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Neutron Physics Division

SDT5. STAINLESS-STEEL BROOMSTICK EXPERIMENT - AN EXPERIMENTAL CHECK OF NEUTRON TOTAL CROSS SECTIONS

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Reference: E. A. Straker, "Experimental Evaluation of Minima in the Total Neutron Cross Sections of Several Shielding Materials," ORNL-TM-2242 (1968). The data on stainless steel, which are unpublished, were obtained through private communication.

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for the
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Abstract

The experimental and calculational details for a CSEWG integral data testing shielding experiment are presented.

Description

This experiment was designed to test a given set of neutron total cross sections for a type-310 stainless steel in the range 1.2-11 MeV. Figure 1 shows a schematic of the arrangement. The stainless-steel sample was a cylinder approximately 4 in. in diameter and placed so that its axis coincided with the axis of the neutron beam. In order to reduce the effect of neutron inscattering in the sample, the distance from the neutron source (the Tower Shielding Reactor II) to the sample was 50 ft and the detector was 50 ft from the sample. The neutron beam was confined to a diameter of 3.5 in. by collimators placed between the reactor and sample near the sample position. To reduce air-scattering effects the reactor and detector were shielded with lead and water and the reactor beam and detector acceptance were tightly collimated.

The detector was a nominal 2 in. x 2 in. NE-213 scintillator. Separation of neutron- and gamma-induced pulses was made by a modified Forte circuit. Throughout this experiment, a 2-in.-thick sample of lead, not pictured in Fig. 1, was placed in the beam to reduce the gamma-ray intensity incident on the NE-213. The unfolding of the pulse-height distributions was accomplished using the FERDoR code.

Data

The uncollided transmitted spectra through 8 in. of stainless steel and the lead (density of stainless steel = 7.95 grams/cm^3) as measured by the NE-213 spectrometer are shown in Fig. 2. The error in the unfolding is such that the spectrum lies somewhere within the darkened area within 68% confidence limits. In addition, there is an estimated 5-10% error in the absolute measurements due to power calibration uncertainties.

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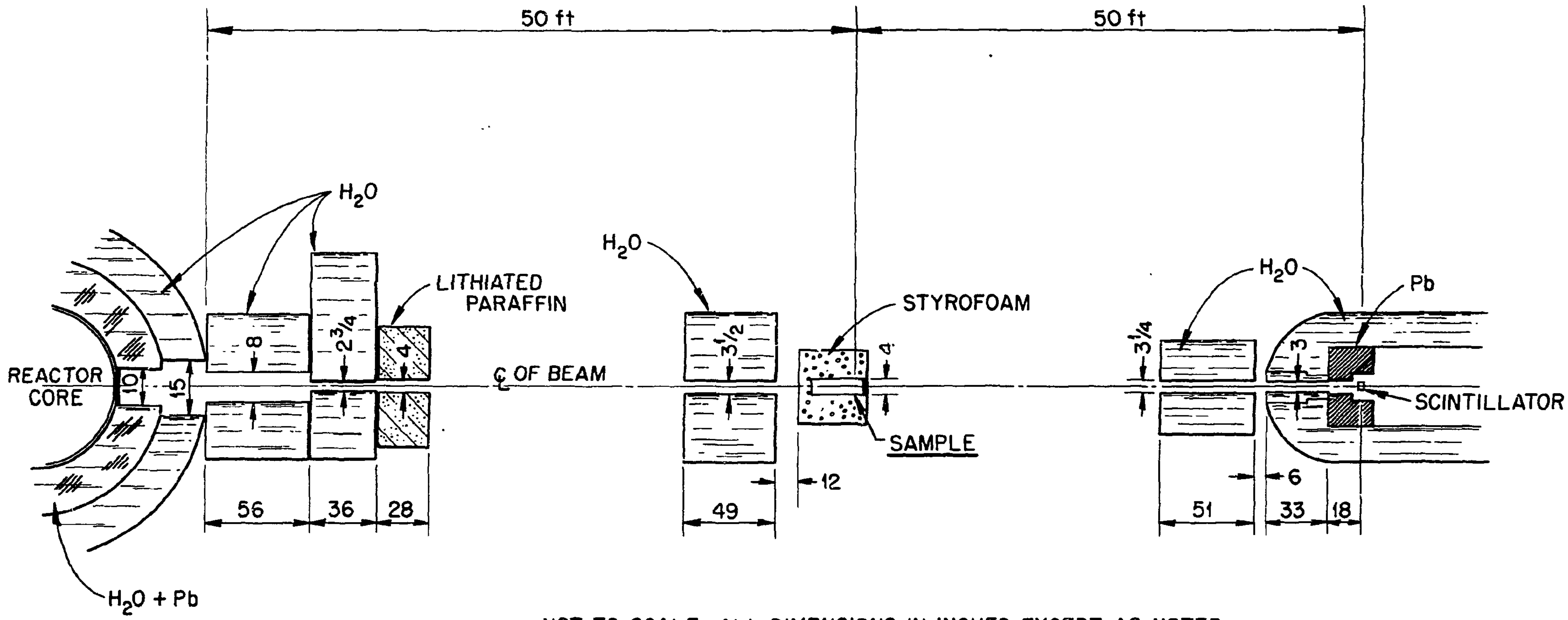

NOT TO SCALE. ALL DIMENSIONS IN INCHES EXCEPT AS NOTED.
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Fig. 1. Schematic of Experimental Arrangement.

