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R-Matrix Analysis of the ^{241}Pu Neutron Cross Sections in the Energy Range Thermal to 300 eV

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Engineering Physics and Mathematics

R-MATRIX ANALYSIS OF THE ^{241}PU NEUTRON CROSS SECTIONS IN THE ENERGY RANGE THERMAL TO 300 eV

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ABSTRACT

The report is a description of the analysis of the ^{241}Pu neutron cross sections in the resolved resonance region at Oak Ridge National Laboratory (ORNL) using the multilevel-multichannel Reich-Moore code SAMMY. The resonance parameters were obtained in the energy range 0 to 300 eV. The table of the resonance parameters is given with some statistical properties of the parameters. Tabulated and graphical comparison between the experimental data and the calculated cross sections are given. The results are available in ENDF/B-V format and will be proposed for the evaluated data library JEF2 and ENDF/B-VI.

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1. INTRODUCTION

The most recent complete review of the ^{241}Pu resonance parameters is that given in Ref. 1. It was shown that a satisfactory set of resonance parameters describing with accuracy the cross sections in the resonance region had not yet been obtained. An attempt to improve the Reich-Moore type resonance parameters obtained at Saclay in 1976 has been made recently by H. Derrien *et al.*[2] by using the Bayesian code SAMMY for the analysis of the total cross-section measurements of Kolar and Carraro[3] and the fission cross-section measurements of Blons[4] and Weston and Todd.[5] The problems encountered by Weston and Wright[12] when evaluating the ^{241}Pu cross sections for ENDF/B-V were not solved. It was concluded that a satisfactory evaluation of the ^{241}Pu resonance region would require at least a precise transmission measurement with thicker samples than those used by Kolar and Carraro. Unfortunately, such transmission measurements are not foreseen for the moment and one should try to extract more information from existing data. Transmission measurements were performed in 1973 by Harvey and Simpson[13] on a 78-m flight path with samples cooled down at liquid nitrogen temperature; the thickest sample was 0.0114 at/b, seven times thicker than the one used by Kolar and Carraro. In the present paper, a new analysis of the ^{241}Pu resonance region is described. This new analysis is based on the 1973 Harvey and Simpson high resolution transmission data which allow the resolved resonance range to be extended up to 300 eV.

The content of this paper is organized as follows. Section 2 describes the experimental data base analyzed. In Section 3 information on the methods and assumptions of the analysis are given. The properties of the resonance parameters obtained are described in Section 4. The calculated average cross sections are shown in Section 5 and are compared to experimental data and to some previous evaluations.

2. THE EXPERIMENTAL DATA BASE

At least eight sets of experimental fission cross sections are available in the resolved resonance region.[4–11] A comparison of the average cross sections obtained from these experiments is found in Weston and Todd.[5] This comparison shows that large discrepancies exist among the experimental data, even in the low energy range not far from the usual thermal normalization range. The reasons for such large discrepancies (as much as 20%) are not well known. It is not possible to include all the data in a SAMMY fit without having some information on the experimental parameters which could be at the origin of the severe discrepancies. In the present work three sets of data have been chosen: Migneco *et al.*,[7] Blons,[4] and Weston and Todd.[5] The measurements of Migneco *et al.* (sample at room temperature) and of Blons (sample at liquid nitrogen temperature) were performed with a resolution good enough for the separation of most of the resonances up to about 300 eV incident neutron energy. The data of Weston and Todd could be analyzed up to about 100 eV. Wagemans and Deruytter data[6] have also been chosen for the analysis in the thermal energy range and for accurate normalization of other data. The experimental characteristics of the fission data are given in Table 1.

The transmission measurements performed by Harvey and Simpson in 1973[13] have been recently reanalyzed and were available for the present work. Two series of measurements were performed with samples cooled down at liquid nitrogen temperature on a 78-m flight path, the first series in the energy range 0.3 to 312 eV and the second series in the energy range 10 eV to several keV. The experimental conditions of the measurements are given in Table 1. The high quality of the resolution allows an accurate determination of the neutron widths at least up to 300 eV. Young and Smith[14] and Simpson and Shuman[15] data are the only total cross sections available in the thermal energy range; they were included in the present fits for the thermal range. Kolar and Carraro[3] total cross sections, which were used in a previous analysis,[2] were not included in the present fits.

The only experimental capture cross sections available are those of Weston and Todd,[5] obtained from a simultaneous measurement of the fission and the absorption. The fission cross sections were normalized on ENDF/B-IV in the energy range 0.02 to 0.03 eV and the absorption cross sections were normalized to the absorption cross section inferred from Kolar and Carraro total cross-section data. It was expected when starting the present analysis that a more accurate normalization should be obtained by using Harvey and Simpson transmission data and that the inconsistencies mentioned by Weston and Wright[12] should disappear.

Finally, the resonance parameters were obtained in the energy range thermal to 300 eV from the experimental data base shown in Table 5.

Table 1. Experimental characteristics of the data analyzed

References	Main characteristics and normalization method
Migneco *et al.* (1970)	σ_f normalized to $\int_{4.65\ \mathrm{eV}}^{10\ \mathrm{eV}} \sigma_f(E)\frac{dE}{E} = 193.6$ b (Hennies[25]); Linac measurement 30.617 m flight path; liquid scintillation detector uncorrected for 0.87% ^{239}Pu contamination.
Blons (1973)	σ_f normalized to the values of $\sigma_0\Gamma_f$ for the 15.95 and 16.66 eV resonances given by Stehn *et al.*;[26] Linac measurement, 10.89 m flight path; gaseous scintillator; uncorrected for 0.87% ^{239}Pu contamination.
Blons *et al.* (1971)	σ_f normalized to $\int_{20\ \mathrm{eV}}^{70\ \mathrm{eV}} \sigma_f(E)dE = 2367.5$ b· eV (James [9]); Linac measurement 10.89 and 50.07 m flight path, gaseous scintillator, uncorrected for 0.87% ^{239}Pu contribution.
Wagemans and Deruytter (1976)	σ_f normalized to $\sigma_f^0 = (1015 \pm 7)$ b by a linear least-squares fit of $\sigma_f\sqrt{E}$ from 0.02481 to 0.02586 eV; Linac measurement, 8.1 m flight path; silicon surface-barrier detectors.
Weston and Todd (1978)	σ_f normalized between 0.02 and 0.03 eV to ENDF/B-IV; Linac measurement, 20- and 85-m flight path; liquid scintillator detector
Harvey and Simpson (1972)	Transmission measurements of three samples: 5.19×10^{-4}, 2.27×10^{-3}, and 1.12×10^{-2} at/b at liquid nitrogen temperature; Linac measurement; 78.30 m flight path; best nominal resolution 0.40 ns/m. Two series of measurement with different filters for low and high energy range.

3. METHOD OF ANALYSIS

3.1 RESONANCE SPINS

The Reich-Moore formalism and the method of analysis used in SAMMY are described elsewhere.[16] A knowledge of the spin of each resonance and the number of open fission channels in each spin state is required. All the resonances in the energy range analyzed were considered as s-wave resonances. The ^{241}Pu nucleus spin and parity is $5/2^+$ and the s-wave resonances are 2^+ or 3^+ resonances. One finds only one measurement for the determination of ^{241}Pu resonance spins in the literature. The measurement was performed by Sauter *et al.*;[17] the spin was obtained for only three resonances: J=2^+ at 13.4 eV and 17.8 eV, and J=3^+ at 14.7 eV. Nevertheless, some information on the average 2^+ and 3^+ fission widths could be obtained by considering the thresholds of the corresponding fission channels. The lowest 2^+ channel pertains to the rotational band built on the fundamental of the ^{242}Pu compound nucleus. This fission channel is completely open and the corresponding average fission width, $< \Gamma f >=< D > /2\pi$, could be relatively important. Some other 2^+ channels could exist in the transition spectrum: γ and double γ vibrations or a combination of bending and mass asymmetry modes;[18] the thresholds of these 2^+ fission channels are not known, but they are probably above the neutron binding energy and the corresponding fission widths should be relatively small. Adding these contributions to the main open channel contribution results in a quite large total fission width for the 2^+ resonances; the 2^+ average total fission width could be as large as 500 meV. The 3^+ transition states are also present in the γ vibration mode and in the combination of bending and mass asymmetry modes just above a 2^+ transition state. The 3^+ fission channels are not completely open. Therefore, one should assume that the average fission widths of the ^{241}Pu s-wave resonances are characterized as follows:

One 2^+ open fission channel, and several 2^+ partly open fission channels leading to a large average 2^+ fission width;

No 3^+ open fission channel, and several 3^+ partly open fission channels leading to a significantly smaller average 3^+ fission width.

