \times 10^{-14} \pm 3.2\% \text{ S } (1.8\% \text{ SE})$		
$^{58}\text{Fe}(n, \gamma) ^{59}\text{Fe}$	A	-3.58	1.009	1.75×10^{-14}
		-0.37	1.000	1.56×10^{-14}
		+2.79	1.006	1.64×10^{-14}
	C	+2.79	1.006	1.61×10^{-14}
	D	-3.40	1.008	1.70×10^{-14}
		No apparent bias.		
		$\bar{x} \ 1.65 \times 10^{-14} \pm 2.7\% \text{ S } (1.5\% \text{ SE})$		
$^{59}\text{Co}(n, \gamma) ^{60}\text{Co}$	H	-0.44	1.000	8.01×10^{-14}
				$\bar{x} \ 8.01 \times 10^{-14} \text{ est. } 6\%$

S - Standard deviation
SE - Standard error

a. Apparent biased result.

TABLE 7. (Continued)

Foil Reaction	Lab.	Axial Distance	Gradient Factor	dps/nucleus
$^{58}\text{Ni}(n,p)^{58}\text{Co}$	A	-3.56 cm	1.026	8.49×10^{-14} (a)
		-0.37	1.001	8.61×10^{-14}
		+2.79	1.018	8.55×10^{-14}
	B	-3.28	1.022	8.99×10^{-14}
	C	+2.79	1.018	8.75×10^{-14}
	D	-3.48	1.024	9.25×10^{-14} (a)
		$\bar{x} \ 8.77 \times 10^{-14} \pm 2.3\% \text{ S } (1.3\% \text{ SE})$		
$^{46}\text{Ti}(n,p)^{46}\text{Sc}$	B	-3.33	1.019	9.17×10^{-15}
	C	+2.79	1.015	7.88×10^{-15}
	H	-0.44	1.001	8.14×10^{-15}
		$\bar{x} \ 8.40 \times 10^{-15} \pm 8.1\% \text{ S } (4.7\% \text{ SE})$		
$^{47}\text{Ti}(n,p)^{47}\text{Sc}$	B	-3.33	1.016	1.58×10^{-14}
	H	-0.44	1.000	1.61×10^{-14}
		$\bar{x} \ 1.59 \times 10^{-14} \pm 1.2\% \text{ S}$		
$^{48}\text{Ti}(n,p)^{48}\text{Sc}$	B	-3.33	1.019	2.07×10^{-16}
	H	-0.44	1.001	2.20×10^{-16}
		$\bar{x} \ 2.13 \times 10^{-16} \pm 4.2\% \text{ S}$		
$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$	B	-3.38	1.011	7.49×10^{-14}
	B	+2.79	1.010	7.37×10^{-14}
	H	-0.44	1.000	8.43×10^{-14}
		$\bar{x} \ 8.43 \times 10^{-14} \pm \text{est. } <4\% \text{ (b)}$		

S - Standard deviation
SE - Standard error

a. Apparent biased result.

b. An axial plot of the ^{64}Cu results and apparent consistency with SAND-11 reduced overlapping 14 foil reaction sets indicates an apparent bias in the Laboratory B results.

TABLE 7. (Continued)

<u>Foil Reaction</u>	<u>Lab.</u>	<u>Axial Distance</u>	<u>Gradient Factor</u>	<u>dps/nucleus</u>
$^{23}\text{Na}(n,\gamma)^{24}\text{Na}$	I	+0.23 cm $\bar{x} \ 1.94 \times 10^{-15} \pm \text{est. } <11\%$	1.000	1.94×10^{-15}
$^{27}\text{Al}(n,\alpha)^{24}\text{Na}$	I	-0.37 $\bar{x} \ 4.85 \times 10^{-16} \pm \text{est. } <8\%$	1.000	4.85×10^{-16}
$^{197}\text{Au}(n,\gamma)^{198}\text{Au}$	A	-0.37 $\bar{x} \ 1.35 \times 10^{-12} \pm \text{est. } <5\%$	1.000	1.35×10^{-12}

TABLE 8. High Power Run 31F Measured Fission and Reaction Rates
Radial Distance from Core Center 5.2 cm

