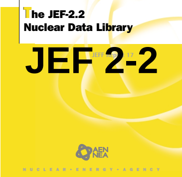

239Pu TOTAL CROSS SECTIONS IN THE ENERGY RANGE 1 KEV TO 500 KEV

H. DERRIEN

Les données expérimentales de transmission neutroniques de trois épaisseurs d'échantillons de 239Pu obtenues à ORNL (1) ont été analysées dans le domaine d'énergie 1 kev à 500 kev dans le but d'obtenir les sections efficaces totales moyennes. Les résultats ont été comparés à d'autres valeurs expérimentales et aux versions actuelles de ENDF/B-VI et JEF2. Quelques ajustements seraient nécessaires sur ces deux fichiers. Le travail a été fait au cours d'une mission de collaboration entre ORNL et Cadarache à ORNL.

I INTRODUCTION

The 239Pu neutron transmissions were measured by J.A. HARVEY et al. (1) with samples cooled down to liquid nitrogen temperature on a 80 m flight path with a nominal resolution ranging from 1.6 ns/m to 0.1 ns/m in the energy range 0.5 ev to several hundred kev. Three sample thicknesses were used in the experiments : 0.07471 at/b, 0.01825 at/b and 0.00646 at/b. The low energy part of the data was analysed with the bayesian Reich-Moore code SAMMY (2) along with several experimental fission and capture data to obtain the resonance parameters in the energy range thermal to 2 kev (3,4). Due mainly to a small experimental background, the systematic errors on the transmissions are not more than 1 %, which was confirmed by the SAMMY resonance analysis on the three samples. Although important self-screening effects are to be expected in unresolved resonance energy range, the aim of the present paper is to show that accurate average total cross sections can be obtained from these transmission data in the energy range 2 kev to 500 kev to be used for cross sections evaluation by statistical and optical model calculations. As a matter of fact, 239Pu total cross section data are scarce and not reliable in the range several kev to 100 kev in the EXFOR international data file (5) ; the cross sections from J.A. HARVEY et al. transmission data could be of great value to fill the gap of accurate data in this energy range.

In the following sections we will present :

1) the problems encountered when evaluating total cross sections from transmission measurements,

2) the methods used for the self-screening corrections and the total cross sections obtained,

3) the comparison with the current ENDF/B-VI evaluation and some other experimental results,

4) the conclusions concerning further work to be performed to update ENDF/B-VI evaluation.

II TRANSMISSION AND TOTAL CROSS SECTION

The neutron total cross section, $\sigma(E)$ at the energy E, is related to the neutron transmission by the equation :

$$T(E) = \exp(-n\sigma(E)) \qquad \text{(I)}$$

n is the thickness of the sample in at/b when the cross section is expressed in barn. However, the transmission cannot be measured at the precise energy E of the neutron but is a value averaged over the experimental resolution in an energy interval E-DE to E+DE depending on the width of the resolution function. The quantity which is really measured is the following :

$$Tr(E) = \int_{E_1}^{E_2} \exp(-n\sigma_\Delta(E'))*R(E-E')dE' \qquad \text{(II)}$$

R is the experimental resolution function ; the interval of integration E1 to E2 depends on the width of the resolution function ; σ_Δ (E') is the Doppler broadened total cross section at energy E. Using the relation (I), one obtains the so-called effective cross sections :

$$\sigma eff(E) = -(1/n) \log Tr(E) \qquad \text{(III)}$$

$\sigma eff(E)$ is smaller than the true total cross section $\sigma_\Delta(E)$ of equation (II). The difference between the effective cross section and the true cross section is the so-called self-screening effect. This effect should be evaluated when deriving total cross sections from transmission measurements. However, the self-screening effect can be neglected in two cases :

1) $n\sigma_\Delta(E)$ is small compared to 1 for each value of E in the interval E1 to E2, in such a way that $\exp(-n\sigma_\Delta(E))$ is very close to $1-n\sigma_\Delta(E)$ for each value of E. This condition can be realised by using thin samples in the transmission measurement ; but the experimental error on the effective cross section will increase since $d\sigma = (-1/n)\ dTr/Tr$ and could reach values much larger than the self-screening effect in thicker samples.

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For instance, to measure a total cross section of 20 barns with 1 % accuracy one needs a thickness of at least 0.05 at/b, if the transmission is measured with 1 % accuracy ; the corresponding $n\sigma_T$ value is 1 for which the self-screening effect would still be quite large,

2) the fluctuations of the cross section are small in the energy range E1 to E2. In this case the average value of the cross section does not depend too much on the resolution function and the self-screening effect, which depends strongly on the variance of the cross section, should be very small.