Consequently, the ^{241}Pu multilevel-multichannel analysis could be started by considering two groups of resonances: one containing the wide resonances, another containing the narrower resonances. In the later stage of the analysis, some changes could be made in the groups to obtain the best fit to the cross sections. At the end of the analysis one could expect that the majority of the resonances in the first group are 2^+ resonances (large average fission width) and that the majority of the resonances of the second group are 3^+ resonances (smaller value of the average fission width). This kind of analysis was already performed by Blons and Derrien[19] in 1976, leading to the values of 595 meV and 87 meV for the average fission width of the 2^+ and 3^+ resonances, in the incident neutron energy range 5 to 105 eV. In the present evaluation, the results obtained by Blons and Derrien were used as prior information for SAMMY. In the energy range 100 to 300 eV the separation

of the resonances in two groups is more difficult, because the number of multiplets increases with the incident neutron energy and there is little chance that the spin assignments should be correct.

3.2 RENORMALIZATION AND RESIDUAL BACKGROUND CORRECTION PARAMETERS

The discrepancies found in the experimental cross sections particularly in the fission cross sections, could be due to a large number of experimental effects: normalization, background corrections, detector efficiency, etc. SAMMY allows a search on the normalization and background corrections; these correction parameters should account for all the experimental effects. They are needed to obtain a unique set of resonance parameters for the description of all the experimental data analyzed. The cross sections to be kept in the evaluated data files are those calculated from the resonance parameters with the corresponding covariance file. The covariance file contains all the information for the calculation of the systematic errors due to the experimental effects in the measured cross sections.

It is difficult to separate the systematic errors due to the normalization and background corrections from those due to the choice of the scattering radius and of the contribution of the resonances external to the energy range analyzed, particularly in the transmission data. Since Harvey and Simpson transmission data were taken with very small experimental background and a normalization accuracy probably better than 1%, very small variations were allowed on the transmission normalization and residual background correction parameters in the SAMMY fits; satisfactory fits were obtained with a scattering radius of 9.50 f and with nine fictitious resonances (four negative energy resonances and five resonances above 300 eV) for the contribution of the external range. For the fission cross sections large variations on the normalization and residual background corrections were needed, since the discrepancies among the input experimental data are important. Table 2 shows an example of correction parameters obtained in a preliminary simultaneous fit of the transmission of Harvey and Simpson and the fission data of Weston and Todd, Blons and Migneco *et al.* not renormalized, in the energy range 2 eV to 20 eV. The data of Weston and Todd needed a small residual background correction and a large normalization adjustment; Blons and Migneco *et al.* data needed a larger background correction varying strongly with energy. In the energy range 20 to 300 eV, the cross sections obtained from a preliminary fit of Blons and Migneco *et al.* data with large normalization and background corrections (Table 3) agree with Weston and Todd data within 1.5% on average (Table 4); that is a strong indication that Weston and Todd data are cleaner than Blons and Migneco *et al.* data at least above 20 eV incident neutron energy.

3.3 DOPPLER AND RESOLUTION PARAMETERS

Blons data were obtained with a sample cooled down at liquid nitrogen temperature. The effective temperature of 102 K and the resolution parameters are found in Ref. 4. The data of Migneco *et al.* and of Weston and Todd were taken at room temperature and the corresponding effective temperature is about 300 K; the resolution parameters are found in Ref. 5 and Ref. 7.

Table 2. Local normalization and background corrections[a]

	Normalization correction	Background correction at		
		3 eV	9 eV	20 eV
Medium sample	1.000 ± 0.001		0.0012	
Thick sample	1.005 ± 0.001		0.0018	
Thin sample	1.001 ± 0.001		0.0030	
Weston and Todd	1.057 ± 0.004	−0.42 b	−0.25 b	−0.27 b
Blons	1.013 ± 0.003	−3.32 b	−1.08 b	−0.07 b
Migneco *et al.*	1.037 ± 0.002	−0.49 b	−1.41 b	2.26 b

[a]Example of normalization and background corrections obtained in a SAMMY correlated fit of the Harvey and Simpson transmissions and the unrenormalized Weston and Todd, Blons, and Migneco *et al.* fission data in the energy range 2 to 20 eV. The 5.7% correction in the Weston and Todd data should decrease to less than 3% after a correct normalization of the data at thermal energy. The corrections should be applied to the experimental data in the following way:

$\sigma_{\text{cor}} = (\sigma_{\text{exp.}} - \text{Background})/\text{normalization}$

Table 3. Local normalization and background corrections between 20 and 300 eV[a]

Energy range (eV)	Blons		Migneco *et al.*	
	NORM	BACK	NORM	BACK
20 – 40	0.977	−1.00	0.974	−1.07
45 – 100	0.949	−2.70	0.978	−1.28
100 – 200	0.903	−0.83	0.906	1.83
200 – 300	0.922	−1.11	0.852	2.58

[a]Normalization corrections (NORM) and average background corrections in barns (BACK) obtained in a correlated SAMMY fit of Blons and Migneco *et al.* fission data in the energy ranges 20 to 300 eV. The corrections should be applied to the experimental data in the following way: $(\sigma_{\text{exp.}} - \text{BACK})/\text{NORM}$.

Table 4. Averaged fission cross sections (barns) in the energy range 20 to 300 eV

Energy range (eV)	Calculated fission	Weston and Todd EXP	Blons		Migneco *et al.*	
			COR	EXP	COR	EXP
20 – 40	66.60	67.98	67.28	64.74	67.06	64.25
50 – 100	40.81	40.54	41.20	36.40	41.82	39.62
100 – 200	26.26	26.60	26.29	22.91	25.55	24.98
200 – 300	28.28	28.83	28.92	25.85	27.58	26.08

[a]The calculated values were obtained from a correlated SAMMY fit of Blons and Migneco *et al.* data with large normalization and background correction. (The correction values are given in Table 3.) The experimental (EXP) and the experimental corrected values (COR) are given for Blons and Migneco *et al.*

The transmission data of Harvey and Simpson were taken with samples cooled down at liquid nitrogen temperature. Little information is available on the temperature of the samples. The best way to find the effective temperature corresponding to each sample was to perform a shape analysis on some isolated resonances or group of resonances at various energy ranges. For the thin and the medium samples reasonable fits were obtained with an effective temperature of 101 $\pm$ 20 K. But the resolution of the thick sample transmission data appeared to be worse. The experimental conditions being the same for all the samples, the difference in the resolution should be due to different temperatures of the samples. As a matter of fact, the shape analysis of the isolated resonances in the thick sample gave $T_{\text{eff}} = 272$ K. Such differences in the sample temperature have not been explained since the experiments were performed in the same runs by translating the sample in the same cryostat. Nevertheless, using $T_{\text{eff}} = 101$ K for the thin and medium samples and $T_{\text{eff}} = 272$ K for the thick sample give consistent results from separate analyses of the data.

One other important parameter for the analysis of the transmission data is the shape of the resolution function. The lithium glass of the detector used in the transmission measurements produces an exponential tail in the resolution function by scattering a large fraction of the incident neutrons.[20] The exponential tail is characterized by a half-life τ varying with the energy of the neutron incident. The parameter τ was also checked by a shape analysis of some isolated resonances; the value of $\tau(\mu s) = 1.5/\sqrt{E(eV)}$ was found, corresponding to 150 ns at 100 eV and 47 ns at 1 keV.

3.4 SCHEMA OF THE ANALYSIS

The analysis was performed separately in the six energy ranges given in Table 5. The totality of the resonances were used in each energy interval, but the Bayes equations were solved only for the resonance parameters of the energy range analyzed. The correlation matrices were obtained in each energy range. Table 5 shows the experimental data analyzed in each energy range. The energy range 0.001 to 3 eV was carefully treated to obtain calculated 2200 m/s cross-section values in agreement with the proposed ENDF/B-VI standard values.[21]

Table 5. Experimental data used as input in SAMMY in the six energy ranges analyzed

Energy range	Experimental data
0.001 – 3 eV	Young and Smith total[14] Simpson and Shuman total[15] Seppi *et al.* fission [24] Wagemans and Deruytter fission[6] Weston and Todd fission and capture[5]
0.3 – 20 eV	Harvey and Simpson transmissions[13] Blons fission[4] Migneco *et al.* fission[7] Weston and Todd fission and capture[5]
20 – 45 eV 45 – 100 eV	Harvey and Simpson transmissions[13] Blons fission[4] Migneco *et al.* fission[7] Weston and Todd fission[5]
100 – 200 eV 200 – 300 eV	Harvey and Simpson transmissions[13] Blons fission[4] Migneco *et al.* fission[7]

4. THE PROPERTIES OF THE RESONANCE PARAMETERS

A number of 245 resonances were used for the description of the cross sections in the energy range thermal to 300 eV including four bound levels and five resonances in the energy range above 300 eV. The parameters of the nine resonances external to the range analyzed have no other physical meaning than to represent the tail contribution of all the bound levels and of all the resonances above the incident neutron energy of 300 eV, in such a way that no file 3 contribution is needed in the evaluated data file. The resonance parameters are listed in Table 6. In the following some statistical properties of the parameters are presented.