Foil Reaction	Lab.	Axial Distance	Gradient Factor	Fissions/nucleus
$^{235}\text{U}(\text{n},\text{f})^{140}\text{Ba}$	A	+0.10 cm	1.000	3.09×10^{-9}
	B	+0.10	1.000	2.85×10^{-9}
	B	-2.06	1.007	2.96×10^{-9}
$^{235}\text{U}/\text{Al}(\text{n},\text{f})^{140}\text{Ba}$	A	-3.12	1.014	2.91×10^{-9}
	A	+3.63	1.019	2.90×10^{-9}
	B	-2.06	1.007	2.86×10^{-9}
$^{235}\text{U}(\text{n},\text{f})^{137}\text{Cs}$	B	+0.10	1.000	2.64×10^{-9}
	C	+4.67	1.031	2.76×10^{-9}
$^{235}\text{U}/\text{Al}(\text{n},\text{f})^{137}\text{Cs}$	C	+4.67	1.031	3.08×10^{-9}
Corrected for 6.75% ^{238}U content and where necessary 16.4% Alloy Comp. No apparent bias.				
$\bar{x} \ 2.85 \times 10^{-9} \pm 5.2\% \text{ S } (2.6\% \text{ SE})$				
$^{238}\text{U}(\text{n},\text{f})^{140}\text{Ba}$	A	+0.10	1.000	1.77×10^{-10}
	B	-3.12	1.020	1.92×10^{-10}
^{137}Cs	C	+4.67	1.041	1.75×10^{-10}
No apparent bias.				
$\bar{x} \ 1.81 \times 10^{-10} \pm 5.1\% \text{ S } (2.9\% \text{ SE})$				
$^{237}\text{Np}(\text{n},\text{f})^{140}\text{Ba}$	A	+0.10	1.000	1.28×10^{-9}
	B	-3.12	1.018	1.25×10^{-9}
	D	-3.12	1.018	1.23×10^{-9}
	D	-3.12	1.018	1.31×10^{-9}
Corrected for 1000 ppm ^{238}Pu . No apparent bias.				
$\bar{x} \ 1.27 \times 10^{-9} \pm 1.3\% \text{ S } (0.8\% \text{ SE})$				

S - Standard deviation
SE - Standard error

TABLE 8. (Continued)

Foil Reaction	Lab.	Axial Distance	Gradient Factor	Fissions/nucleus
$^{232}\text{Th}(n,f)^{140}\text{Ba}$	A	+0.10 cm	1.000	5.09×10^{-11}
	B	-2.06	1.004	4.39×10^{-11}
		$\bar{x} \ 4.74 \times 10^{-11} \pm 10\% \text{ S}$		
$^{54}\text{Fe}(n,p)^{54}\text{Mn}$	A	-3.12	1.022	3.63×10^{-11}
	A	-0.38	1.003	3.66×10^{-11}
	A	+3.63	1.027	3.58×10^{-11} (a)
	B	-2.06	1.011	3.83×10^{-11}
	C	+4.67	1.042	3.82×10^{-11}
	D	-3.12	1.022	3.91×10^{-11}
	D	+3.63	1.027	3.87×10^{-11}
	E	+2.87	1.019	3.77×10^{-11}
	F	+2.87	1.019	3.92×10^{-11}
	F	+2.87	1.019	3.94×10^{-11}
	G	-5.59	1.057	3.62×10^{-11}
	G	-6.68	1.081	3.80×10^{-11}
		$\bar{x} \ 3.80 \times 10^{-11} \pm 2.7\% \text{ S (1\% SE)}$		
$^{58}\text{Fe}(n,\gamma)^{59}\text{Fe}$	A	-3.12	1.006	8.37×10^{-12}
	A	-0.38	1.000	8.37×10^{-12}
	A	+3.63	1.008	8.50×10^{-12}
	B	-2.06	1.002	8.52×10^{-12}
	C	+4.67	1.014	8.76×10^{-12}
	F	+2.87	1.006	9.40×10^{-12} (a)
	G	-6.68	1.032	8.10×10^{-12}
		$\bar{x} \ 8.45 \times 10^{-12} \pm 3.2\% \text{ S (1.6\% SE)}$		
$^{59}\text{Co}(n,\gamma)^{60}\text{Co}$	A	-0.38	1.000	3.02×10^{-11}
	G	-6.68	1.007	3.10×10^{-11}
S - Standard deviation		$\bar{x} \ 3.06 \times 10^{-11} \pm 1.7\% \text{ S}$		
SE - Standard error				

a. Apparent biased result.