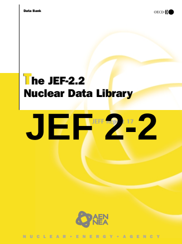
Practically, three energy ranges of the cross section should be considered :

1) the well resolved resonance region where the fluctuations of the cross section are very large, the values ranging from several barns between resonances to several thousands of barns at the peak of resonances ; several sample thicknesses are needed to have good accuracy over all the ranges of the cross section values. In this energy region the transmissions are analysed in terms of resonance parameters using least square fitting codes with adequate nuclear reaction formalisms and taking into account all the experimental effects of the transmission measurements. The true values of the Doppler broadened cross sections can then be calculated by the resonance parameters. The self-screening has no effect on the results. Moreover, the self screening can be calculated with good accuracy because the true values of the cross section are known from the resonance parameters,

2) the unresolved resonance region where the resonances are not well resolved. Strong fluctuations still exist in the cross section due to unresolved multiplets of resonances which cannot be analysed in terms of resonance parameters. In this region, one tries to obtain average values of the cross sections to be interpreted by average resonance parameters with statistical model or optical model codes. The self-screening effects are very important and should be evaluated with good accuracy to obtain reliable values of the average total cross sections and, consequently, of the statistical or optical model parameters ;

3) the higher energy range where the resonances overlap so much that there are no strong fluctuations in the cross section. The cross section is quite smooth and varies very little over an energy range equivalent to the width of the experimental resolution function. In this energy region the self-screening effect is negligible ; the effective cross section is equal to the true cross section averaged over the width of the resolution function and does not depend on the thickness of the samples used for the transmission measurements.

How can one evaluate with a reasonable accuracy the self-screening effect in the intermediate energy range where it is needed ? Since this effect increases smoothly with the thickness of the sample, the true cross section could be obtained by extrapolation from the effective cross sections obtained by using several sample thicknesses, bearing in mind that too thin samples cannot be used due to poor accuracy on the corresponding effective cross section. In some cases, when the self-screening effect is important, the accuracy achieved on the extrapolated cross section cannot be better than the accuracy on the thiner sample effective cross section. Another way of evaluating the self-screening correction is to calculate all the quantities involved by using resonance parameters obtained the by Monte-Carlo method or directly inferred from the set of resonance parameters known in the resolved range region, taking into account all the experimental effects ; this method will be used below in the energy range above 10 kev.



III THE 239PU TOTAL CROSS SECTION IN THE ENERGY RANGE 1 KEV TO 500 KEV

Average effective cross section values, the values corrected for self screening effects and ENDF/B-VI evaluated data are given in Table 1 in the energy range 1 kev to 10 kev. The experimental data are averaged values ; for instance, the value given at 1.025 kev is the cross section averaged in the energy range 1.000 kev to 1.050 kev ; the value given at 1.075 kev is the cross section averaged in the energy range 1.050 kev to 2.000 kev, etc... The effective cross section obtained from the 0.07471 at/b, 0.01825 at/b and 0.00646 at/b sample transmissions are given in column (1), (2), (3) respectively. In general (1) is smaller than (2) and (2) is smaller than (3), the differences being much larger than the errors corresponding to the expected 1 % experimental errors on the transmissions and are mainly due to the self-screening effect wich is seen to be as large as 35 % of the thick sample effective cross section in the low energy part of the data. The values in column (4) are an estimate of the true average cross section obtained by extrapolation from the three effective cross sections. To find the best extrapolation schema to be used with the three experimental effective cross sections, the resonance parameters obtained in ref. 3 were used to calculate the average effective cross sections in 8 energy intervals in the energy range 0.8 kev to 1 kev, and the corresponding average Doppler broadened cross sections. The results of the calculations are shown on Table 2; the effective cross sections are in column (1), (2) and (3) and the true total cross section is in column (4). Column (5) is the result of a graphical linear extrapolation using the effective cross sections versus the square root of the sample thickness. This method was found to be the best to obtain corrected cross section values in reasonable agreement with the true values of the cross sections. However, there is a tendancy to overestimate the cross sections by a few %. Therefore, the error on the corrected cross-sections of column (4) of Table 1 could be as large as 4 %, which is much larger than the statistical accuracy achieved on the experimental effective cross sections.