4.1 THE LEVEL SPACING

Due to the small value of the average level spacing and to a quite large value of the average total width ($< \Gamma > / < D >$ larger than 0.4), the resonance overlapping is important. Therefore, one should expect that a large number of small resonances may not be seen in the experimental data and that some of the large cross section peaks may correspond to unresolved multiplets, both effects increasing with the incident neutron energy when the resolution width increases. The spacing stairstep histogram is shown in Fig. 1. The observed average level spacing is 1.15 eV, 1.25 eV, and 1.45 eV in the energy range 0 to 100 eV, 100 to 200 eV, and 200 to 300 eV respectively, showing a loss of 25% of the levels in the energy range 200 to 300 eV compared to the energy range 0 to 100 eV. The number of multiplets is increasing rapidly above 200 eV incident neutron energy. For this reason, the evaluation of the statistical properties of the parameters from the set of identified resonances should be limited to the energy range up to 200 eV.

One should note that an abnormal large spacing of 5.5 eV was observed in the set of resonance parameters of Blons and Derrien.[19] This anomaly disappears in the present set of parameters since two small resonances were identified at 54.27 and 55.90 eV in transmission data of Harvey and Simpson.

4.2 THE NEUTRON WIDTHS AND THE S-WAVE STRENGTH FUNCTION

The integral distribution of the reduced neutron widths, $2g\Gamma_n^o$, of the 167 resonances identified in the energy range 0 to 200 eV is shown in Fig. 2. The distribution could not be represented by a Porter-Thomas distribution without assuming that an important fraction of resonances with small $2g\Gamma_n^o$ values were not detected. The Porter-Thomas distribution displayed on the figure was normalized to 220 resonances, assuming that 53 resonances with $2g\Gamma_n^o$ values smaller than 0.10×10^{-3} ($eV^{1/2}$) were missing in the set of identified resonances; the corresponding average reduced neutron width is 0.216×10^{-3} ($eV^{1/2}$) giving an s-wave strength function value of 1.188×10^{-4} and a corrected average level spacing of 0.91 eV, which is 24% smaller than the one observed in the low-energy range of the transmission data. The agreement between the distribution of observed reduced

Table 6. Energy, angular momentum, neutron width, capture width, fission width (channel 1), fission width (channel 2) of Pu-241 resonances in ENDF/B-V format

9.42410+ 4	2.38986+ 2	0	0	1	09441	2151		78
9.42410+ 4	1.00000+ 0	0	1	1	09441	2151		79
1.00000- 5	3.00000+ 2	1	3	0	09441	2151		80
2.50000+ 0	9.54000- 1	0	0	1	09441	2151		81
2.38986+ 2	0.00000+ 0	0	0	1470	2459441	2151		82
-5.9534E+01	2.0000E+00	5.9613E-01	4.4501E-02	4.1526E-01	4.2980E-02	9441	2151	
-5.5795E+00	3.0000E+00	2.2888E-03	3.6438E-02	1.6481E+00	1.5760E-02	9441	2151	
-1.4048E+00	3.0000E+00	1.5130E-06	1.9251E-02	-1.8713E-02	3.6942E-04	9441	2151	
-1.2249E-01	3.0000E+00	1.3973E-05	5.1072E-02	1.5468E-02	5.0123E-04	9441	2151	
2.6639E-01	3.0000E+00	4.3713E-05	3.2555E-02	-7.8042E-02	4.8130E-04	9441	2151	
1.7350E+00	2.0000E+00	2.0798E-06	4.0000E-02	6.8219E-02	2.7418E-01	9441	2151	
4.2819E+00	3.0000E+00	5.7561E-04	3.0731E-02	2.6803E-02	0.0000E+00	9441	2151	
4.5823E+00	2.0000E+00	4.7835E-04	3.1280E-02	-1.9686E-02	1.2489E-01	9441	2151	
5.8107E+00	2.0000E+00	2.7728E-03	6.3570E-02	-1.1390E+00	2.1007E-01	9441	2151	
6.9322E+00	3.0000E+00	6.1947E-04	3.0250E-02	-1.0442E-01	4.5173E-04	9441	2151	
8.6145E+00	3.0000E+00	7.7938E-04	2.9325E-02	8.1770E-04	6.0040E-02	9441	2151	
9.6208E+00	2.0000E+00	5.9155E-04	3.9289E-02	2.0009E-01	1.7131E-03	9441	2151	
9.9226E+00	2.0000E+00	1.8935E-03	8.8500E-02	8.6900E-01	2.9278E-04	9441	2151	
1.2793E+01	2.0000E+00	8.7576E-04	3.0553E-02	-2.3286E-01	4.4892E-04	9441	2151	
1.3430E+01	3.0000E+00	2.3820E-03	3.3765E-02	3.6897E-07	2.2959E-02	9441	2151	
1.4754E+01	2.0000E+00	7.6085E-03	2.8977E-02	7.3749E-02	2.8291E-02	9441	2151	
1.5987E+01	2.0000E+00	1.7456E-03	4.0000E-02	-4.3441E-01	8.3513E-03	9441	2151	
1.6674E+01	3.0000E+00	1.0735E-03	2.4641E-02	2.0644E-01	1.5440E-03	9441	2151	
1.7853E+01	3.0000E+00	2.8250E-03	3.6041E-02	5.9507E-04	1.8731E-02	9441	2151	
1.8269E+01	3.0000E+00	1.3010E-04	4.0000E-02	-3.2455E-02	1.5573E-04	9441	2151	
2.0720E+01	3.0000E+00	3.4529E-04	3.8056E-02	1.2483E-02	4.5453E-02	9441	2151	
2.1921E+01	3.0000E+00	9.9690E-05	3.2884E-02	-1.2066E-02	0.0000E+00	9441	2151	
2.2995E+01	3.0000E+00	8.0627E-04	4.4463E-02	2.1114E-01	3.2203E-02	9441	2151	
2.3679E+01	2.0000E+00	5.7370E-04	4.1864E-02	4.0304E-01	-5.7001E-03	9441	2151	
2.4103E+01	3.0000E+00	1.1466E-03	4.2440E-02	-3.3662E-02	-5.9771E-02	9441	2151	
2.4529E+01	2.0000E+00	2.0506E-04	4.0000E-02	4.4557E-01	0.0000E+00	9441	2151	
2.6429E+01	2.0000E+00	5.4046E-03	3.4507E-02	1.1160E-02	2.6810E-01	9441	2151	
2.7437E+01	2.0000E+00	2.0992E-04	4.0000E-02	-4.9285E-01	0.0000E+00	9441	2151	
2.8857E+01	2.0000E+00	5.5605E-03	4.0230E-02	4.9228E-01	1.2118E-01	9441	2151	
2.9567E+01	2.0000E+00	7.2007E-04	3.8537E-02	-1.8319E-03	-1.6947E-01	9441	2151	
3.1021E+01	3.0000E+00	2.1206E-03	3.7298E-02	0.0000E+00	-2.6136E-01	9441	2151	
3.3403E+01	3.0000E+00	1.8527E-04	4.3736E-02	7.3123E-02	6.4594E-02	9441	2151	
3.3813E+01	3.0000E+00	3.1847E-04	4.2121E-02	0.0000E+00	1.0133E-01	9441	2151	
3.4932E+01	2.0000E+00	3.1106E-03	3.9298E-02	-1.1177E+00	3.2651E-01	9441	2151	
3.5049E+01	3.0000E+00	3.3368E-04	4.0000E-02	8.9681E-03	9.6819E-03	9441	2151	
3.6287E+01	3.0000E+00	6.1151E-05	4.0000E-02	4.7236E-03	3.1157E-02	9441	2151	
3.7637E+01	2.0000E+00	4.4292E-04	3.9666E-02	2.2375E-02	8.5867E-01	9441	2151	
3.8173E+01	3.0000E+00	3.1090E-04	3.6798E-02	-1.3385E-02	7.0306E-02	9441	2151	
3.8480E+01	3.0000E+00	3.0000E-05	4.0000E-02	0.0000E+00	1.0000E-02	9441	2151	
3.9404E+01	3.0000E+00	1.3803E-03	3.9435E-02	6.2841E-02	1.1612E-01	9441	2151	
3.9909E+01	3.0000E+00	1.4842E-03	4.7948E-02	8.9779E-02	0.0000E+00	9441	2151	
4.0807E+01	2.0000E+00	2.6427E-03	4.0752E-02	-9.9627E-01	-1.6643E-02	9441	2151	
4.2818E+01	3.0000E+00	2.3240E-04	4.0000E-02	1.8520E-01	0.0000E+00	9441	2151	
4.3478E+01	3.0000E+00	2.3072E-04	3.0000E-02	0.0000E+00	2.9321E-02	9441	2151	
4.6570E+01	3.0000E+00	1.2538E-03	3.8523E-02	0.0000E+00	-2.4613E-01	9441	2151	