TABLE 8. (Continued)

Foil Reaction	Lab.	Axial Distance	Gradient Factor	dps/nucleus
$^{46}\text{Ti}(n,p)^{46}\text{Sc}$	A	-3.12	1.017	4.88×10^{-12}
	A	-0.38	1.000	4.84×10^{-12}
	A	+3.63	1.023	4.75×10^{-12}
	B	-2.06	1.008	4.77×10^{-12}
	C	+4.67	1.034	4.85×10^{-12}
	F	+3.63	1.023	5.43×10^{-12}
	G	-6.68	1.076	4.82×10^{-12}
$^{58}\text{Ni}(n,p)^{58}\text{Co}$	A	-3.12	1.020	5.07×10^{-11}
	A	-0.38	1.002	5.09×10^{-11}
	A	+3.63	1.026	5.03×10^{-11}
	B	-2.06	1.012	5.00×10^{-11}
	C	+4.67	1.041	5.21×10^{-11}
	D	-3.12	1.020	5.36×10^{-12}
	E	+2.87	1.018	5.18×10^{-12}
	F	+2.87	1.018	$5.96 \times 10^{-12(a)}$
	F	+2.87	1.018	$5.88 \times 10^{-12(a)}$
	F	+2.87	1.026	$5.70 \times 10^{-12(a)}$
	G	-6.68	1.079	5.35×10^{-12}
	G	-5.59	1.056	5.17×10^{-12}
		$\bar{x} \ 5.17 \times 10^{-12} \pm 2.3\% \text{ S } (1\% \text{SE})$		
$^{47}\text{Ti}(n,p)^{47}\text{Sc}$	A	-3.12	1.014	8.76×10^{-12}
	A	-0.38	1.000	8.50×10^{-12}
	A	+3.63	1.019	8.56×10^{-12}
	B	-2.06	1.006	8.12×10^{-12}
	G	-6.68	1.068	$10.1 \times 10^{-12(a)}$
		$\bar{x} \ 8.36 \times 10^{-12} \pm 4.1\% \text{ S } (2.9\% \text{SE})$		

S - Standard deviation
SE - Standard error

a. Apparent biased results.

TABLE 8, (Continued)

Foil Reaction	Lab.	Axial Distance	Gradient Factor	ips./nu ~
$^{48}\text{Tl}(n,p)^{48}\text{Sc}$	A	-3.12 cm	1.017	1.70×10^{-13}
	A	-0.38	1.000	1.17×10^{-13}
	A	+3.63	1.026	1.22×10^{-13}
	B	-2.06	1.009	1.26×10^{-13}
	G	-6.68	1.078	1.24×10^{-13}
No apparent bias.				
$\bar{x} 1.23 \times 10^{-13} \pm 2.7\% S (1.5\% SE)$				
$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$	B	-2.06	1.006	4.9×10^{-11}
	H	-3.12	1.010	4.77×10^{-11}
	H	+3.63	1.015	4.65×10^{-11}
$\bar{x} 4.71 \times 10^{-11} \pm 1.8\% S (a)$				
$^{23}\text{Na}(n,\gamma)^{24}\text{Na}$	I	0.10	1.000	1.08×10^{-12}
	$\bar{x} 1.08 \times 10^{-12}$ estd. <11%			
$^{27}\text{Al}(n,\alpha)^{24}\text{Na}$	I	+1.19	1.007	2.77×10^{-13}
	$\bar{x} 2.77 \times 10^{-13} \pm$ estd. <8%			
$^{197}\text{Au}(n,\gamma)^{198}\text{Au}$	A	-0.38	1.000	4.39×10^{-10}
	G	-6.68	1.048	4.91×10^{-10}
$\bar{x} 4.65 \times 10^{-10} \pm 7.9\% S$				

S - Standard deviation
SE - Standard error

a. Comparison of axial and radial plotted data and apparent consistency with SAND-11 reduced overlapping 34 foil reaction sets indicates an apparent bias in the Laboratory B result.