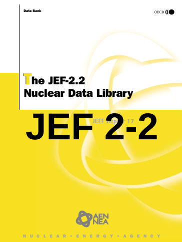


TABLE 1

ENERGY (Kev)	TOTAL CROSS SECTION (BARNS) (1)	(2)	(3)	(4)	(5)
1.025	20.369	22.981	24.024	25.50	24.105
1.075	18.767	22.269	24.083	25.69	23.935
1.125	22.203	24.385	24.786	26.25	25.240
1.175	17.936	19.633	19.654	20.95	20.982
1.225	17.154	18.098	18.387	19.02	18.953
1.275	20.762	24.347	25.826	27.78	27.325
1.325	20.754	22.472	22.859	24.17	23.142
1.375	19.198	20.958	20.500	21.73	22.197
1.425	18.173	19.978	20.707	21.77	20.909
1.475	18.574	19.543	19.187	20.05	19.973
1.525	16.148	17.036	17.351	17.97	19.895
1.575	16.396	18.396	19.429	19.39	19.193
1.625	19.142	21.417	22.394	23.58	22.870
1.675	17.224	19.531	20.027	21.82	20.630
1.725	18.358	20.532	22.112	23.13	21.206
1.775	16.575	19.113	20.456	21.52	23.315
1.825	21.370	25.239	26.178	28.40	26.149
1.875	18.435	19.828	19.880	21.03	19.908
1.925	15.865	17.287	16.935	18.07	18.470
1.975	17.471	19.082	20.705	21.19	20.330
2.050	15.552	16.663	17.071	17.31	18.282
2.150	17.920	19.179	18.721	19.63	20.330
2.250	16.372	17.976	18.799	19.50	18.973
2.350	18.381	20.366	20.717	22.13	21.109
2.450	17.795	19.386	20.516	21.10	20.181
2.550	16.876	18.704	19.747	20.39	19.236
2.650	17.817	20.061	20.858	22.12	21.315
2.750	16.874	18.158	18.487	19.32	19.194
2.850	17.775	19.161	19.217	20.37	19.369
2.950	19.825	22.294	22.951	24.64	23.703
3.050	16.434	17.414	17.401	18.23	17.843
3.150	17.973	19.069	18.918	19.80	20.214
3.250	18.619	19.605	20.559	20.28	19.967
3.350	15.685	16.421	16.552	17.03	16.704
3.450	16.664	17.213	17.520	17.70	18.585
3.550	15.656	15.837	15.805	16.02	16.746
3.650	18.129	19.800	19.771	21.12	20.654
3.750	15.579	16.742	17.105	17.81	17.331
3.850	18.088	19.017	18.691	19.47	19.401
3.950	17.229	18.326	18.826	19.30	19.387
4.125	16.656	17.636	17.167	18.03	17.914
4.375	15.816	16.846	17.126	17.76	18.249
4.625	16.677	17.801	17.708	17.65	17.539
4.875	15.904	16.642	17.457	17.62	17.886
5.125	15.872	16.758	16.819	17.28	17.826
5.375	16.054	16.657	16.784	17.08	17.669
5.625	16.196	17.035	17.159	17.53	17.524
5.375	16.786	16.429	16.797	16.80	17.386
6.125	16.503	17.228	17.718	18.14	17.257
6.375	15.757	16.038	16.541	16.71	17.137
6.625	15.591	15.913	15.992	16.19	17.004
6.875	15.154	16.038	16.318	16.89	16.895
7.125	15.686	16.299	16.783	17.05	16.870
7.375	15.262	15.694	15.137	15.75	16.950
7.625	15.461	15.710	15.830	16.09	16.730
7.875	15.170	15.651	16.360	16.33	16.690
8.125	15.090	15.575	15.797	16.15	16.590
8.375	15.735	15.963	16.292	16.40	16.540
8.625	15.852	16.277	16.815	17.01	16.480
8.875	15.164	15.478	16.341	16.32	16.430
9.125	15.554	15.771	15.638	15.92	16.310
9.375	15.355	15.729	15.813	16.12	16.210

(1),(2),(3) experimental effective cross sections obtained from the transmissions of the 3 samples.
(4) corrected cross sections obtained by extrapolation from (1),(2) and (3).
(5) ENDF/B-VI data.

TABLE 2

ENERGY RANGE(ev)	TOTAL CROSS SECTION(barns) (1)	(2)	(3)	(4)	(5)
800-825	17.62	18.71	19.01	19.10(7.7%)	19.80(+3.7%)
825-850	20.96	22.72	23.38	23.93(14.1%)	24.40(+2.1%)
850-875	17.05	17.94	18.21	18.26(7.1%)	18.69(+2.4%)
875-900	19.30	23.34	25.92	28.16(45.9%)	28.21(+0.2%)
900-925	21.41	23.64	24.37	24.81(15.9%)	25.80(+4.0%)
925-950	19.56	20.81	21.12	21.32(9.0%)	21.78(+2.2%)
950-975	19.96	25.53	28.36	30.40(52.3%)	31.30(+3.0%)
950-999	26.35	32.79	36.04	38.37(45.6%)	37.90(-1.2%)
800-999	20.27	23.18	24.55	25.54(26.0%)	25.99(+1.7%)

(1),(2),(3) the calculated effective cross sections.
(4) the calculated true cross section;the figures between parentheses are the self screening effect in the thick sample.
(5) the extrapolated cross sections;the figures between parentheses are the deviation between the results of the extrapolation and the true cross sections.

Above 9.5 kev the self-screening effect is, on average, smaller than 4 % of the thick sample effective cross section, which is 0.6 b for a cross section of 15 b. That is equivalent to an error of 4 %, 1 % and 0.4 % on the experimental transmission of the thick, medium and thin sample respectively. Therefore the method of extrapolation can hardly been used for the self screening correction from the three sample effective cross sections. The correction becomes smaller than the experimental error on the effective cross section obtained from the medium and the thin sample. Moreover, the medium and thin sample effective cross sections become smaller than the thick sample effective cross section, as is shown on Table 3 where the data are averaged on wide energy ranges. The differences could be due to small systematic errors in the medium and thin sample transmissions. An error of 0.3 % on the medium sample transmission and of 0.2 % on the thin sample transmission could be at the origin of the differences. However, these figures show that the 3 sample transmissions are consistent to better than 1 %.