Table 6. Cont'd

4.7348E+01	3.0000E+00	1.2233E-04	3.9219E-02	8.1896E-02	1.3750E-01	9441 2151
4.8103E+01	2.0000E+00	7.2587E-03	4.2366E-02	-2.7692E-01	2.0683E-01	9441 2151
5.0405E+01	3.0000E+00	5.2617E-04	4.0341E-02	1.5884E-02	3.1031E-01	9441 2151
5.2343E+01	2.0000E+00	5.3285E-05	4.0000E-02	3.2000E-02	0.0000E+00	9441 2151
5.4270E+01	3.0000E+00	3.0000E-05	4.0000E-02	-1.5000E-02	0.0000E+00	9441 2151
5.5900E+01	3.0000E+00	3.5491E-05	4.0000E-02	0.0000E+00	1.5000E-02	9441 2151
5.7230E+01	3.0000E+00	3.2000E-05	4.0000E-02	5.0000E-03	0.0000E+00	9441 2151
5.7950E+01	2.0000E+00	2.1600E-04	4.0000E-02	1.5000E-01	0.0000E+00	9441 2151
5.8137E+01	2.0000E+00	1.2388E-03	4.0000E-02	1.5410E-01	-3.5723E-01	9441 2151
5.9459E+01	2.0000E+00	2.5839E-03	4.0000E-02	-6.5939E-02	4.4740E-01	9441 2151
6.0559E+01	3.0000E+00	3.6376E-03	4.0000E-02	1.2963E-01	-5.6766E-03	9441 2151
6.0831E+01	2.0000E+00	1.3042E-03	4.0000E-02	4.1309E-03	4.5689E-01	9441 2151
6.2258E+01	2.0000E+00	7.1471E-03	4.0000E-02	-5.3532E-01	1.4106E-01	9441 2151
6.4430E+01	3.0000E+00	8.5714E-05	4.0000E-02	0.0000E+00	3.1000E-02	9441 2151
6.5729E+01	3.0000E+00	4.5506E-03	4.0000E-02	2.4073E-01	5.2475E-03	9441 2151
6.6615E+01	3.0000E+00	2.5477E-03	4.0000E-02	-3.5949E-03	-1.3361E-01	9441 2151
6.8283E+01	3.0000E+00	1.0944E-03	4.0000E-02	4.3959E-02	0.0000E+00	9441 2151
6.9249E+01	3.0000E+00	9.3420E-04	4.0000E-02	0.0000E+00	2.2164E-02	9441 2151
7.1670E+01	3.0000E+00	8.4000E-05	4.0000E-02	-4.7000E-02	0.0000E+00	9441 2151
7.2279E+01	2.0000E+00	2.0050E-03	4.0000E-02	1.1556E-01	2.7032E-01	9441 2151
7.3937E+01	3.0000E+00	4.4904E-04	4.0000E-02	1.3265E-02	0.0000E+00	9441 2151
7.5869E+01	3.0000E+00	4.0815E-03	4.0000E-02	7.9636E-02	0.0000E+00	9441 2151
7.7127E+01	3.0000E+00	3.2346E-03	4.0000E-02	0.0000E+00	-1.1319E-02	9441 2151
7.7323E+01	2.0000E+00	3.1427E-03	4.0000E-02	6.5172E-01	1.1852E+00	9441 2151
8.0205E+01	3.0000E+00	4.3212E-03	4.0000E-02	0.0000E+00	6.2625E-02	9441 2151
8.1212E+01	2.0000E+00	8.4689E-05	4.0000E-02	1.5058E+00	0.0000E+00	9441 2151
8.1564E+01	2.0000E+00	1.5229E-02	4.0000E-02	8.1160E-01	-2.3493E-01	9441 2151
8.3217E+01	2.0000E+00	5.5179E-03	4.0000E-02	-7.6190E-05	4.9530E-02	9441 2151
8.4201E+01	3.0000E+00	2.8134E-04	4.0000E-02	4.2938E-01	0.0000E+00	9441 2151
8.5401E+01	3.0000E+00	2.0586E-03	4.0000E-02	0.0000E+00	1.0335E-01	9441 2151
8.5688E+01	3.0000E+00	1.9746E-03	4.0000E-02	1.2737E-01	0.0000E+00	9441 2151
8.5867E+01	2.0000E+00	4.9733E-03	4.0000E-02	-1.0254E+00	-3.0069E-02	9441 2151
8.6975E+01	3.0000E+00	5.4234E-03	4.0000E-02	0.0000E+00	6.1435E-02	9441 2151
8.8036E+01	2.0000E+00	1.9548E-03	4.0000E-02	2.2849E-01	1.1789E-02	9441 2151
8.8854E+01	3.0000E+00	4.7336E-04	4.0000E-02	0.0000E+00	-1.5825E+00	9441 2151
8.9283E+01	2.0000E+00	3.7873E-03	4.0000E-02	2.7846E-03	1.0072E+00	9441 2151
9.0713E+01	3.0000E+00	1.4123E-03	4.0000E-02	-2.6697E-03	-2.8258E-01	9441 2151
9.1600E+01	2.0000E+00	8.0000E-05	4.0000E-02	0.0000E+00	2.5000E-02	9441 2151
9.2542E+01	2.0000E+00	2.2525E-04	4.0000E-02	2.5000E-03	0.0000E+00	9441 2151
9.3739E+01	3.0000E+00	2.8811E-04	4.0000E-02	-6.7650E-02	0.0000E+00	9441 2151
9.5470E+01	2.0000E+00	1.2900E-03	4.0000E-02	9.1173E-03	4.1516E-01	9441 2151
9.6028E+01	3.0000E+00	4.4058E-04	4.0000E-02	-1.0173E-02	1.5109E-02	9441 2151
9.6599E+01	2.0000E+00	4.7422E-04	4.0000E-02	3.3492E-01	4.5966E-03	9441 2151
9.7569E+01	3.0000E+00	5.1160E-04	4.0000E-02	1.1193E-02	-2.5946E-01	9441 2151
9.8358E+01	3.0000E+00	7.3385E-03	4.0000E-02	1.9618E-01	-7.6655E-03	9441 2151
9.9732E+01	3.0000E+00	2.3423E-03	4.0000E-02	4.2738E-01	2.0478E-02	9441 2151
1.0082E+02	2.0000E+00	1.4256E-03	4.0000E-02	5.2731E-01	2.8381E-01	9441 2151
1.0152E+02	3.0000E+00	1.1372E-03	4.0000E-02	-6.2843E-02	-3.1662E-03	9441 2151
1.0243E+02	2.0000E+00	2.8914E-03	4.0000E-02	1.2112E+00	6.0862E-03	9441 2151
1.0362E+02	3.0000E+00	1.1056E-03	4.0000E-02	2.3548E-03	3.0330E-02	9441 2151
1.0798E+02	3.0000E+00	1.2657E-03	4.0000E-02	7.5449E-02	1.0757E-02	9441 2151