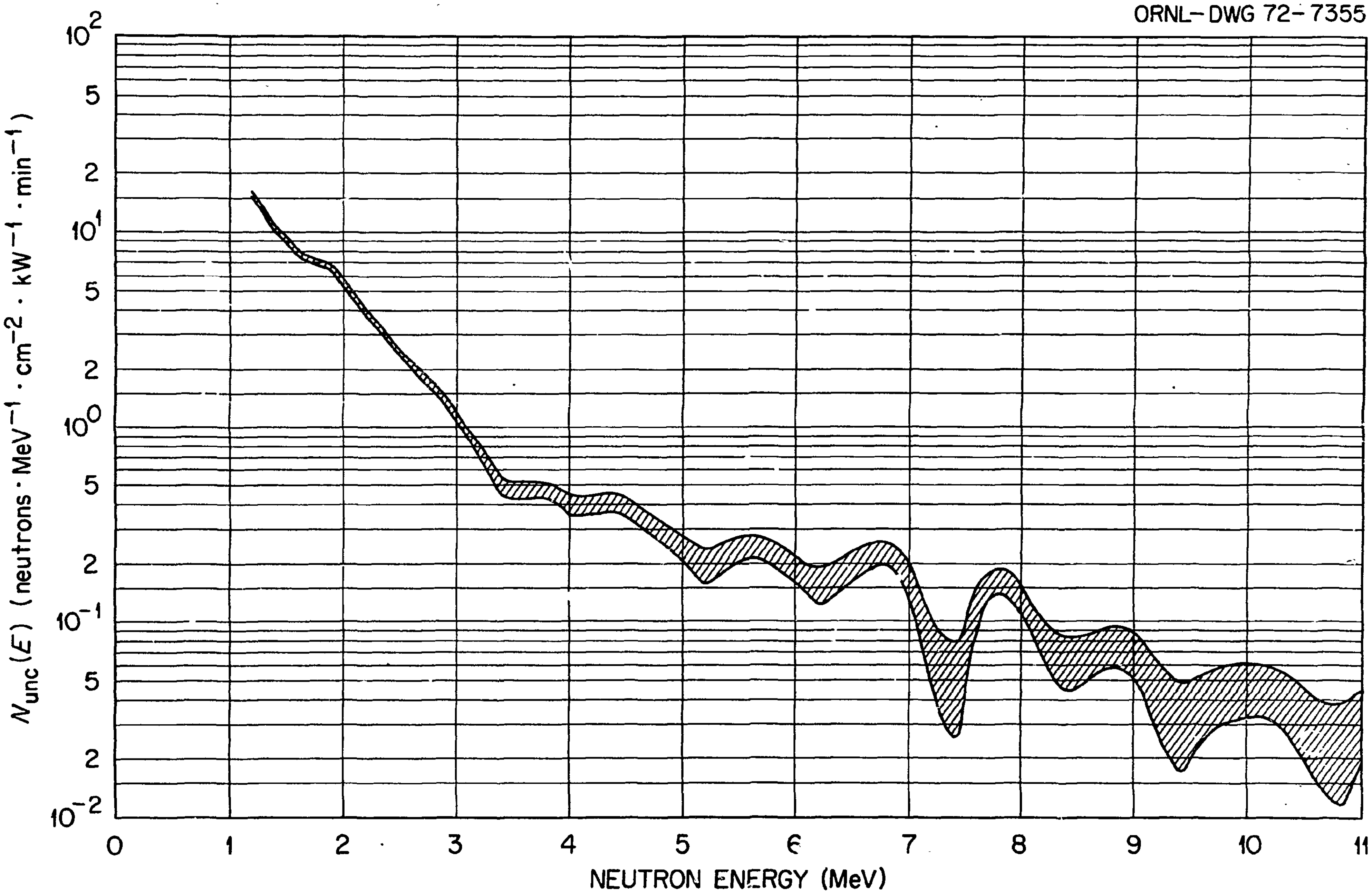

Fig. 2. Transmitted Spectrum Through Type-310 Stainless Steel.

The spectrum measured by the NE-213 at the same location when the stainless steel is removed from the beam, but with the lead still in place, is shown in Fig. 3 and tabulated in Table I. The resolution function of the NE-213 spectrometer system and unfolding procedure are shown in Table II, expressed as full width at half maximum (percent of peak energy).

There are at least two compositions of type-310 stainless steel found in the literature. Table III lists these atomic concentrations.

Since a chemical analysis of the stainless steel actually used in the experiment was not performed, the above two compositions can be taken as roughly the limits of the actual composition of the sample.

Method of Calculation

The calculation consists first of determining a transmitted uncollided spectrum $N_{unc}(\Delta E')$.

$$N_{unc}(\Delta E') = \sum_{E_i \text{ in } \Delta E'} N_0(E_i) e^{-\Sigma_{tot}(E_i)t} \Delta E_i/\Delta E', \quad (1)$$

where $N_0(E_i)$ is taken or interpolated from Table I, t = 20.32 cm, and the energy intervals ΔE_i, which in general may be of variable width, are chosen sufficiently small that all of the structure in the vicinity of all of the minima in the total cross section is included. The total number of energy subintervals, ΔE_i, used in the region 0.5-12 MeV should follow as closely as possible the number suggested in the report sheet. The values of $N_{unc}(\Delta E')$ are to be binned into far fewer intervals, ($\Delta E'$), shown in the attached report sheet.