TABLE 3

ENERGY RANGE Kev	K barn	M barn	N barn	K-M	DT/T %	K-N	DT/T %
10.- 20.	14.503	14.624	15.534	-0.12	0.2	-1.03	0.7
20.- 30.	13.758	13.808	13.559	-0.05	0.1	0.20	0.1
30.- 50.	13.008	12.789	12.506	0.22	0.4	0.50	0.3
50.-100.	12.190	12.024	11.881	0.17	0.3	0.31	0.2
100.-200.	11.169	10.945	10.783	0.22	0.4	0.39	0.3
200.-300.	10.117	10.010	9.753	0.11	0.2	0.37	0.3
300.-400.	9.285	9.084	9.022	0.20	0.4	0.26	0.2
400.-500.	8.678	8.683	8.509	0.00	0.0	0.18	0.1
500.-565.	8.200	9.259	7.927	0.25	0.5	0.27	0.2

K,M,N are the effective total cross sections,in barns, obtained from the thick,the medium and the thin sample transmissions respectively.K-M and K-N are the cross section differences.DT/T are the corresponding deviations in % on the transmission of the medium and thin sample respectively.

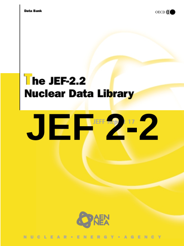
For the purpose of obtaining the self-screening corrections in the energy ranges above 10 kev, the following method have been used at 10 kev, 20 kev, 30 kev and 60 kev :

1) The sample of known resonances in the resolved energy range 0 kev to 1 kev (ref. 3) was used to obtain a set of s wave resonance parameters in a 150 ev energy interval at 10 kev, 20 kev, 30 kev and 60 kev. An equivalent set of p wave resonances was also obtained.

2) These sets of parameters were used to calculate the Doppler broadened cross sections at liquid nitrogen temperature, the corresponding resolution broadened transmissions and the effective cross sections for the three samples in an 100 ev interval at 10 kev, 20 kev, 30 kev and 60 kev. Fig. 1 and 2 show the calculated data at 10 kev and 60 kev.

3) Estimation of the self-screening corrections were obtained from the three sample calculated effective cross sections. Fig. 3 shows the variations of the self-screening corrections from 1 kev to 60 kev. The values in the energy range 1 kev to 9 kev are those obtained by extrapolation from the three sample experimental data as explained above. The self-screening effect appears to vary linearly in log-log scale and is quite well represented by the following relation :

$$Scr = 35.0*\exp(-0.945 \mathrm{Log} E) \qquad (IV)$$



Scr is the correction in % to be applied to the thick sample effective cross section and E is the neutron energy in kev. Above 50 kev the correction is smaller than 1 %. The uncertainty on Scr is about 20 % in the energy range 10 kev to 100 kev. The correction is less than 0.5 % Above 100 kev. The above relationship was applied to the thick sample effective cross sections, which are shown in column (1) in Table 4, to obtain the values shown in column (2) in Table 4.

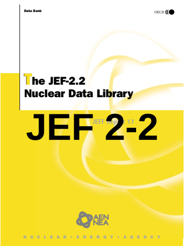


TABLE 4

ENERGY Kev	CROSS SECTION(barns) (1)	(2)	(3)
9.625	15.410	16.03	16.080
9.875	14.943	15.54	15.990
10.250	14.459	15.02	16.040
10.750	15.028	15.59	15.930
11.250	14.765	15.29	15.840
11.750	14.717	15.22	15.750
12.250	14.709	15.19	15.660
12.750	14.934	15.41	15.580
13.250	14.783	15.23	15.500
13.750	14.662	15.09	15.420
14.250	14.455	14.87	15.350
14.750	14.469	14.87	15.280
15.250	14.160	14.54	15.210
15.750	14.651	15.03	15.050
16.250	14.836	15.21	15.090
16.750	14.456	14.81	15.030
17.250	13.987	14.32	14.970
17.750	14.356	14.69	14.910
18.250	14.444	14.77	14.860
18.750	13.990	14.30	14.810
19.250	14.194	14.50	14.760
19.750	13.925	14.22	14.700
20.500	14.164	14.45	14.620
21.500	13.860	14.13	14.550
22.500	13.563	13.81	14.470
23.500	13.883	14.13	14.390
24.500	13.952	14.19	14.310
25.500	13.999	14.23	14.250
26.500	13.621	13.84	14.180
27.500	13.903	14.12	14.120
28.500	13.318	13.51	14.060
29.500	13.321	13.51	14.000
30.000	13.384	13.57	13.988
35.000	12.920	13.08	13.727
40.000	13.048	13.19	13.504
45.000	12.890	13.01	13.311
50.000	12.943	13.06	13.140
55.000	12.643	12.74	12.990
60.000	12.596	12.69	12.850
65.000	12.474	12.56	12.726
70.000	12.278	12.36	12.613
75.000	12.126	12.20	12.508
80.000	11.942	12.01	12.412
85.000	11.909	11.97	12.322
90.000	11.830	11.89	12.237
95.000	11.820	11.88	12.157
100.000	11.743	11.80	12.082
110.000	11.545	11.59	11.944
120.000	11.470	11.51	11.805
130.000	11.416	11.46	11.681
140.000	11.138	11.17	11.557
150.000	11.259	11.29	11.433
160.000	11.110	11.14	11.318
170.000	10.998	11.03	11.204
180.000	10.924	10.95	11.094
190.000	10.678	10.70	10.986
200.000	10.603	10.63	10.880
210.000	10.611	10.63	10.777
220.000	10.358	10.38	10.675
230.000	10.312	10.33	10.575
240.000	10.183	10.20	10.478
250.000	10.083	10.10	10.382
260.000	10.023	10.04	10.287
270.000	9.921	9.94	10.195
280.000	9.778	9.79	10.104
290.000	9.750	9.77	10.015
300.000	9.693	9.71	9.926
325.000	9.426	9.44	9.714
350.000	9.286	9.30	9.516
375.000	9.153	9.16	9.331
400.000	8.864	8.87	9.158
425.000	8.876	8.89	8.996
450.000	8.710	8.72	8.845
475.000	8.505	8.51	8.704
500.000	8.324	8.33	8.571