TABLE 9. Low Power Run 31E (R = 5.18 cm) Measured Reaction Rates

$^{235}\text{U}(\text{n},\text{f})$ (a)			$^{54}\text{Fe}(\text{n},\text{p})^{54}\text{Mn}$		$^{197}\text{Au}(\text{n},\gamma)^{198}\text{Au}$	
	Z, cm	Fissions/ Nucleus ($\times 10^{-12}$)	Z, cm	dps/nucleus ($\times 10^{-15}$)	Z, cm	dps/nucleus ($\times 10^{-12}$)
^{140}Ba	-2.74	5.72 (b)	-3.53	61.8	-0.44	1.35
^{99}Mo	-1.70	5.09	-3.40	65.1	+14.73	1.47
^{140}Ba	-1.70	5.16 (b)	-3.20	71.7	+17.93	1.86
	-1.70	5.21	-0.44	62.7	+38.86	4.82
	+0.23	5.01	+2.79	63.5	+59.18	4.91
	+3.51	5.65	+2.79	60.6		
^{99}Mo	+4.47	4.98	+14.86	37.9		
	+4.47	5.20 (b)	+18.06	25.8		
^{140}Ba	+15.65	4.48	+38.99	2.59		
	+19.53	4.12	+59.31	1.20		
	+40.69	4.14				
	+59.82	2.57				
$^{238}\text{U}(\text{n},\text{f})$ (c)			$^{59}\text{Co}(\text{n},\gamma)^{60}\text{Co}$		$^{46}\text{Ti}(\text{n},\text{p})^{46}\text{Sc}$	
		($\times 10^{-15}$)		($\times 10^{-14}$)		($\times 10^{-15}$)
^{140}Ba	-1.70	328	-0.44	8.01	-3.33	9.00
	+0.23	322	+14.88	11.1	-0.44	8.13
^{99}Mo	+4.47	312	+17.93	16.5	+2.79	7.71
^{140}Ba	+15.42	185	+38.86	48.1	+14.94	5.06
	+18.67	126	+59.18	43.0	+18.19	3.34
	+39.65	18.5				
	+59.82	2.42				
$^{232}\text{Th}(\text{n},\text{f})$			$^{58}\text{Fe}(\text{n},\gamma)^{59}\text{Fe}$		$^{47}\text{Ti}(\text{n},\text{p})^{47}\text{Sc}$	
		($\times 10^{-16}$)		($\times 10^{-14}$)		($\times 10^{-15}$)
^{140}Ba	-1.70	839	-3.53	1.74	-3.33	15.6
	+0.23	829	-3.40	1.69	-0.44	16.1
^{99}Mo	+4.47	763	-0.44	1.57	+14.94	9.99
^{140}Ba	+15.42	540	+2.79	1.59	+18.19	6.87
	+18.67	309	+2.79	1.63		
	+39.65	48.3	+14.86	1.62		
	+54.82	25.3	+18.06	1.65		
			+38.99	2.19		
			+59.31	1.63		
$^{237}\text{Np}(\text{n},\text{f})^{140}\text{Ba}$			$^{58}\text{Ni}(\text{n},\text{p})^{58}\text{Co}$		$^{48}\text{Ti}(\text{n},\text{p})^{48}\text{Sc}$	
		($\times 10^{-14}$)		($\times 10^{-16}$)		($\times 10^{-17}$)
	-2.74	233	-3.56	837	-3.33	20.3
	-2.74	233	-3.48	904	-0.44	22.0
	-1.70	228	-3.28	879	+14.94	12.9
	+0.23	215	-0.44	860	+18.19	9.19
	+4.47	187	+2.79	860		
	+15.42	142	+2.79	841		
	+18.67	104	+14.73	532		
	+39.65	22.7	+17.96	367		
	+59.82	4.69	+38.89	38.8		
			+59.21	4.22		
					$^{27}\text{Al}(\text{n},\alpha)^{24}\text{Na}$	
						($\times 10^{-18}$)
					-0.44	485
					+14.94	288
					+18.19	186
					+39.12	18.3
					+59.44	1.92

a. 93.25% enriched ^{235}U .b. Alloy - 16.4% enriched ^{235}U .c. 99.9977% ^{235}U , depleted uranium.

TABLE 9. (Continued)

$^{24}\text{Mg}(n,p)^{24}\text{Na}$		$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$	
dps/nucleus		dps/nucleus	
Z, cm	($\times 10^{-18}$)	Z, cm	($\times 10^{-14}$)
-0.44	930	-3.38	7.40
+14.91	587	-0.44	8.43
+18.14	365	+2.79	7.30
+39.07	37.6	+14.88	8.73
+59.39	4.01	+18.08	9.84
		+39.01	9.58
		+59.33	7.88
$^{23}\text{NaCl}(n,\gamma)^{24}\text{Na}$		$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$ Self Shielding	
(dps/nucleus)		Thickness, mil	
Z, cm	($\times 10^{-15}$)	Z, cm	($\times 10^{-14}$)
+0.23	1.94	+9.47	20
+15.42	1.76		
+18.67	1.89		
+39.65	2.29		
+59.82	1.53		
$^{45}\text{Sc}(n,\gamma)^{46}\text{Sc}$			
(dps/nucleus)			
Z, cm	($\times 10^{-14}$)		
+0.44	6.72		
+14.73	6.05		
+17.93	6.26		
+38.86	6.89		
+59.18	5.40		
$^{127}\text{I}(n,2n)^{126}\text{I}$			
(dps/nucleus)			
Z, cm	($\times 10^{-17}$)		
+0.23	77.3		
+15.42	43.0		
+18.67	31.9		
+39.65	6.75		
+59.82	2.77		
$^{54}\text{Fe}(n,a)^{51}\text{Cr}$			
(dps/nucleus) (a)			
Z, cm	($\times 10^{-16}$)		
-3.53	4.30		
-0.44	2.65		
+2.79	2.99		
+14.86	2.90		
+18.06	2.69		
+59.31	4.94		