The second part of the calculation consists of folding the values of $N_{unc}(\Delta E')$ with the resolution function of the NE-213 spectrometer system:

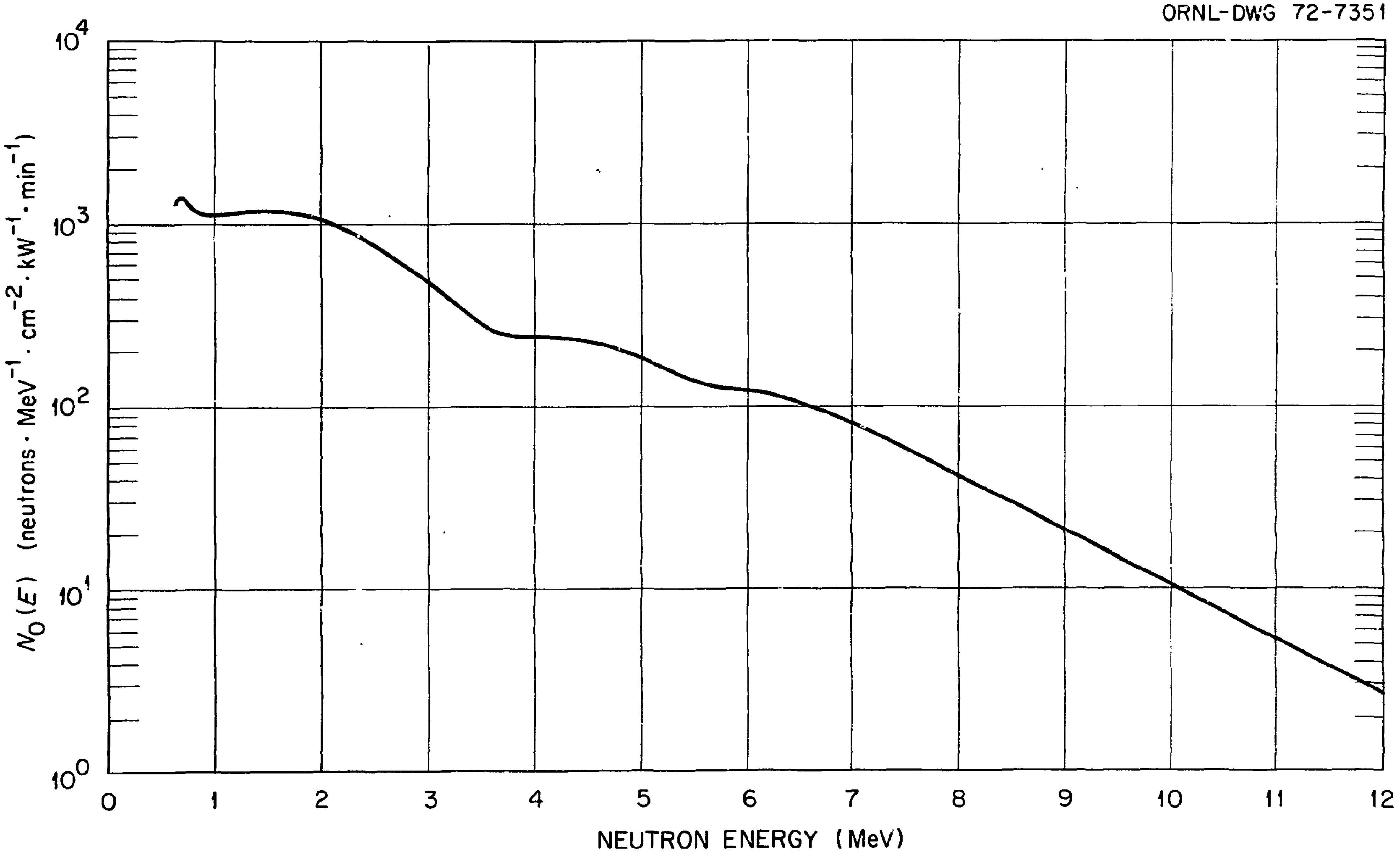

Fig. 3. Source Spectrum for Type-310 Stainless Steel.

Table I. Tabulated Source Spectrum (Spectrum Transmitted Through the Lead) in Units of Neutrons/MeV/cm²/Kilowatt/Min as a Function of Energy in MeV*

E	$N_0(E)$	E	$N_0(E)$	E	$N_0(E)$	E	$N_0(E)$
0.50	1122	2.2	946	4.4	226	8.2	35.5
0.55	1149	2.3	878	4.5	216	8.4	31.1
0.60	1230	2.4	797	4.6	208	8.6	27.0
0.65	1351	2.5	743	4.7	201	8.8	23.6
0.70	1378	2.6	676	4.8	193	9.0	21.1
0.75	1311	2.7	622	4.9	188	9.2	18.0
0.80	1162	2.8	568	5.0	180	9.4	15.7
0.85	1135	2.9	520	5.2	163.5	9.6	13.6
0.90	1108	3.0	473	5.4	148.5	9.8	12.0
0.95	1095	3.1	419	5.6	135	10.0	10.5
1.0	1081	3.2	365	5.8	125.7	10.2	9.1
1.1	1095	3.3	324	6.0	119	10.4	8.0
1.2	1108	3.4	291	6.2	112	10.6	7.0
1.3	1122	3.5	270	6.4	104	10.8	6.1
1.4	1149	3.6	254	6.6	96.0	11.0	5.2
1.5	1155	3.7	242	6.8	87.8	11.2	4.6
1.6	1149	3.8	232	7.0	79.7	11.4	4.1
1.7	1135	3.9	230	7.2	70.3	11.6	3.5
1.8	1095	4.0	236	7.4	60.8	11.8	3.1
1.9	1081	4.1	238	7.6	53.4	12.0	2.7
2.0	1054	4.2	236	7.8	46.6		
2.1	1000	4.3	232	8.0	40.5		