(1) average effective cross section obtained from the thick sample transmission data.
(2) corrected cross section obtained by applying the equation IV to (1).
(3) ENDF/B-VI data.

VI COMPARISON WITH ENDF/B-VI AND SOME OTHER EXPERIMENTAL RESULTS.

The total cross section in the current version of ENDF/B-VI is shown in column (5) of Table 1 and in column (3) of Table 4. The present results and ENDF/B-VI are averaged over wider energy range in Table 5. Below 4 kev, ENDF/B-VI is lower by about 2 %. In the energy range 1 kev to 4 kev, ENDF/B-VI evaluation (6) was performed by using average total cross sections obtained from Saclay experimental transmission data of two sample thicknesses (7). The self-screening correction on Saclay effective cross sections could have been underestimated. On the other hand, the present results could have been overestimated by the extrapolation procedure (4 % accuracy as mentioned above). Therefore, the accuracy of the ENDF/B-VI total cross section cannot be better than 4 % in this energy range.

In the energy range 4 kev to 30 kev, ENDF/B-VI is about 2 % larger on average. The experimental total cross section data available for the ENDF/B-VI evaluation (6) were scarce and not reliable ; the basis for the total cross section evaluation was a statistical model calculation with statistical parameters inferred from the resolved resonance region and from an optical model calculation at higher energy. However, the differences between the present results and ENDF/B-VI would disappear by using a nuclear radius about 1.3 % smaller in the ENDF/B-VI calculations (9.34 f instead of 9.46 f).

Above 30 kev, the ENDF/B-VI values were obtained from a coupled channel optical model fit of the available experimental data above 50 kev (8). The present results are in the lowest part of the experimental data base used for ENDF/B-VI evaluation. However, in the energy range 40 kev to 500 kev, the most accurate total cross section data in the ENDF/B-VI experimental data base are those of POENITZ et al. (9). The fig. 4 shows the data of POENITZ et- al and the present results compared to ENDF/B-VI. The present results are, on average, 1.2 % lower than the data of POENITZ et al. and 2.0 % lower than ENDF/B-VI. Including them in the ENDF/B-VI experimental data base will improve the accuracy of the evaluation by lowering the results to values closer to the data of POENITZ et al. and to the present data.

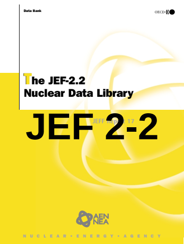
TABLE 5

ENERGY RANGE Kev	THIS WORK BARNS	ENDF/B-VI BARNS	DIFFERENCES ABSOLUTE	RELATIVE
1.- 2.	22.45	21.94	-0.51	-2.3%
2.- 4.	19.70	19.43	-0.27	-1.4%
4.- 10.	16.71	17.01	0.30	1.8%
10.- 20.	14.91	15.29	0.38	2.5%
20.- 30.	13.99	14.29	0.30	2.1%
30.- 50	13.21	13.63	0.42	3.2%
50.-100.	12.34	12.60	0.26	2.1%
100.-200.	11.26	11.60	0.34	3.0%
200.-300.	10.18	10.48	0.30	2.9%
300.-400.	9.40	9.62	0.22	2.3%
300.-500.	8.75	8.85	0.18	2.1%

V CONCLUSION

The high resolution transmission data of HARVEY et al. were used to obtain the 239Pu average total neutron cross sections in the energy range 1 kev to 500 kev. The effective cross sections were corrected for self-screening effects in the samples used in the transmission measurements.