Table 6. Cont'd

1.0912E+02	3.0000E+00	1.9443E-03	4.0000E-02	2.8649E-01	-1.2439E-01	9441 2151
1.0984E+02	2.0000E+00	4.4820E-04	4.0000E-02	3.5218E-01	9.0786E-02	9441 2151
1.1045E+02	3.0000E+00	3.7100E-04	4.0000E-02	5.2537E-01	1.8330E-01	9441 2151
1.1319E+02	2.0000E+00	8.7137E-04	4.0000E-02	-6.1756E-02	1.6912E-02	9441 2151
1.1494E+02	3.0000E+00	2.6339E-04	4.0000E-02	5.0000E-02	5.0000E-02	9441 2151
1.1560E+02	3.0000E+00	2.1531E-04	4.0000E-02	1.5400E-01	1.0000E-01	9441 2151
1.1722E+02	2.0000E+00	5.1637E-03	4.0000E-02	2.5929E-01	1.6009E-01	9441 2151
1.1906E+02	3.0000E+00	1.6670E-04	4.0000E-02	6.9615E-02	4.8592E-02	9441 2151
1.2025E+02	3.0000E+00	2.6024E-04	4.0000E-02	1.7975E-03	-3.7160E-01	9441 2151
1.2143E+02	2.0000E+00	6.3661E-05	4.0000E-02	8.7585E-01	1.3526E-01	9441 2151
1.2226E+02	3.0000E+00	5.2394E-03	4.0000E-02	3.7832E-01	1.7741E-01	9441 2151
1.2230E+02	2.0000E+00	1.5836E-03	4.0000E-02	1.6197E-01	1.0611E-02	9441 2151
1.2339E+02	2.0000E+00	3.9375E-03	4.0000E-02	4.7987E-02	1.8204E-02	9441 2151
1.2396E+02	2.0000E+00	1.7372E-03	4.0000E-02	4.7723E-01	8.0775E-01	9441 2151
1.2596E+02	3.0000E+00	1.8081E-04	4.0000E-02	4.9801E-01	0.0000E+00	9441 2151
1.2616E+02	3.0000E+00	2.8372E-04	4.0000E-02	2.5413E-01	5.9263E-02	9441 2151
1.2816E+02	2.0000E+00	2.2034E-03	4.0000E-02	1.1490E+00	3.7038E-04	9441 2151
1.2855E+02	2.0000E+00	6.0649E-03	4.0000E-02	2.0143E-03	4.9997E-02	9441 2151
1.3010E+02	3.0000E+00	1.6507E-03	4.0000E-02	3.0803E-01	6.5995E-03	9441 2151
1.3077E+02	2.0000E+00	1.2913E-02	4.0000E-02	7.0941E-02	-1.1799E-03	9441 2151
1.3308E+02	3.0000E+00	2.7208E-03	4.0000E-02	7.8552E-01	5.0340E-03	9441 2151
1.3370E+02	2.0000E+00	6.6441E-03	4.0000E-02	4.6927E-02	1.7265E-03	9441 2151
1.3474E+02	3.0000E+00	4.0375E-03	4.0000E-02	1.8336E+00	3.0693E-03	9441 2151
1.3664E+02	2.0000E+00	1.5053E-03	4.0000E-02	-2.3982E-02	1.0011E-03	9441 2151
1.3832E+02	3.0000E+00	3.4896E-03	4.0000E-02	3.0101E-01	8.0574E-02	9441 2151
1.4024E+02	2.0000E+00	7.6890E-03	4.0000E-02	1.0061E-01	5.6752E-03	9441 2151
1.4217E+02	2.0000E+00	1.7303E-02	4.0000E-02	1.2835E-02	1.7691E-01	9441 2151
1.4505E+02	3.0000E+00	1.4398E-03	4.0000E-02	1.7109E-01	2.8130E-01	9441 2151
1.4616E+02	2.0000E+00	8.6744E-03	4.0000E-02	5.0221E-02	1.5393E-01	9441 2151
1.4692E+02	3.0000E+00	1.6647E-03	4.0000E-02	9.8021E-01	1.1126E-02	9441 2151
1.4896E+02	2.0000E+00	2.8809E-03	4.0000E-02	7.2015E-02	4.6803E-02	9441 2151
1.5010E+02	2.0000E+00	6.8563E-03	4.0000E-02	4.2378E-01	1.2693E-01	9441 2151
1.5020E+02	3.0000E+00	7.5566E-05	4.0000E-02	5.0599E-02	9.8585E-04	9441 2151
1.5104E+02	2.0000E+00	4.5720E-03	4.0000E-02	3.0008E-01	1.7820E-01	9441 2151
1.5245E+02	3.0000E+00	1.3232E-03	4.0000E-02	5.8656E-01	2.0632E-01	9441 2151
1.5368E+02	3.0000E+00	7.4159E-03	4.0000E-02	3.8502E-03	3.5159E-01	9441 2151
1.5548E+02	2.0000E+00	2.5802E-03	4.0000E-02	1.4707E-01	1.7139E-02	9441 2151
1.5633E+02	3.0000E+00	3.5000E-04	4.0000E-02	1.0000E-01	0.0000E+00	9441 2151
1.5733E+02	2.0000E+00	4.8068E-04	4.0000E-02	4.5000E-01	0.0000E+00	9441 2151
1.5898E+02	2.0000E+00	6.2255E-03	4.0000E-02	2.1704E-01	-3.1068E-02	9441 2151
1.5952E+02	2.0000E+00	1.7138E-03	4.0000E-02	4.9276E-02	2.3035E-03	9441 2151
1.6066E+02	3.0000E+00	2.6504E-03	4.0000E-02	7.7059E-03	2.2788E-01	9441 2151
1.6168E+02	3.0000E+00	2.0000E-04	4.0000E-02	2.5000E-02	2.5000E-02	9441 2151
1.6276E+02	2.0000E+00	2.8032E-03	4.0000E-02	-4.2467E-01	8.5067E-01	9441 2151
1.6461E+02	3.0000E+00	3.1649E-03	4.0000E-02	-4.0013E-04	6.4431E-01	9441 2151
1.6558E+02	2.0000E+00	8.3658E-04	4.0000E-02	2.7757E-01	-1.5348E-01	9441 2151
1.6612E+02	3.0000E+00	2.0000E-04	4.0000E-02	5.0000E-02	5.0000E-02	9441 2151
1.6716E+02	3.0000E+00	6.7970E-04	4.0000E-02	1.5734E-02	1.6961E-02	9441 2151
1.6784E+02	2.0000E+00	4.7387E-04	4.0000E-02	5.0000E-02	5.0000E-02	9441 2151
1.6869E+02	2.0000E+00	3.8765E-03	4.0000E-02	4.3959E-03	2.1910E-01	9441 2151
1.6974E+02	3.0000E+00	1.4105E-03	4.0000E-02	3.6234E-02	4.9283E-01	9441 2151

Table 6. Cont'd

1.7136E+02	3.0000E+00	2.0000E-04	4.0000E-02	2.0000E-02	0.0000E+00	9441 2151
1.7299E+02	3.0000E+00	4.4415E-04	4.0000E-02	1.3555E-01	3.5761E-02	9441 2151
1.7422E+02	3.0000E+00	1.0856E-02	4.0000E-02	6.4361E-03	1.1686E-01	9441 2151
1.7500E+02	3.0000E+00	8.1328E-03	4.0000E-02	5.6939E-02	-5.5989E-03	9441 2151
1.7584E+02	2.0000E+00	1.7095E-02	4.0000E-02	1.3453E-01	1.8729E+00	9441 2151
1.7714E+02	3.0000E+00	1.3381E-03	4.0000E-02	2.5837E-02	-9.2249E-02	9441 2151
1.7782E+02	3.0000E+00	1.5000E-04	4.0000E-02	1.0000E-01	0.0000E+00	9441 2151
1.7884E+02	2.0000E+00	1.4265E-03	4.0000E-02	-1.7506E-01	1.9770E-01	9441 2151
1.8000E+02	2.0000E+00	1.2920E-03	4.0000E-02	1.3070E-01	3.8897E-01	9441 2151
1.8287E+02	3.0000E+00	8.2870E-03	4.0000E-02	1.1810E-01	6.5557E-03	9441 2151
1.8355E+02	2.0000E+00	3.4837E-03	4.0000E-02	2.6199E-01	1.1563E-01	9441 2151
1.8473E+02	3.0000E+00	2.0000E-04	4.0000E-02	1.0000E-01	0.0000E+00	9441 2151
1.8732E+02	2.0000E+00	9.7768E-04	4.0000E-02	-1.4690E-02	7.3512E-02	9441 2151
1.8900E+02	3.0000E+00	1.9952E-03	4.0000E-02	7.8556E-02	1.5114E-02	9441 2151
1.8971E+02	3.0000E+00	2.4772E-03	4.0000E-02	1.1120E-01	1.0164E-02	9441 2151
1.9038E+02	2.0000E+00	1.1078E-02	4.0000E-02	4.2572E-02	1.2724E+00	9441 2151
1.9278E+02	3.0000E+00	7.9878E-04	4.0000E-02	8.2345E-01	3.9803E-02	9441 2151
1.9292E+02	2.0000E+00	1.1354E-02	4.0000E-02	8.1468E-01	-1.8484E-02	9441 2151
1.9555E+02	3.0000E+00	1.8876E-04	4.0000E-02	1.3777E-01	0.0000E+00	9441 2151
1.9590E+02	3.0000E+00	1.4506E-02	4.0000E-02	1.2913E-01	-4.1114E-01	9441 2151
1.9700E+02	3.0000E+00	9.1076E-04	4.0000E-02	5.0000E-03	0.0000E+00	9441 2151
1.9746E+02	2.0000E+00	1.1808E-02	3.9434E-02	1.8511E+00	3.4505E-02	9441 2151
1.9800E+02	3.0000E+00	3.7072E-03	4.2316E-02	2.1625E-01	-1.5672E-02	9441 2151
1.9940E+02	2.0000E+00	1.9141E-02	4.0000E-02	1.6373E+00	-2.1571E-05	9441 2151
2.0078E+02	3.0000E+00	7.5900E-04	4.0000E-02	8.1824E-02	-5.4259E-03	9441 2151
2.0274E+02	2.0000E+00	3.1325E-02	4.0000E-02	-1.4006E-01	2.8345E-02	9441 2151
2.0593E+02	3.0000E+00	6.5802E-03	4.0000E-02	3.1079E-02	-1.1208E-01	9441 2151
2.0751E+02	3.0000E+00	2.7030E-03	4.0000E-02	-2.0037E-02	6.8618E-04	9441 2151
2.0945E+02	2.0000E+00	6.4392E-03	4.0000E-02	1.2927E+00	4.9384E-03	9441 2151
2.1044E+02	3.0000E+00	1.8372E-03	4.0000E-02	1.8004E-01	6.1036E-02	9441 2151
2.1194E+02	2.0000E+00	8.2147E-03	4.0000E-02	6.1583E-01	3.4417E-01	9441 2151
2.1334E+02	3.0000E+00	1.3325E-04	4.0000E-02	3.5000E-03	0.0000E+00	9441 2151
2.1459E+02	3.0000E+00	5.8856E-03	4.0000E-02	-3.0443E-01	5.8292E-04	9441 2151
2.1755E+02	2.0000E+00	2.4803E-02	4.0000E-02	2.6702E+00	-3.8419E-03	9441 2151
2.1760E+02	3.0000E+00	1.7257E-02	4.0000E-02	1.6619E+00	5.4582E-03	9441 2151
2.1914E+02	2.0000E+00	5.3684E-03	4.0000E-02	1.0209E-01	-2.1049E-01	9441 2151
2.1945E+02	2.0000E+00	6.1298E-03	4.0000E-02	9.0942E+00	1.4436E-02	9441 2151
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2.2190E+02	2.0000E+00	4.1998E-03	4.0000E-02	5.2700E-01	6.4328E-01	9441 2151
2.2455E+02	2.0000E+00	3.9955E-03	4.0000E-02	1.6487E-01	-1.4004E+00	9441 2151
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2.2807E+02	2.0000E+00	1.5925E-02	4.0000E-02	6.7704E-03	1.0237E-02	9441 2151
2.2903E+02	3.0000E+00	2.0158E-03	4.0000E-02	6.5542E-01	1.8034E-02	9441 2151
2.2987E+02	2.0000E+00	1.3577E-02	4.0000E-02	4.6828E-01	7.7497E-03	9441 2151
2.3075E+02	3.0000E+00	1.8668E-03	4.0000E-02	6.1331E-01	-1.0465E-04	9441 2151
2.3157E+02	2.0000E+00	6.7338E-03	4.0000E-02	5.9989E-01	2.2897E-01	9441 2151
2.3326E+02	3.0000E+00	3.0720E-02	4.0000E-02	1.5543E-05	1.5260E-02	9441 2151
2.3463E+02	3.0000E+00	3.1702E-03	4.0000E-02	-3.0184E-03	2.9788E-02	9441 2151
2.3599E+02	2.0000E+00	4.1112E-03	4.0000E-02	1.7782E-02	2.3740E-01	9441 2151