a. Counting precision listed by experimenter as very poor. Precision ranged from 11% to $\pm 50\%$ at 95% CL.

TABLE 10. High Power Run 31F - Measured Reaction Rates

$^{235}\text{U}(n,f)$				$^{238}\text{U}(n,f)$ (contd)			
	R, cm	Z, cm	Fissions/ Nucleus ($\times 10^{-9}$) (a)		R, cm	Z, cm	Fissions/ Nucleus ($\times 10^{-11}$)
^{140}Ba	5.18	-3.12	2.87 (b)	^{140}Ba	5.89	+0.18	17.6
		-2.06	2.94 (b)			+15.42	9.17
		-2.06	2.84			+18.49	7.73
		+0.10	2.85			+39.50	1.00
		+0.10	3.09			+59.77	0.135
^{137}Cs		+0.10	2.64				
^{140}Ba		+3.63	2.84 (b)				
^{137}Cs		+4.64	2.67	13.14	+1.12	16.7	
		+4.64	2.98 (b)		+15.29	8.79	
^{140}Ba		+15.32	2.28		+18.57	1.27	
		+18.82	2.15		+39.37	0.837	
		+39.34	1.94		+59.69	0.124	
		+59.87	1.35				
	5.89	+1.80	2.86		24.65	+1.14	9.32
		+16.56	2.36			+5.37	5.90
		+18.87	2.15			+18.54	4.38
		+39.88	2.23			+39.32	0.637
		+59.77	1.31			+59.82	0.105
	13.14	+1.20	2.75		33.6	+1.33	3.84
		+16.28	2.13			+15.37	2.16
		+19.38	2.19			+18.77	1.73
		+39.98	1.78			+39.42	0.320
		+60.07	1.27				
	24.65	+1.14	1.97	$^{237}\text{Np}(n,f) ^{140}\text{Ba}$			
		+15.60	1.58			($\times 10^{-10}$)	
		+19.02	1.51	5.18	-3.12	12.3 (d)	
		+39.88	1.27		-3.12	12.9	
		+60.12	0.802		-3.12	12.1	
					+0.10	12.8	
					+15.32	8.03	
	33.6	+1.33	1.28		+18.64	6.18	
		+15.52	1.15		+39.34	1.24	
		+18.77	1.07		+59.87	0.287	
		+40.13	0.695				
		+60.25	0.388		5.89	+0.18	12.5
						+15.42	7.62
						+18.49	6.01
						+39.50	0.986
						+59.77	0.296
$^{238}\text{U}(n,f)$							
			($\times 10^{-11}$) (c)				
^{140}Ba	5.18	-3.12	18.8		13.14	+0.10	11.2
		+0.10	17.7			+15.29	7.15
^{137}Cs		+4.67	16.8			+18.57	5.58
^{140}Ba		+15.32	9.98			+39.37	1.12
		+18.64	7.55			+59.69	0.236
		+39.34	0.999				
		+59.87	0.135				

a. AZZ results were corrected for 6.75% ^{238}U content

b. ^{235}U /Alloy Samples. Corrections made for 16.4% U content and 6.8% ^{235}U .

c. All results were corrected for 0.0023% ^{235}U contamination

d. All results corrected for 1000 ppm ^{238}Pu contamination.