The results have been compared to the total cross section in the current version of ENDF/B-VI. Apart from the energy range 1 kev to 4 kev, where the accuracy of the present data depends strongly on the accuracy on very large self screening corrections, ENDF/B-VI values are on average larger than the present results by 2 % to 3 % which is at the limit of the accuracy achieved on the present data. In the energy range above 40 kev, the present results are in good agreement with the data of POENITZ et al. At least above 10 kev, the accuracy of ENDF/B-VI evaluation could be improved by including the present results to the experimental total cross section data base.



REFERENCES

/1/ J.A. HARVEY et al., Internat. Conf. on Nuclear Data for Science and Technology, May 30 - June 3, 1988, Mito, Japan (1988).

/2/ N.M. LARSON, ORNL/TM-9179/R2 (1989).

/3/ H. DERRIEN et al., ORNL/T/M-10986 (1989).

/4/ H. DERRIEN, to be published.

/5/ EXFOR international data file from nuclear data centre.

/6/ H. DERRIEN, 239Pu Evaluation for JEF2 and ENDF/B-VI (1989).

/7/ H. DERRIEN, Thesis, Orsay, Serie A, number 1172 (1973).

/8/ P. YOUNG, 239Pu Evaluation for ENDF/B-VI (1989).

/9/ W.P. POENITZ et al., Nuc. Sci. Eng. 78,333 (1981).

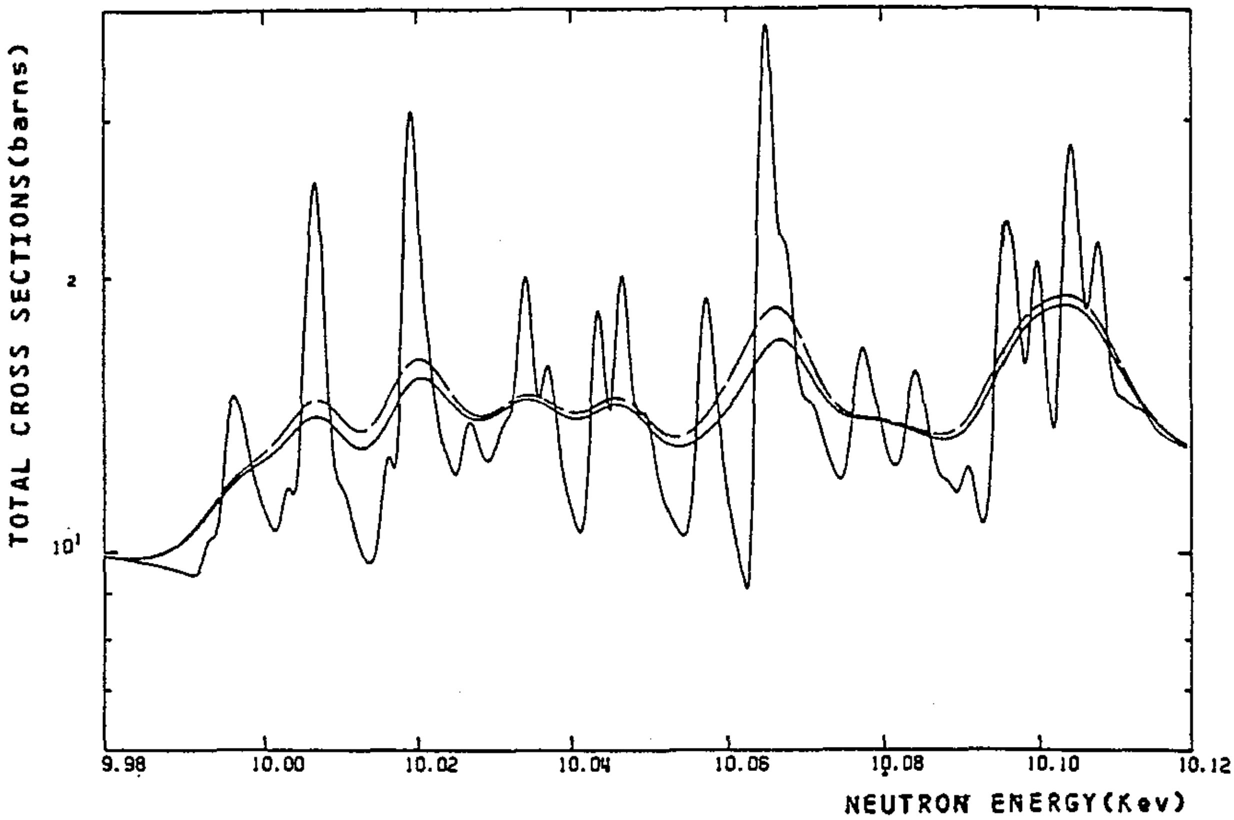


FIG.1 - The line with well resolved stuctures represents the Doppler broadaned cross sections calculated from a set of resonance parameters.The two other lines represent the corresponding effective cross sections obtained from the transmission broadened by the experimental resolution for two sample thicknesses(0.01825 at/b and 0.07471 at/b).The differences between the effective cross sections are due to the self-screening effect in the samples.