*Interpolation in this table should follow the formula:

$$N_0(E) = \frac{E_2 - E}{E_2 - E_1} N_0(E_1) + \frac{E - E_1}{E_2 - E_1} N_0(E_2), \text{ where } E_1 \leq E \leq E_2.$$

Table II. Energy Resolution of the Spectrometer System*

E(MeV)	a FWHM/E(%)	E(MeV)	a FWHM/E(%)	E(MeV)	a FWHM/E(%)
0.5	47.5	3.3	18.8	6.2	13.5
0.6	44	3.4	18.5	6.4	13.2
0.7	41	3.5	18.2	6.6	13.0
0.8	38.5	3.6	18.0	6.8	12.8
0.9	36	3.7	17.7	7.0	12.6
1.0	33.5	3.8	17.4	7.2	12.4
1.1	32.5	3.9	17.1	7.4	12.2
1.2	31	4.0	16.9	7.6	12.1
1.3	30	4.1	16.7	7.8	11.9
1.4	29	4.2	16.5	8.0	11.8
1.5	27.5	4.3	16.3	8.2	11.6
1.6	26.5	4.4	16.1	8.4	11.5
1.7	26	4.5	15.9	8.6	11.4
1.8	25	4.6	15.7	8.8	11.3
1.9	24.5	4.7	15.5	9.0	11.2
2.0	24	4.8	15.3	9.2	[illegible]
2.1	23.5	4.9	15.2	9.4	10.9
2.2	23	5.0	15.1	9.6	10.8
2.3	22.5	5.1	14.9	9.8	10.7
2.4	22	5.2	14.7	10.0	10.5
2.5	21.5	5.3	14.5	10.2	10.3
2.6	21.2	5.4	14.4	10.4	10.2
2.7	20.8	5.5	14.3	10.6	10.1
2.8	20.4	5.6	14.2	10.8	10.0
2.9	20.1	5.7	14.1	11.0	9.8
3.0	19.7	5.8	13.9	11.4	9.7
3.1	10.4	5.9	13.8	11.8	9.6
3.2	10.1	6.0	13.7	12.2	9.6

*Interpolation in this table should follow the formula:

$$a(E) = \frac{E_2 - E}{E_2 - E_1}\, a(E_1) + \frac{E - E_1}{E_2 - E_1}\, a(E_2) \text{ where } E_1 \le E \le E_2.$$

Table III. Composition of Type-310 Stainless Steel

Composition A[1]		Composition B[2]	
Element	Atomic Concentration (atoms/barn·cm)	Element	Atomic Concentration (atoms/barn·cm)
Iron (ave.)	0.0436 (50.75 wt%)	Iron (ave.)	0.0466 (54.25 wt%)
Nickel (ave.)	0.0167 (20.5 wt%)	Nickel (ave.)	0.0167 (20.5 wt%)
Chromium (ave.)	0.0230 (25.0 wt%)	Chromium (ave.)	0.0230 (25.0 wt%)
Silicon (max.)	0.0026 (1.5 wt%)	Carbon	0.0010 (0.25 wt%)
Manganese (max.)	0.0017 (2.0 wt%)		
Carbon (max.)	0.0010 (0.25 wt%)		

[1] Stainless Steel Handbook, Allegheny Ludlum Steel Corporation, Pittsburgh, Pa., p. 27 (1951).

[2] Handbook of Chemistry and Physics, 35th Edition, Chemical Rubber Publishing Company, p. 1433 (1954).

$$N_{unc}(E) = \sum_{E'} N_{unc}(\Delta E')R(E' \rightarrow E)\Delta E'.$$

$R(E' \rightarrow E)$ is a gaussian centered at E', the midpoint of $\Delta E'$, and using the values appearing in Table II, becomes

$$R(E' \rightarrow E) = \frac{93.944}{aE'} \exp - \left\{\left[\frac{(E - E') \times 235.4820}{E'a}\right]^2 /2\right\},$$

where a is the FWHM value at E' expressed in the units of Table II. The smeared calculated spectra $N_{unc}(E)$ may then be compared directly with the reported experimental spectra.

For the case of stainless steel, $\Sigma_{tot}(E_i)$ in equation (1) may be written

$$\Sigma_{tot}(E_i) = \sum_n \text{ADEN}(n) \times \sigma^n_{tot}(E_i), \qquad (2)$$

where ADEN and σ^n_{tot} are the atomic density and microscopic cross section for element n.

The exponential in equation (1) becomes a product of the exponentials of the individual elements n:

$$N_{unc}(\Delta E') = \sum_{E_i \text{ in } \Delta E'} (N_0(E_i)\Delta E_i/\Delta E')(\prod^n e^{-\text{ADEN}(n)\sigma^n_{tot}(E_i)t}). \qquad (3)$$

Since it is time consuming to obtain a representation of $\Sigma_{tot}(E_i)$ from the individual elemental contributions expressed by equation (2) because n different tapes must be read and the data pre-processed, the alternative of using equation (3) can be used instead, using the code package already available. To use the code, the transmission through one element is calculated in one submission to the computer. The resulting values of $N_{unc}(\Delta E')$, each calculated using as the source the values from Table I, are then entered for each element on the report sheet. For these runs, the smoothed fluxes are to be ignored. The resulting unsmoothed transmitted flux through the stainless steel is then hand calculated using the following formula and entered on the report sheet:

$$N_{unc}(\Delta E') = [\prod^{n} N^{n}_{unc}(\Delta E')]/[\bar{N}_0(\Delta E')]^{n-1}, \quad (4)$$

where $\bar{N}_0(\Delta E')$ is the average value of N_0 in the range $\Delta E'$ from Table I.