TABLE 10. (Continued)

$^{237}\text{Np}(n,f)^{140}\text{Ba}$ (contd)			$^{197}\text{Au}(n,\gamma)^{198}\text{Au}$ (contd)			$^{54}\text{Fe}(n,p)^{54}\text{Mn}$ (contd)		
Fissions/ Nucleus ($\times 10^{-10}$)			dps/nucleus ($\times 10^{-10}$)			dps/nucleus ($\times 10^{-13}$)		
R, cm	Z, cm		R, cm	Z, cm		R, cm	Z, cm	
24.65	+0.15	6.65 ^(a)	13.14	-5.87	4.53	5.89	-62.87	0.788
	+15.37	4.66		-0.737	4.27		-52.71	2.39
	+18.54	3.49		+14.81	5.58		-47.63	4.17
	+39.32	0.857		+18.03	7.47		-42.55	7.91
	+59.82	0.186		+38.84	19.8		-37.47	14.4
				+59.23	20.9		-32.39	27.2
33.6	+0.18	3.17					-27.31	55.8
	+15.37	2.23	24.65	-5.89	3.51		-22.23	98.4
	+18.77	1.90		-0.432	3.42		-17.15	189
	+39.42	0.512		+14.76	4.35		-12.07	285
	+59.84	0.106		+18.01	5.69		-6.99	331
				+38.79	11.9		-5.56	335
				+54.23	12.1		-2.46	345
$^{232}\text{Th}(n,f)^{140}\text{Ba}$							-0.41	337
		($\times 10^{-13}$)	33.6	-5.87	3.26		+3.89	333
				-0.414	2.98		+7.06	313
5.18	-2.06	438		+14.78	3.09		+10.16	282
	+0.10	509		+18.08	3.32		+11.92	240
	+15.32	324		+38.91	3.90		+11.92	239
	+18.64	229		+59.28	3.54		+11.92	239
	+39.34	27.8					+13.18	246
	+59.87	8.82					+14.78	211
							+17.96	149
5.89	+0.18	478			($\times 10^{-13}$)		+21.91	95.8
	+15.42	287					+25.72	59.7
	+18.49	194	5.18	-62.87	0.791		+29.53	42.2
	+39.50	24.5		-52.71	2.42		+31.12	32.9
	+59.77	3.64		-42.55	7.39		+34.23	24.5
				-32.39	26.8		+37.31	18.9
13.14	+0.10	469		-22.23	105		+38.86	15.3
	+15.29	249		-12.07	306		+42.23	10.5
	+18.57	194		-6.99	358		+46.04	6.20
	+39.37	24.5		-6.68	351		+49.85	4.41
	+59.69	3.22		-5.59	343 ^(b)		+51.28	3.39
				-3.12	355		+54.45	2.28
24.65	+0.15	267		-2.46	354		+57.63	1.71
	+15.37	163		-2.06	379		+59.18	1.33
	+18.54	117		-0.38	365		+63.66	0.905
	+39.32	20.3		+2.87	385		+68.74	0.546
	+59.82	2.65		+2.87	387		+73.82	0.365
				+2.87	370			
33.6	+0.18	125		+3.63	377	13.14	-62.87	0.681
	+15.37	53.9		+3.63	349		-52.71	2.19
	+18.77	53.9		+4.67	367		-47.63	3.76
	+39.42	8.61		+12.10	257		-42.55	7.12
	+59.84	1.72		+12.10	258		-37.47	13.1
				+13.18	263		-32.39	26.2
				+14.78	222		-27.31	52.0
				+18.06	154		-22.23	96.6
				+22.23	88.7		-17.15	190
				+26.04	58.8		-12.07	283
5.18	-6.68	4.68		+29.85	41.4		-9.53	304
	-0.381	4.39		+37.31	17.4		-7.30	322
	+14.18	5.54		+42.23	10.4		-5.87	332
	+18.05	6.19		+46.04	6.61		-4.90	339 ^(b)
	+38.87	21.7		+49.85	4.35		-0.74	330
	+59.31	22.3		+57.63	1.73		+6.83	318
				+64.14	1.00		+11.59	242
5.89	+0.406	4.65		+69.22	0.485		+11.59	242
	+14.78	5.76		+72.30	0.326		+11.59	239
	+17.96	7.99					+14.45	224
	+38.86	22.5					+14.81	202
	+59.18	22.8					+18.03	135

a. ^{237}Np results corrected for 1000 ppm ^{238}Pu contamination.b. 97.12% ^{54}Fe enriched Fe_2O_3

TABLE 10. (Continued)

[illegible]

a. 97.12% ^{54}Fe enriched Fe_2O_3

TABLE 10. (Continued)