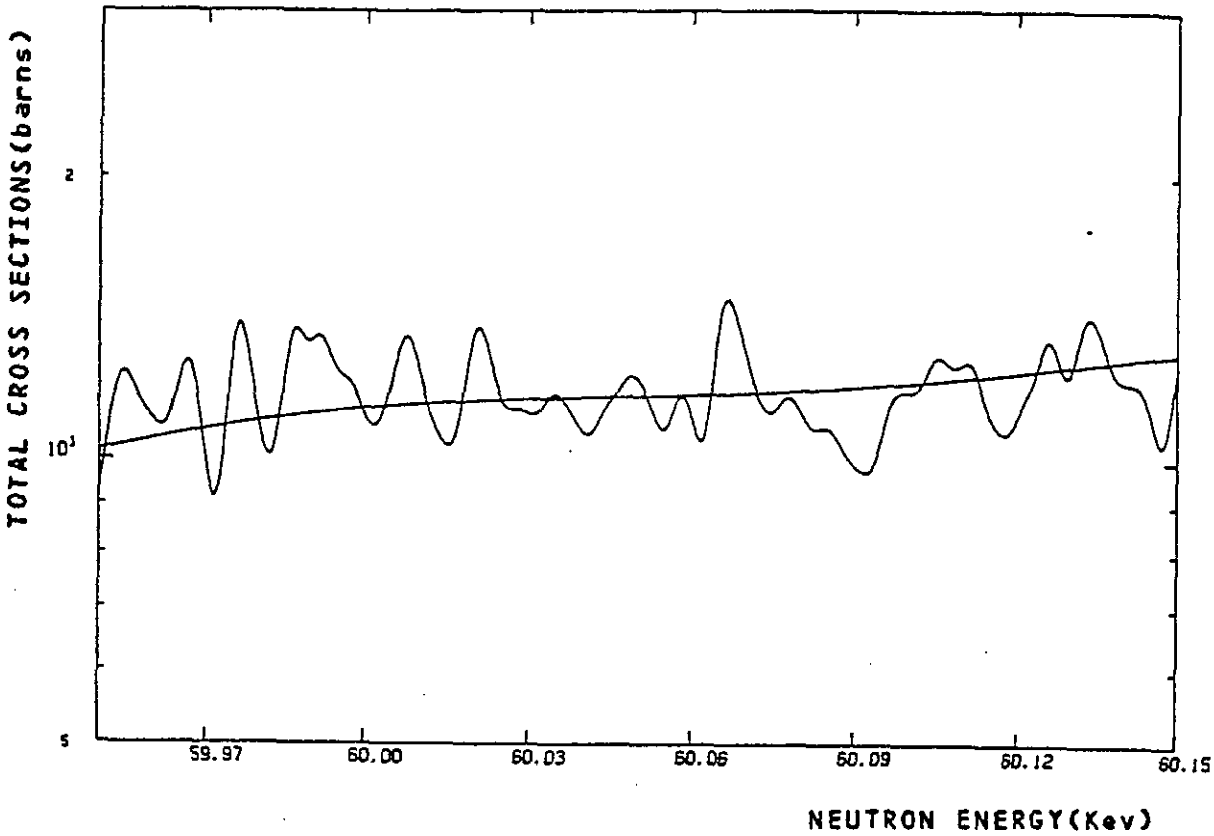


FIG.2 -The line with resolved structures represents the Doppler broadened cross sections calculated from a set of resonance parameters.The line without structure represents the corresponding effective cross sections obtained from the transmission broadened by the experimental resolution for two samples thicknesses(0.01825 at/b and 0.07471 at/b).The differences between the effective cross sections of the two samples are less than 1% at all energies and do not appear on the figure.In this energy range the self-screening effect is small.