The smoothing of $N_{unc}(\Delta E')$ is then accomplished with one more submission of the code to the computer, using $N_{unc}(\Delta E')$ as the source and the T = 0.0 option (see the following section).

Codes

A FORTRAN package is available to perform much of the manipulation described in the preceding section. Subroutine XSECT and its subroutines access the total cross section from an ENDF/B tape and interpolate the cross section for any energy according to the interpolation scheme specified on the tape. It will only access pointwise data so that any evaluation at least partially described by resonance parameters above 500 keV cannot be accessed by this code. (See Table IV.) In general, it will be necessary to obtain a pointwise representation of the same tapes from Brookhaven in this instance. However, it is still possible to obtain an adequate calculation of the stainless-steel broomstick experiment, even though resonance parameters are used above 500 keV for nickel and chromium, using the ENDF/B evaluation with resonance parameters. To do this, set

Table IV. Parameters Describing the Stainless-Steel Broomstick Experiment and the ENDF/B Evaluations Used to Calculate the Unsmoothed Transmitted Flux

COMPOSITION	ELEM(I)	T	ADEN	MATNØ	IFLAG	COMMENTS
A	IRØN	20.32	0.0436	1180	1	Resonance parameters are used below 690 keV for chromium and below 650 keV for nickel. Setting IFLAG = 1 allows a resonance parameter tape to be used above 700 keV. For consistency, this value is used for all the elements in the steel. If a pointwise tape is used for chromium and nickel, set IFLAG = 0 for all elements.
	NICKEL	20.32	0.0167	1123	1	
	CHRØMIUM	20.32	0.0230	1121	1	
	SILICØN	20.32	0.0026	1151	1	
	MANGANESE	20.32	0.0017	1019	1	
	CARBØN	20.32	0.0010	1165	1	
B	IRØN	20.32	0.0466	1180	1	

IFLAG = 1 on card C (see below). This allows the calculation to start at 700 keV rather than 500 keV, even though all the input data start at 500 keV. If a pointwise evaluation is used, IFLAG should be set to 0. The main routine calculates the uncollided flux, smoothes the uncollided flux with the resolution function of the spectrometer system, and outputs the fluxes both before and after smoothing in the energy grid suggested in the report sheet.

To calculate the unsmoothed elemental transmitted fluxes:

Card A. T, ADEN (12F6.3). T, the thickness of the cylinder in centimeters, and ADEN the atomic density in atoms/barn·cm are shown in the following table (Table IV).

Card B. ELEM(I),I=1,20(20A4). ELEM(I) is the element studied (see Table IV).

Card C. MATNØ, MØDE, NDFB, IFLAG (12I6). MATNØ is the MAT number of the ENDF/B evaluation (see Table IV), MØDE = 1 if binary, = 2 if BCD, and depends on the particular version of the tape an installation possesses. NDFB is the logical tape number of the ENDF/B tape, and IFLAG = 0 if the pointwise ENDF/B representation is used and 1 if resonance parameters are used.

Cards D. ERG(I),I=1,86(12F6.3). The energy values in MeV at which the source is tabulated in Table I. ERG(1) = 0.50 and ERG(86) = 12.0.

Cards E. FZERØ(I),I=1,86(12F6.3). The source spectrum in units of neutrons/MeV/cm^2/kilowatt/min tabulated in Table I. FZERØ(1) = 1122 and FZERØ(86) = 2.7.

Cards F. NINT(I),I=1,85(12I6). The number of subintervals ΔE_i within each $\Delta E'$ used in calculating the uncollided flux (see report sheet). Use the suggested values appearing in the report sheet. NINT(1) = 150 and NINT(85) = 10.

Cards G. ER(I),I=1,84(12F6.3). The energy value in MeV at which the resolution function of the spectrometer system is specified in Table II. ER(1) = 0.50 and ER(84) = 12.2.

Cards H. PCTWID(I),I=1,84(12F6.3). The values of a, the resolution of the spectrometer system, in units of percent of peak energy of the full width at half maximum, also tabulated in Table II. PCTWID(1) = 47.5 and PCTWID(84) = 9.6.

Cards I. ES(I),I=1,75(12F6.3). The energy values in MeV at which the smoothed uncollided spectrum is to be calculated (see the report sheet). ES(1) = 0.80 and ES(75) = 11.0.

The code requires a storage of approximately 92 K bytes (23 K words) on the IBM-360/75 or 360/91 computer with a running time of approximately 20 sec on the IBM-360/91 for each component in the stainless steel. For Composition A of the stainless steel shown in Table III, six problems must be submitted to the computer; for Composition B, one additional problem must be submitted, i.e., a different concentration for the iron.

For the calculations shown in Table IV, the smoothed transmitted fluxes (although outputted) are to be ignored.

To calculate the smoothed transmitted fluxes through the stainless steel, the elemental unsmoothed transmitted fluxes calculated in Table IV are combined by hand using equation (4) for each of the two compositions and then entered on Cards E. The value of T on card A must be 0.0. This calculation must be done in two submissions to the computer, one submission for each composition.

Card A. Blank

Card B. Omit

Card C. Omit

Cards D. Same as before.

Cards E. SUM(I),I=1,86(12F6.3). The unsmoothed transmitted fluxes through the stainless steel hand calculated from equation (4) for a given composition of the stainless steel, in units of neutrons/MeV/cm^2/kilowatt/min. The first four values are zero if IFLAG = 1 in the prior calculations, with SUM(5) = $[\prod^{n} N^{n}_{unc}(\Delta E' = 0.70 - 0.75)]/(1.3445 \times 10^3)^{n-1}$, and SUM(86) = $[\prod^{n} N^{n}_{unc}(\Delta E' = 11.8 - 12.0)]/(2.90)^{n-1}$.