$^{58}\text{Fe}(n,\gamma)^{59}\text{Fe}$ (contd)			$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$			$^{63}\text{Cu}(n,\alpha)^{60}\text{Co}$ (contdj)		
R, cm	Z, cm	dps/nucleus ($\times 10^{-12}$)	R, cm	Z, cm	dps/nucleus ($\times 10^{-11}$)	R, cm	Z, cm	dps/nucleus ($\times 10^{-15}$)
24.65	+6.83	6.01	5.18	-3.12	4.78	13.14	-5.87	194
	+11.59	5.69		-2.06	3.93		-0.74	206
	+11.59	5.52		+3.63	4.68		+14.81	123
	+11.59	5.60		+14.78	4.80		+18.03	81.2
	+14.76	5.62		+18.06	5.61		+38.81	7.47
	+18.01	6.47		+38.89	7.23		+59.23	0.864
	+21.27	6.92		+59.31	4.43			
	+27.62	7.57				24.65	-5.89	117
	+35.24	7.48					-0.43	117
	+38.79	7.25	5.89	-0.41	4.82		+14.76	75.2
	+44.93	6.48		+17.96	5.47		+18.01	52.9
	+52.55	5.27		+38.86	7.20		+38.79	6.66
	+59.23	4.82		+59.18	4.55		+59.23	0.452
	+63.82	3.84						
	+68.90	3.26	13.14	-5.87	3.74	33.6	-5.87	41.1
	+73.80	2.89		-0.74	4.30		-0.41	41.8
				+14.81	4.38		+14.77	25.6
33.6	-62.39	1.80		+18.03	5.21		+18.08	19.5
	-52.23	2.59		+38.81	6.64		+38.91	0.334
	-42.07	3.47		+59.23	4.15		+59.28	0.489
	-31.91	4.33						
	-21.75	4.75	24.65	-5.89	3.67	$^{46}\text{Ti}(n,p)^{46}\text{Sc}$		
	-11.59	4.99		-0.43	3.62	($\times 10^{-13}$)		
	-6.51	4.99		+14.76	3.78	5.18	-6.68	44.8
	-5.87	5.08		+18.01	4.12		-3.12	47.9
	-0.41	5.17		+38.79	4.76		-2.06	47.3
	+6.35	5.03		+59.23	2.82		-0.38	48.4
	+11.59	4.61					+3.63	46.8
	+11.59	4.64	33.6	-0.41	3.11		+3.63	53.0
	+11.59	4.61		+14.77	2.89		+4.67	46.9
	+14.77	4.84		+18.08	2.99		+14.78	29.6
	+18.08	4.87		+38.91	2.58		+18.05	20.1
	+21.91	4.68		+59.28	1.44		+38.89	1.80
	+28.18	4.59	$^{63}\text{Cu}(n,\alpha)^{60}\text{Co}$				+59.31	0.174
	+28.18	4.64	($\times 10^{-15}$)			5.89	-0.41	45.7
	+28.26	4.80					+14.78	27.8
	+35.88	3.43	5.18	-6.68	219		+17.96	20.0
	+38.91	3.68		-3.12	220		+38.86	1.82
	+45.88	3.05		-2.06	231		+59.18	0.163
	+49.61	2.84		-0.38	234			
	+49.61	2.82		+3.63	216	13.14	-5.87	42.2
	+49.61	2.77		+14.78	135		-0.74	45.2
	+49.69	2.84		+18.06	92.3		+14.81	28.0
	+53.50	2.61		+38.89	8.38		+18.03	18.0
	+59.28	2.33		+59.31	1.09		+38.81	1.69
	+63.66	2.08					+59.23	0.182
	+69.22	1.98	5.89	-0.41	204			
	+71.92	1.99		+14.78	127	24.65	-5.89	23.6
	+71.92	2.24		+17.96	86.4		-0.43	25.9
	+71.92	2.16		+38.86	8.13		+14.76	16.8
	+72.30	2.04		+59.18	0.931		+18.01	12.2
							+38.79	1.43
							+59.23	0.151
						33.6	-5.87	8.55
							-0.41	9.30
							+14.78	5.63
							+18.08	4.37
							+38.91	0.731
							+59.28	0.115

TABLE 10. (Continued)

[illegible]

a. 99.89% enriched ^{58}Ni

b. *Experimenter indicates results questionable as pellet was powdered and weighing precision poor on the small amount of material available for analysis.*

TABLE 10. (Continued)

[illegible]

TABLE 10. (Continued)