Table 6. Cont'd

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2.4096E+02 2.0000E+00 1.1184E-02 4.0000E-02 8.8259E-03-4.6808E-019441 2151
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3.2000E+02 3.0000E+00 1.8786E-02 4.0000E-02 2.8127E-01 3.5850E-019441 2151
4.0000E+02 2.0000E+00 4.3967E-01 4.0000E-02 6.4308E-01 5.4664E-019441 2151
0.         0.         0.         0.         0.         0.         9441 2  0
0.         0.         0.         0.         0.         0.         9441 0  0
                                                                        0 0  0
                                                                       -1 0  0
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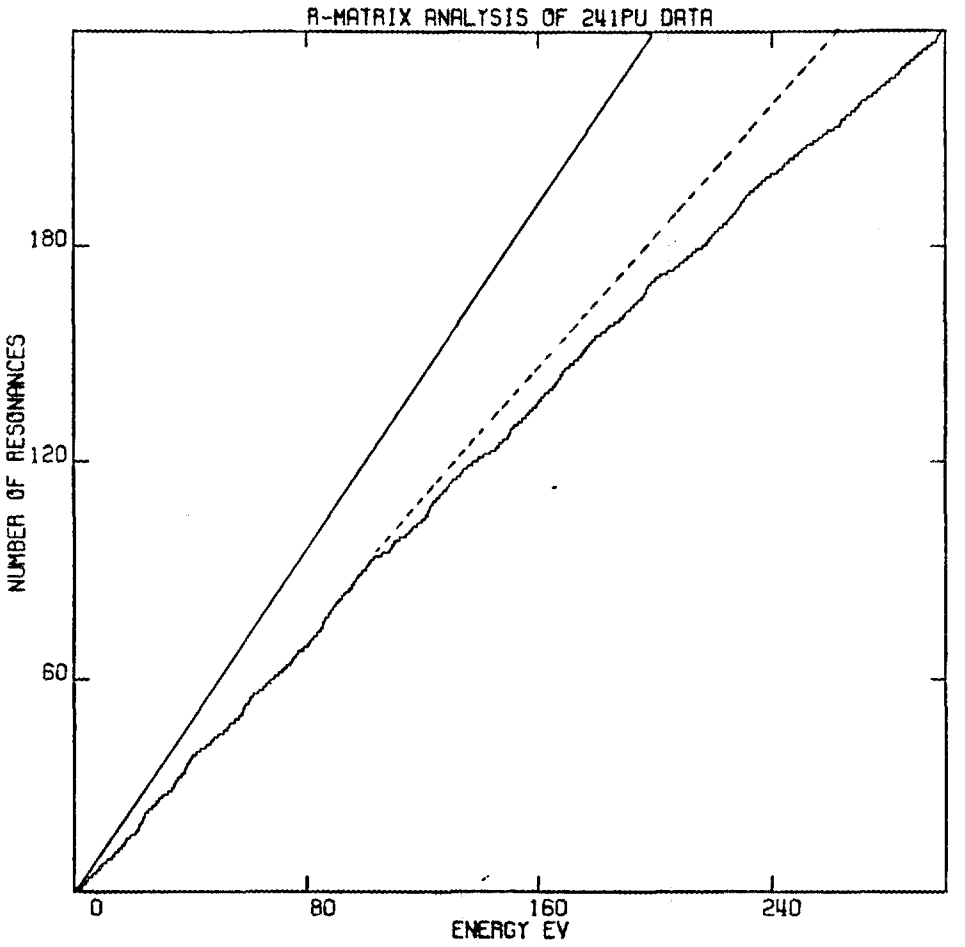

Fig. 1. Pu-241 spacing stairstep histogram. The dashed straight line corresponds to an average level spacing of 1.15 eV. The solid straight line corresponds to an average level spacing of 0.83 eV obtained in Ref. 19 by the Monte Carlo method showing that, even at 100 eV incident neutron energy, 27% of levels could be missed. At 300 eV, 34% of the levels could be missed.

neutron widths and the Porter-Thomas distribution for large values of $2g\Gamma_n^o$ is poor, suggesting that the number of unresolved multiplets could be large even in the low energy part of the cross sections, and the correct value of the average level spacing could be lower than 0.90 eV.

Figure 3 shows the cumulative stairstep histogram of the reduced neutron widths. One observes strong fluctuations in the slope of the histogram corresponding to strong fluctuations in the local values of the strength function. The strength function values calculated in six energy intervals are given in Table 7. A particularly large value is observed in the energy range 200 to 250 eV which is about twice the value observed in the energy range 100 to 150 eV. Not more than a 40% difference