Cards F. Omit

Cards G. Same as before

Cards H. Same as before

Cards I. Same as before

A dummy tape may need to be mounted for the smoothing calculation. By following the report sheet, the sequence of calculations should be straightforward.

Report sheet for the stainless-steel "broomstick" experiment.
Calculated values of $N^n_{unc}(\Delta E')$ and approximate number of subintervals ΔE_i for each $\Delta E'$ used.

$\Delta E'$ (MeV)	$N^n_{unc}(\Delta E')$ (neutrons/cm^2/MeV/kW/min) Fe (.0436)	Fe (.0466)	Ni (.0167)	Cr (.0230)	Si (.0026)	Mn (.0017)	C (.0010)	Number of sub-intervals $\Delta E'/\Delta E_i$
0.50-0.55*	____	____	____	____	____	____	____	150
0.55-0.60*	____	____	____	____	____	____	____	150
0.60-0.65*	____	____	____	____	____	____	____	150
0.65-0.70*	____	____	____	____	____	____	____	150
0.70-0.75	____	____	____	____	____	____	____	150
0.75-0.80	____	____	____	____	____	____	____	150
0.80-0.85	____	____	____	____	____	____	____	150
0.85-0.90	____	____	____	____	____	____	____	150
0.90-0.95	____	____	____	____	____	____	____	150
0.95-1.00	____	____	____	____	____	____	____	150
1.0-1.1	____	____	____	____	____	____	____	200
1.1-1.2	____	____	____	____	____	____	____	200
1.2-1.3	____	____	____	____	____	____	____	150
1.3-1.4	____	____	____	____	____	____	____	150
1.4-1.5	____	____	____	____	____	____	____	150
1.5-1.6	____	____	____	____	____	____	____	150
1.6-1.7	____	____	____	____	____	____	____	150
1.7-1.8	____	____	____	____	____	____	____	150
1.8-1.9	____	____	____	____	____	____	____	150
1.9-2.0	____	____	____	____	____	____	____	150
2.0-2.1	____	____	____	____	____	____	____	50
2.1-2.2	____	____	____	____	____	____	____	50
2.2-2.3	____	____	____	____	____	____	____	50
2.3-2.4	____	____	____	____	____	____	____	50
2.4-2.5	____	____	____	____	____	____	____	50
2.5-2.6	____	____	____	____	____	____	____	50
2.6-2.7	____	____	____	____	____	____	____	50

*Values of $N^n_{unc}(\Delta E')$ are zero if the IFLAG = 1 option is used.

Report sheet for the stainless-steel "broomstick" experiment (continued). Calculated values of $N^n_{unc}(\Delta E')$ and approximate number of subintervals ΔE_i for each $\Delta E'$ used.

	$N^n_{unc}(\Delta E')$ (neutrons/cm^2/MeV/kW/min)							
$\Delta E'$ (MeV)	Fe (.0436)	Fe (.0466)	Ni (.0167)	Cr (.0230)	Si (.0026)	Mn (.0017)	C (.0010)	Number of subintervals $\Delta E'/\Delta E_i$
2.7-2.8	____	____	____	____	____	____	____	50
2.8-2.9	____	____	____	____	____	____	____	50
2.9-3.0	____	____	____	____	____	____	____	50
3.0-3.1	____	____	____	____	____	____	____	30
3.1-3.2	____	____	____	____	____	____	____	30
3.2-3.3	____	____	____	____	____	____	____	30
3.3-3.4	____	____	____	____	____	____	____	30
3.4-3.5	____	____	____	____	____	____	____	30
3.5-3.6	____	____	____	____	____	____	____	30
3.6-3.7	____	____	____	____	____	____	____	30
3.7-3.8	____	____	____	____	____	____	____	30
3.8-3.9	____	____	____	____	____	____	____	30
3.9-4.0	____	____	____	____	____	____	____	30
4.0-4.1	____	____	____	____	____	____	____	30
4.1-4.2	____	____	____	____	____	____	____	30
4.2-4.3	____	____	____	____	____	____	____	30
4.3-4.4	____	____	____	____	____	____	____	30
4.4-4.5	____	____	____	____	____	____	____	10
4.5-4.6	____	____	____	____	____	____	____	10
4.6-4.7	____	____	____	____	____	____	____	10
4.7-4.8	____	____	____	____	____	____	____	10
4.8-4.9	____	____	____	____	____	____	____	10
4.9-5.0	____	____	____	____	____	____	____	10
5.0-5.2	____	____	____	____	____	____	____	20
5.2-5.4	____	____	____	____	____	____	____	20
5.4-5.6	____	____	____	____	____	____	____	20
5.6-5.8	____	____	____	____	____	____	____	20

Report sheet for the stainless-steel "broomstick" experiment (continued). Calculated values of $N^n_{unc}(\Delta E')$ and approximate number of subintervals ΔE_i for each $\Delta E'$ used.