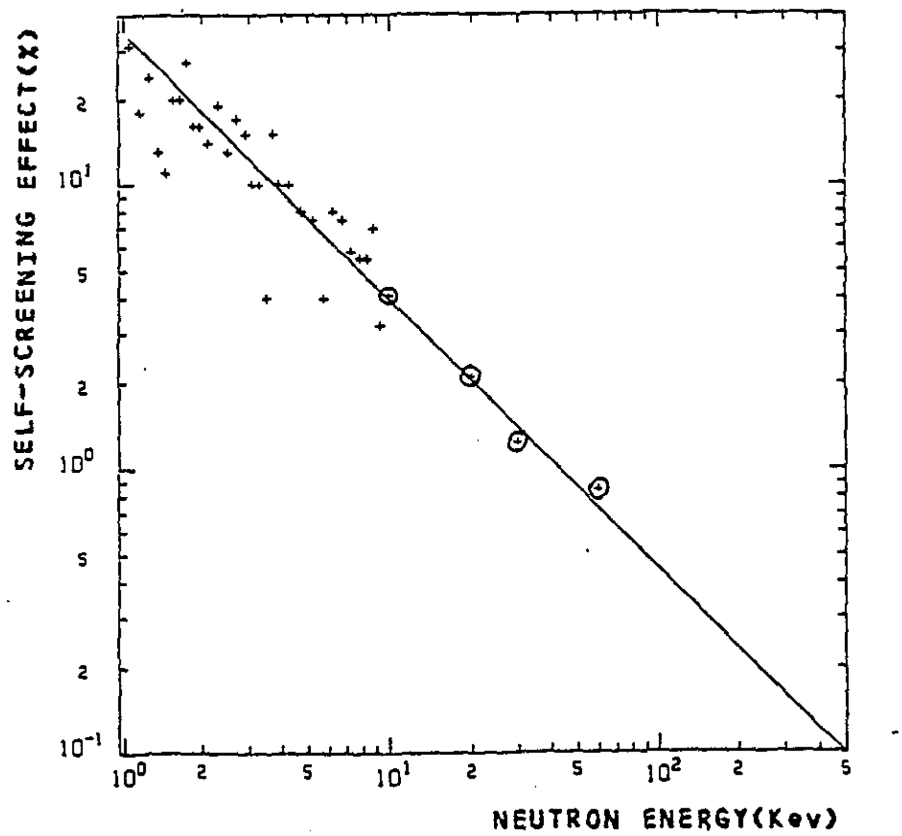


FIG.3-Self-screening effects in the 0.07471·at/b sample. The values (+) obtained by extrapolation from the effective experimental cross sections in the energy range 1 kev to 10 kev and the values (o) obtained by calculation in the energy range above 10 kev are shown.The variation of the self-screening effect versus energy is linear in log-log scale and be represented by the relation:

$$scr(X)=35.0\exp(-0.945\log E)$$ with E in kev

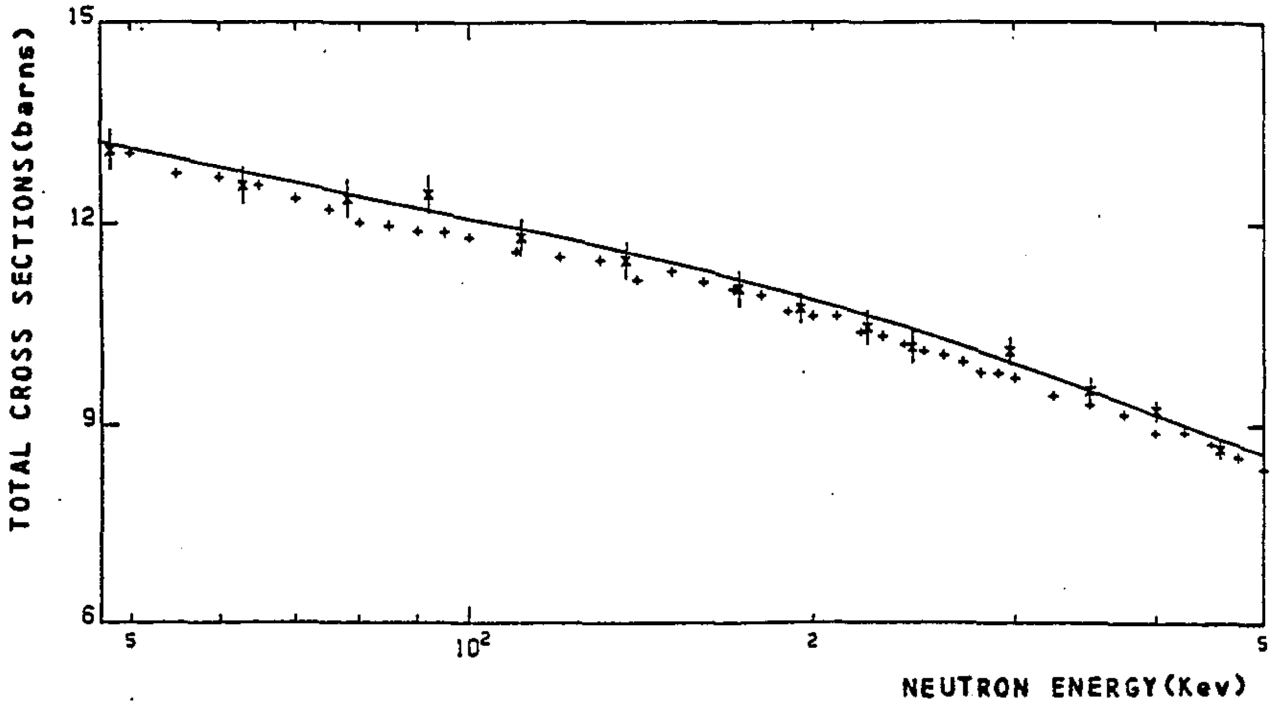


FIG.4- 239Pu total cross sections in the energy range 45 kev to 500 kev.The values obtained in the present work(+) are shown with POENITZ et al. values(x) and ENDF/B-VI(solid line). The accuracy on the present results is about 2%.