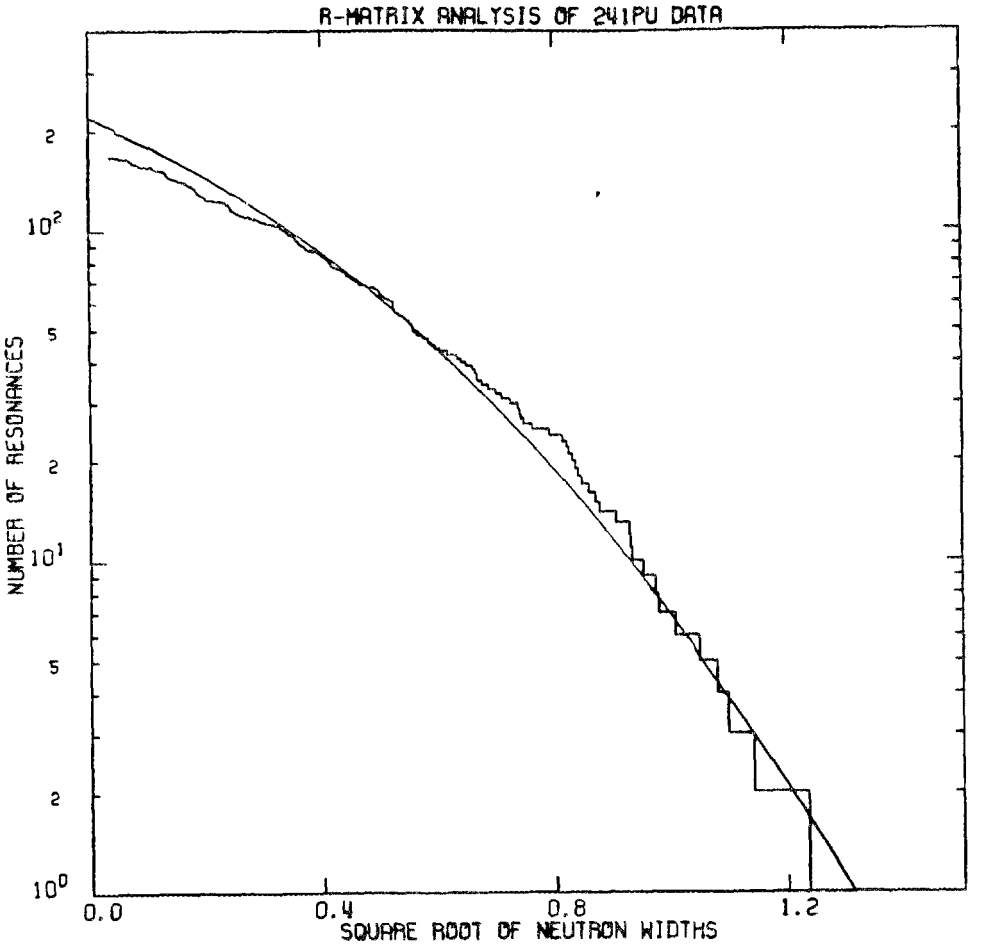

Fig. 2. Pu-241 integral distribution of the reduced neutron widths $2g\Gamma_n^o$ for the resonances identified in the energy range 0 to 200 eV. The curve is a Porter-Thomas distribution normalized to 220 resonances and to an average value of 0.216×10^{-3} $eV^{1/2}$.

could be expected from the usual Porter-Thomas fluctuations of the neutron widths. Comparisons with other results[2,3,22] obtained from the analysis of the Kolar and Carraro[3] total cross sections are also shown in Table 7; the strength function obtained by Blons *et al.*[22] from a single level analysis in the energy range thermal to 150 eV is 5% smaller than the value obtained in the present work, while the value obtained by Kolar and Carraro[3] is 7% larger in the energy range 10 to 50 eV.

The s-wave strength function calculated from the neutron widths of the 236 resonances identified in the energy range 0 to 300 eV is $(1.23 \pm 0.11) \times 10^{-4}$. The error indicated here is the sampling error. This value should not be affected by the existence of a large number of unresolved multiplets, since the parameters obtained by the SAMMY shape analysis are representative of the total area of the multiplets.

Table 7. The s-wave strength function in several energy ranges[a]

Energy range (eV)	Present work	Previous ORNL[2]	Blons *et al.*[22]	Kolar and Carrro[3]
0 – 50	1.312	1.354	1.282	
50 – 100	1.117	1.043	1.059	
100 – 150	0.913		0.850	
150 – 200	1.296			
200 – 250	1.775			
250 – 300	1.054			
12.8 – 50.4	1.334	1.339	1.304	1.441
0 – 300	1.232			

[a]The values are multiplied by 10^4.

4.3 THE FISSION WIDTHS

The integral distribution of the total fission widths of the 236 resonances identified in the energy range 0 to 300 eV is given in Fig. 4. The theoretical distribution drawn on the figure is a χ^2 distribution, $P(\nu, x)$, with $\nu = 1$ and normalized to 270 values. There is no evidence, from the shape of the distribution, of two families of resonances with very different average fission widths. The average total fission width of the 236 resonances is 460.4 meV. The spin 2^+ was assigned to 129 resonances and the spin 3^+ to 107 resonances with average fission widths of 690 and 270 meV, respectively. The corresponding effective number of fission channels is 2.0 for the 2^+ states and 1.2 for the 3^+ states, in agreement with the assumption made above on the number of open or partially open fission channels. But, at least above 100 eV incident neutron energy, these results could not be taken too seriously, since there is very little chance that the spin assignments could be correct.

In the 0 to 100 eV energy range the results obtained by the Reich-Moore analysis of Blons and Derrien[19] of the total cross section of Kolar and Carraro and Blons fission cross sections were used as input in the present SAMMY analysis. Only few modifications were made and the average fission widths are the same as those obtained by Blons and Derrien. An attempt was made by Blons and Derrien to obtain the parameters of the 2^+ and 3^+ fission channels. Their results should be used for the evaluation of the statistical properties of the fission channels (see Ref. 19).

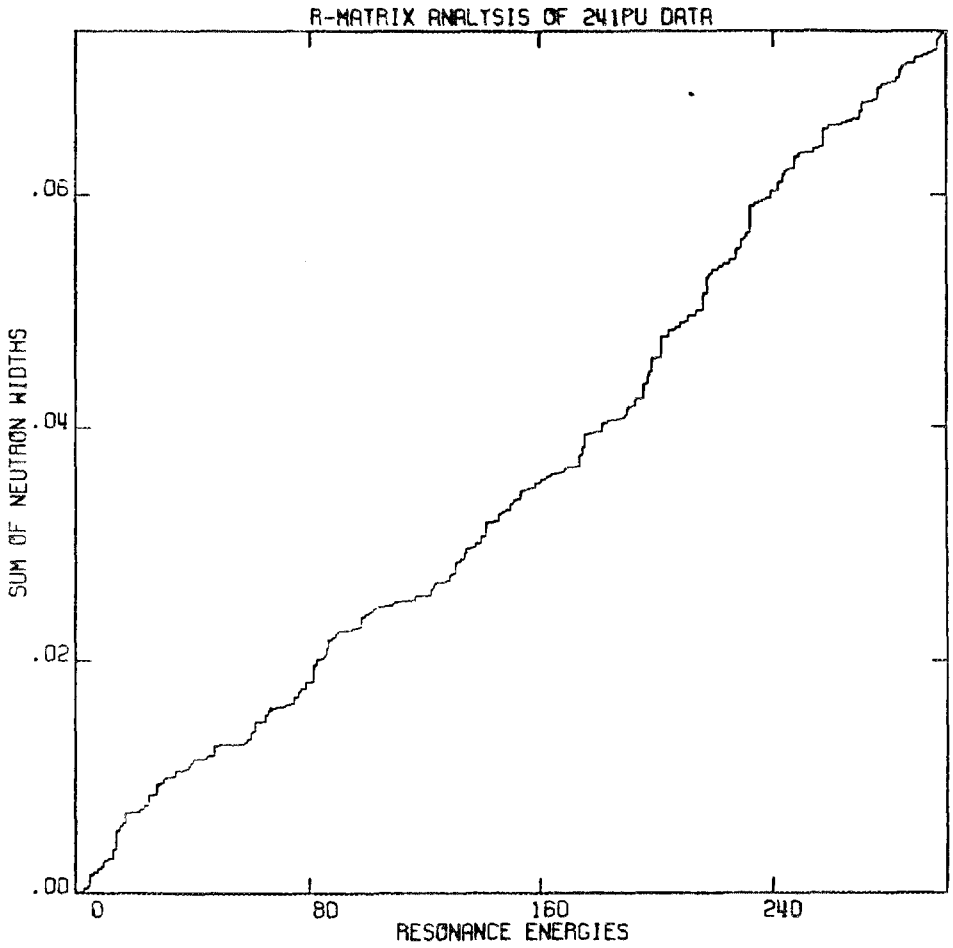

Fig. 3. Pu-241 cumulative stairstep histogram of the reduced neutron widths $2g\Gamma_n^o$.

4.4 THE CAPTURE WIDTHS

The capture widths have been obtained for 33 resonances in the energy range 0 to 50 eV. The average value, evaluated from the isolated narrow resonances, is 34.90 meV, in agreement with the value of 36 ± 1 meV calculated by M. S. Moore.[23] One should note that the capture widths obtained in the energy range 0 to 20 eV (30.08 meV on average) are significantly smaller than those obtained in the energy range 20 to 50 eV (40.1 meV on average). This could be due to an experimental effect related to the sample temperature in the low-energy and/or the high-energy transmission runs; the difficulties for the evaluation of an accurate Doppler width could be the origin of large errors in the determination of the total width of the resonances.