	$N^n_{unc}(\Delta E')$ (neutrons/cm^2/MeV/kW/min)							
$\Delta E'$ (MeV)	Fe (.0436)	Fe (.0466)	Ni (.0167)	Cr (.0230)	Si (.0026)	Mn (.0017)	C (.0010)	Number of sub-intervals $\Delta E'/\Delta E_i$
5.8-6.0	____	____	____	____	____	____	____	20
6.0-6.2	____	____	____	____	____	____	____	20
6.2-6.4	____	____	____	____	____	____	____	20
6.4-6.6	____	____	____	____	____	____	____	20
6.6-6.8	____	____	____	____	____	____	____	20
6.8-7.0	____	____	____	____	____	____	____	20
7.0-7.2	____	____	____	____	____	____	____	20
7.2-7.4	____	____	____	____	____	____	____	20
7.4-7.6	____	____	____	____	____	____	____	20
7.6-7.8	____	____	____	____	____	____	____	20
7.8-8.0	____	____	____	____	____	____	____	20
8.0-8.2	____	____	____	____	____	____	____	20
8.2-8.4	____	____	____	____	____	____	____	20
8.4-8.6	____	____	____	____	____	____	____	20
8.6-8.8	____	____	____	____	____	____	____	20
8.8-9.0	____	____	____	____	____	____	____	20
9.0-9.2	____	____	____	____	____	____	____	20
9.2-9.4	____	____	____	____	____	____	____	20
9.4-9.6	____	____	____	____	____	____	____	20
9.6-9.8	____	____	____	____	____	____	____	20
9.8-10.0	____	____	____	____	____	____	____	20
10.0-10.2	____	____	____	____	____	____	____	10
10.2-10.4	____	____	____	____	____	____	____	10
10.4-10.6	____	____	____	____	____	____	____	10
10.6-10.8	____	____	____	____	____	____	____	10
10.8-11.0	____	____	____	____	____	____	____	10

Report sheet for the stainless-steel "broomstick" experiment (continued). Calculated values of $N^n_{unc}(\Delta E')$ and approximate number of subintervals ΔE_i for each $\Delta E'$ used.

	$N^n_{unc}(\Delta E')$ (neutrons/cm^2/MeV/kW/min)							
$\Delta E'$ (MeV)	Fe (.0436)	Fe (.0466)	Ni (.0167)	Cr (.0230)	Si (.0026)	Mn (.0017)	C (.0010)	Number of sub-intervals $\Delta E'/\Delta E_i$
11.0-11.2	____	____	____	____	____	____	____	10
11.2-11.4	____	____	____	____	____	____	____	10
11.4-11.6	____	____	____	____	____	____	____	10
11.6-11.8	____	____	____	____	____	____	____	10
11.8-12.0	____	____	____	____	____	____	____	10

Report sheet for the stainless-steel "broomstick" experiment (continued). Hand calculated values of $N_{unc}(\Delta E')$ for stainless steel and calculated values of $N_{unc}(E)$, i.e., smoothed data to be compared with experiment.

		$N_{unc}(\Delta E')$				
		Composition A†	Composition B†		$N_{unc}(E)$	
ΔE' (MeV)	$\bar{N}_0$ (neutrons/cm^2/MeV/kW/min)	$[\prod_{n=1}^{6} N^n_{unc}(\Delta E')]/(\bar{N}_0)^5$	$[\prod_{n=1}^{4} N^n_{unc}(\Delta E')]/(\bar{N}_0)^3$	E (MeV)	Comp. A	Comp. B
0.50-0.55*	1.1355×10^3	____	____			
0.55-0.60*	1.1895×10^3	____	____			
0.60-0.65*	1.2905×10^3	____	____			
0.65-0.70*	1.3645×10^3	____	____			
0.70-0.75	1.3445×10^3	____	____			
0.75-0.80	1.2365×10^3	____	____			
0.80-0.85	1.1485×10^3	____	____	0.80	____	____
0.85-0.90	1.1215×10^3	____	____	0.85	____	____
0.90-0.95	1.1015×10^3	____	____	0.90	____	____
0.95-1.00	1.088×10^{33}	____	____	0.95	____	____
1.0-1.1	1.088×10^3	____	____	1.0	____	____
1.1-1.2	1.1015×10^3	____	____	1.1	____	____
1.2-1.3	1.115×10^3	____	____	1.2	____	____
1.3-1.4	1.1355×10^3	____	____	1.3	____	____
1.4-1.5	1.152×10^3	____	____	1.4	____	____
1.5-1.6	1.152×10^3	____	____	1.5	____	____
1.6-1.7	1.142×10^3	____	____	1.6	____	____
1.7-1.8	1.115×10^3	____	____	1.7	____	____
1.8-1.9	1.088×10^3	____	____	1.8	____	____
1.9-2.0	1.0675×10^3	____	____	1.9	____	____

†For Composition A, $N_{unc}(\Delta E',SS) = N_{unc}(\Delta E',.0436\ Fe) \times N_{unc}(\Delta E',.0167\ Ni) \times N_{unc}(\Delta E',.0230\ Cr) \times N_{unc}(\Delta E',.0026\ Si) \times N_{unc}(\Delta E',.0017\ Mn) \times N_{unc}(\Delta E',.0010\ C)/\bar{N}_0^5$. For Composition B, $N_{unc}(\Delta E',SS) = N_{unc}(\Delta E',.0466 \times N_{unc}(\Delta E',.0167\ Ni) \times N_{unc}(\Delta E',.0230\ Cr) \times N_{unc}(\Delta E',.0010\ C)/\bar{N}_0^3$.

*Values of $N_{unc}(\Delta E')$ are zero if the IFLAG = 1 option is used.

Report sheet for the stainless-steel "broomstick" experiment (continued). Hand calculated values of $N_{unc}(\Delta E')$ for stainless steel and calculated values of $N_{unc}(E)$, i.e., smoothed data to be compared with experiment.