$^{59}\text{Co}(n,\gamma)^{60}\text{Co}$ Self-Shielding (contd)			$^{54}\text{Fe}(n,\alpha)^{51}\text{Cr}$ (contd)			$^{45}\text{Sc}(n,\gamma)^{46}\text{Sc}$ (contd)		
Z, cm	Foil ^(a)	dps/nucleus ($\times 10^{-10}$)	R, cm	Z, cm	dps/nucleus ($\times 10^{-14}$)	R, cm	Z, cm	dps/nucleus ($\times 10^{-11}$)
+50.52	30 AlW	4.68	5.89	-0.41	31.0	5.18	+18.06	2.68 ^(c)
		4.81		+14.78	17.1		+38.89	5.29 ^(c)
		5.02		+17.96	11.8		+59.31	2.20 ^(c)
	20 W	--		+38.86	2.29			
		1.82		+59.18	1.43	5.89	-0.406	3.55 ^(c)
		1.74					+4.78	3.66 ^(c)
+51.61	5 F	2.21	13.14	-5.87	36.3	13.14	-5.87	3.02
		2.25		-4.90	35.3 ^(b)			
		2.46		-0.74	33.9			
	0.5 F	3.92		+14.81	17.3	24.65	-5.89	2.56 ^(c)
		3.85		+18.03	21.4		59.23	1.76 ^(c)
		3.92		+38.81	1.62			
				+59.23	1.42	33.6	-5.87	1.76 ^(c)
$^{59}\text{Co}(n,2n)^{58}\text{Co}$			$^{54}\text{Fe}_2\text{O}_3(n,\gamma)^{55}\text{Fe}$ (b)					
		($\times 10^{-13}$)						
+6.35	30 AlW	3.50		-5.89	22.9			
		910		-5.26	19.9 ^(b)			
		125		-0.43	16.5			
	20 W			+14.76	50.6			
				+18.01	7.49	5.18	-5.59	18.1
				+38.79	1.46	13.14	-4.90	16.6
						24.65	-5.26	11.2
+7.59	5 F	2.13	33.6	-5.87	6.77	33.6	-5.18	9.58
		0.980		-5.18	6.68			
		1.05		-0.41	8.37			
	0.5 F	1.14		+14.77	4.01			
		1.12		+18.08	3.82			
		1.13		+38.91	1.41			
+31.50	0.5 F	14.1		+49.61	2.06			
		14.2		+59.28	0.327			
+51.61	5 F	0.816		+71.91	0.0436	5.18	-5.59	46.1
						13.14	-4.90	16.6
						24.65	-5.26	13.8
						33.6	-5.18	6.99
$^{59}\text{Co}(n,p)^{59}\text{Fe}$			$^{197}\text{Au}(n,2n)^{196}\text{Au}$			$^{51}\text{V}(n,p)^{48}\text{Sc}$		
		($\times 10^{-13}$)			($\times 10^{-13}$)			
+6.35	30 AlW	5.38	5.18	-6.68	12.7			
		7.27		-0.381	13.7			
		6.42						
+6.35	20 W	5.53	5.89	+14.79	10.9	5.18	-5.59	8.75
+7.59	5 F	4.98		+17.96	7.20	13.14	-4.90	8.10
		5.11				24.65	-5.26	4.68
	0.5 F	5.43	13.14	+5.87	13.2	33.6	-5.18	1.80
		5.56		-0.74	13.7			
		5.35		+14.81	8.45			
+31.50	0.5 F	72.4						
		35.3	24.65	-5.89	6.72			
+51.61	5 F	4.24		-0.43	6.07			
				+14.76	5.91			
				+18.01	6.29			
$^{54}\text{Fe}(n,\alpha)^{51}\text{Cr}$			$^{45}\text{Sc}(n,\gamma)^{46}\text{Sc}$			$^{58}\text{Ni}(n,\alpha)^{55}\text{Fe}$ (d)		
		dps/nucleus ($\times 10^{-14}$)			dps/nucleus ($\times 10^{-11}$)			
R, cm	Z, cm		R, cm	Z, cm		R, cm	Z, cm	dps/nucleus ($\times 10^{-12}$)
5.18	-6.68	37.7				5.18	-5.59	49.0
	-5.59	37.0 ^(a)				13.14	-4.90	1.60
	-3.12	35.0				24.65	-5.26	1.08
	-0.38	31.1				33.6	-5.18	0.377
	+3.63	83.1	5.18	-6.68	2.90 ^(c)			
	+14.78	17.4		-0.381	1.77 ^(c)			
	+18.06	14.5		+14.78	3.01 ^(c)			

a. 30 AlW - 30 mil 0.483% Co/Al Alloy

20 W - 20 mil wire

5 F - 5 mil foil

0.5 F - 0.5 mil foil

b. 97.12% ^{54}Fe enriched Fe_2O_3

c. Results questioned by participant due to loss of foil integrity

d. 99.89% enriched ^{58}Ni

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