$\Delta E'$ (MeV)	$\bar{N}_0$ (neutrons/cm^2/MeV/kW/min)	$N_{unc}(\Delta E')$ Composition A: $[\prod_{n=1}^{6} N^n_{unc}(\Delta E')]/(\bar{N}_0)^5$	$N_{unc}(\Delta E')$ Composition B: $[\prod_{n=1}^{4} N^n_{unc}(\Delta E')]/(\bar{N}_0)^3$	E (MeV)	$N_{unc}(E)$ Comp. A	$N_{unc}(E)$ Comp. B
2.0-2.1	1.027×10^3	______	______	2.0	____	____
2.1-2.2	9.73×10^2	______	______	2.1	____	____
2.2-2.3	9.12×10^2	______	______	2.2	____	____
2.3-2.4	8.375×10^2	______	______	2.3	____	____
2.4-2.5	7.70×10^2	______	______	2.4	____	____
2.5-2.6	7.095×10^2	______	______	2.5	____	____
2.6-2.7	6.49×10^2	______	______	2.6	____	____
2.7-2.8	5.95×10^2	______	______	2.7	____	____
2.8-2.9	5.44×10^2	______	______	2.8	____	____
2.9-3.0	4.965×10^2	______	______	2.9	____	____
3.0-3.1	4.46×10^2	______	______	3.0	____	____
3.1-3.2	3.92×10^2	______	______	3.1	____	____
3.2-3.3	3.445×10^2	______	______	3.2	____	____
3.3-3.4	3.075×10^2	______	______	3.3	____	____
3.4-3.5	2.805×10^2	______	______	3.4	____	____
3.5-3.6	2.62×10^2	______	______	3.5	____	____
3.6-3.7	2.48×10^2	______	______	3.6	____	____
3.7-3.8	2.37×10^2	______	______	3.7	____	____
3.8-3.9	2.31×10^2	______	______	3.8	____	____
3.9-4.0	2.33×10^2	______	______	3.9	____	____
4.0-4.1	2.37×10^2	______	______	4.0	____	____
4.1-4.2	2.37×10^2	______	______	4.1	____	____
4.2-4.3	2.34×10^2	______	______	4.2	____	____
4.3-4.4	2.29×10^2	______	______	4.3	____	____
4.4-4.5	2.21×10^2	______	______	4.4	____	____
4.5-4.6	2.12×10^2	______	______	4.5	____	____

Report sheet for the stainless-steel "broomstick" experiment (continued). Hand calculated values of $N_{unc}(\Delta E')$ for stainless steel and calculated values of $N_{unc}(E)$, i.e., smoothed data to be compared with experiment.

		$N_{unc}(\Delta E')$				
		Composition A	Composition B		$N_{unc}(E)$	
$\Delta E'$ (MeV)	$\bar{N}_0$ (neutrons/cm^2/MeV/kW/min)	$[\prod_{n=1}^{6} N^n_{unc}(\Delta E')]/(\bar{N}_0)^5$	$[\prod_{n=1}^{4} N^n_{unc}(\Delta E')]/(\bar{N}_0)^3$	E (MeV)	Comp. A	Comp. B
4.6-4.7	2.045×10^2			4.6		
4.7-4.8	1.97×10^2			4.7		
4.8-4.9	1.905×10^2			4.8		
4.9-5.0	1.84×10^2			4.9		
5.0-5.2	1.7175×10^2			5.0		
5.2-5.4	1.56×10^2			5.2		
5.4-5.6	1.4175×10^2			5.4		
5.6-5.8	1.3035×10^2			5.6		
5.8-6.0	1.2235×10^2			5.8		
6.0-6.2	1.155×10^2			6.0		
6.2-6.4	1.08×10^2			6.2		
6.4-6.6	1.00×10^2			6.4		
6.6-6.8	9.19×10^1			6.6		
6.8-7.0	8.375×10^1			6.8		
7.0-7.2	7.50×10^1			7.0		
7.2-7.4	6.555×10^1			7.2		
7.4-7.6	5.71×10^1			7.4		
7.6-7.8	5.00×10^1			7.6		
7.8-8.0	4.355×10^1			7.8		
8.0-8.2	3.80×10^1			8.0		
8.2-8.4	3.33×10^1			8.2		
8.4-8.6	2.905×10^1			8.4		
8.6-8.8	2.53×10^1			8.6		
8.8-9.0	2.235×10^1			8.8		
9.0-9.2	1.955×10^1			9.0		
9.2-9.4	1.685×10^1			9.2		

Report sheet for the stainless-steel "broomstick" experiment (continued). Hand calculated values of $N_{unc}(\Delta E')$ for stainless steel and calculated values of $N_{unc}(E)$, i.e., smoothed data to be compared with experiment.

		$N_{unc}(\Delta E')$			$N_{unc}(E)$	
		Composition A	Composition B			
$\Delta E'$ (MeV)	$\bar{N}_0$ (neutrons/cm^2/MeV/kW/min)	$[\prod_{n=1}^{6} N^n_{unc}(\Delta E')]/(\bar{N}_0)^5$	$[\prod_{n=1}^{4} N^n_{unc}(\Delta E')]/(\bar{N}_0)^3$	E (MeV)	Comp. A	Comp. B
9.4-9.6	1.465×10^1	______	______	9.4	______	______
9.6-9.8	1.28×10^1	______	______	9.6	______	______
9.8-10.0	1.125×10^1	______	______	9.8	______	______
10.0-10.2	9.80	______	______	10.0	______	______
10.2-10.4	8.55	______	______	10.2	______	______
10.4-10.6	7.50	______	______	10.4	______	______
10.6-10.8	6.55	______	______	10.6	______	______
10.8-11.0	5.65	______	______	10.8	______	______
11.0-11.2	4.90	______	______	11.0	______	______
11.2-11.4	4.35	______	______			
11.4-11.6	3.80	______	______			
11.6-11.8	3.30	______	______			
11.8-12.0	2.90	______	______			