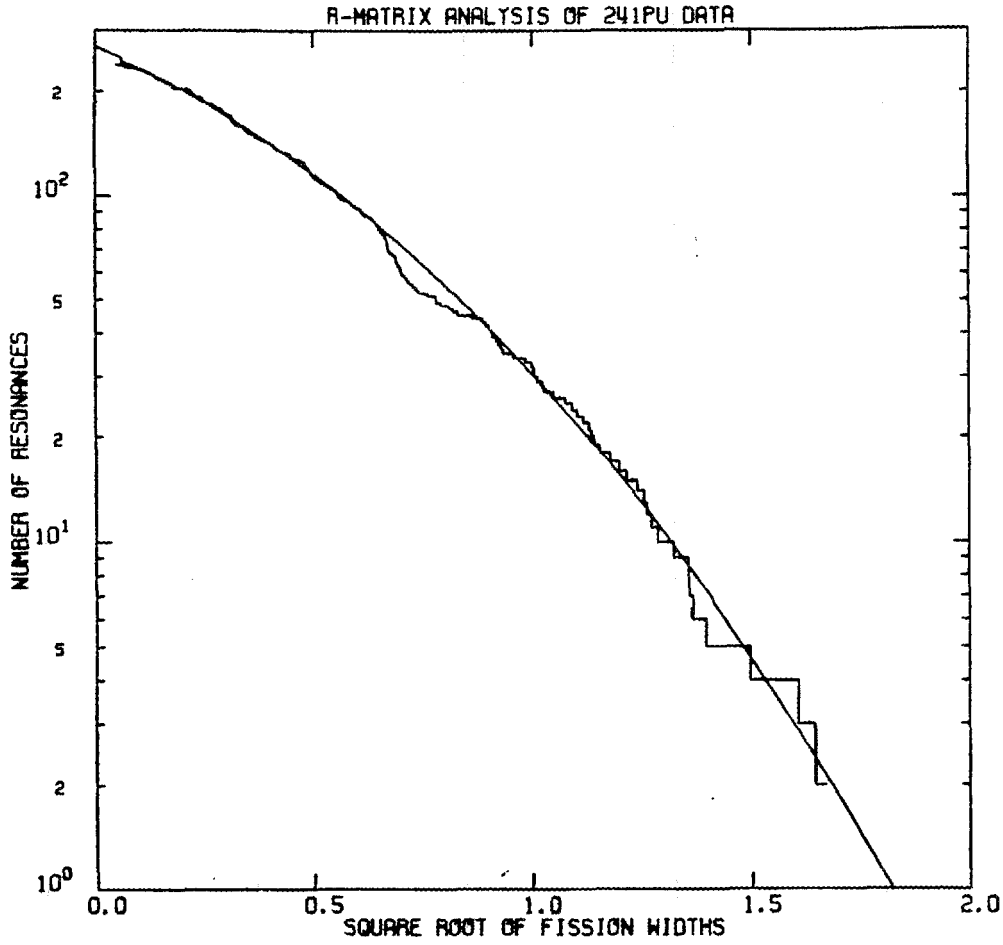

Fig. 4. Pu-241 integral distribution of the total fission widths for the resonances identified in the energy range 0 to 300 eV. The theoretical curve corresponds to a χ^2 distribution, $P(\nu, x)$, with $\nu = 1$ and normalized to 270 resonances and to an average fission width of 400 meV. The good agreement between the experimental distribution and the theoretical one is spurious, since the experimental distribution could be strongly distorted by the important number of missed levels and unresolved multiplets.

A comparison between the capture widths obtained in this work and those given by Blons and Derrien[22] in the energy range 17 to 34 eV is shown in Table 8. The Blons and Derrien values were obtained from a multilevel Breit-Wigner analysis of the total cross sections of Kolar and Carraro and the fission cross section of Blons. The capture widths were also obtained by Kolar and Carraro from a Breit-Wigner analysis of Geel transmission and fission data.[3] Some of the values are shown in Table 8. They are much larger than those obtained in the present work and in Blons' analysis.

Table 8. Capture widths (meV) for some well isolated resonances

Resonance energy (eV)	Present work	Blons	Kolar and Carraro
0.26	32.6		
4.28	30.7		
4.58	31.3		
6.93	30.2		
8.61	29.3		
12.79	30.6		
13.63	33.8		
14.75	29.0		
16.67	24.6		
17.85	36.0	45	43
20.72	38.1	33	46
22.99	44.5	46	66
24.10	42.4	41	51
26.43	34.5	38	50
31.02	37.3	54	54
38.17	36.7		
39.40	39.4		
39.90	47.9		

A constant value of 40 meV was used for all the resonances in the energy range above 50 eV.

4.5 THE COVARIANCE MATRICES

Partial correlation matrices were obtained for the six energy ranges analyzed. Tables 9 and 10 show parts of the covariance matrices obtained in the energy range 0.4 to 20 eV and 200 to 300 eV. From these examples one sees that only the short range correlations from resonance to resonance are important. Consequently a reasonably accurate full correlation matrix could be obtained by assembling the six partial matrices. If the resonances are sorted by increasing energy, only the elements near the diagonal should be kept.

4.6 CONCLUSIONS ON THE AVERAGE RESONANCE PARAMETERS

The important number of missed levels renders difficult the determination of accurate values of the average resonance parameters. However, the following values could be used as starting values for statistical model calculations in the unresolved region:

Table 9a. Partial correlation matrix of ^{241}Pu resonance parameters[a]

			26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
27	3.0857E-04	.000	-3	100																							
28	0.3749	.017	-5	2	100																						
29	2.5752E-02	.007	-6	-5	-38	100																					
30	7.3692E-05	.200	0	1	0	0	100																				
31	0.4956	.022	9	-6	-29	-34	0	100																			
32	1.0450E-03	.000	2	-1	1	1	0	1	100																		
33	1.635	.066	-4	1	3	3	0	-5	0	100																	
34	8.5012E-03	.008	-2	3	-2	0	0	-4	-37	5	100																
35	3.284	.016	1	1	-4	-3	0	0	-27	-29	31	100															
36	0.2684	.174	0	6	1	1	0	0	4	2	5	-1	100														
37	3.6774E-04	.000	-3	0	3	1	0	-4	1	1	-4	-4	-10	100													
38	0.6071	.017	-3	1	3	1	0	-3	2	-1	2	0	7	8	100												
39	1.9951E-02	.007	-8	1	5	8	0	-9	3	4	4	-1	-1	1	-38	100											
40	9.2857E-02	.156	0	-1	0	-1	0	-2	19	3	6	8	-7	-17	9	-3	100										
41	0.4442	.024	10	1	-7	-7	0	13	1	-5	1	1	5	2	-4	-38	-16	100									
42	1.8378E-03	.000	0	0	0	0	0	0	0	-2	7	9	1	3	11	2	20	3	100								
43	2.6385E-03	.020	0	-1	1	0	0	0	-18	-2	-1	-1	-11	-14	-18	-8	-7	-20	-9	100							
44	3.256	.100	1	-1	0	-1	0	3	-26	-3	-3	-2	-5	-13	-9	-8	0	-16	8	54	100						
45	3.1558E-02	.203	0	1	0	0	0	0	0	0	1	1	1	5	0	1	2	0	-12	2	0	100					
46	1.0838E-02	.006	2	0	0	0	0	1	-1	0	2	1	0	0	0	0	0	0	0	-1	-1	0	100				
47	1.3868E-04	.067	0	1	-1	-1	0	-1	1	0	-4	-2	0	0	-1	-1	-1	0	0	0	1	0	-57	100			
48	7.311	.107	0	1	0	1	0	1	-4	0	8	6	0	-1	1	0	-2	2	1	3	3	0	-49	33	100		
49	13.52	.049	3	-1	-1	-2	0	0	4	-1	-11	-7	1	0	-3	-2	0	-1	-2	-2	0	0	-1	44	52	100	
50	6.3684E-04	.000	3	0	1	1	0	3	-4	0	5	4	0	-1	0	-1	-1	2	1	1	1	0	21	-12	4	8	100
51	0.8496	.027	-9	2	7	6	0	-11	0	6	1	-3	0	3	5	8	0	-11	0	-1	-3	0	0	1	-1	1	-15
52	3.3925E-03	.007	-5	0	0	1	0	-4	5	1	-7	-7	0	1	0	3	0	-3	-1	0	0	0	-22	22	2	9	-69
53	1.542	.078	-2	-1	-1	-2	0	-5	14	-1	-26	-20	1	2	-3	0	1	-5	-4	-4	-3	-1	-25	24	-9	18	-36
54	1.446	.012	5	0	-4	-4	0	9	-9	-3	16	14	-1	-3	0	-6	-2	11	2	5	5	1	2	0	14	-3	-17
55	3.1318E-03	.001	5	1	2	3	0	0	-6	1	10	7	0	0	2	3	-1	-1	2	2	2	0	22	-18	8	-2	44
56	8.7552E-03	.003	-1	1	2	6	0	-2	1	1	-2	-4	-2	1	1	5	-2	-2	1	5	4	0	3	1	4	7	23
57	11.10	.010	-2	-2	-2	-4	0	-2	16	-2	-31	-22	0	1	-4	-3	2	-2	-4	-3	-2	-1	-19	17	-20	10	-36
58	8.626	.041	1	3	2	3	0	2	-16	2	32	22	-1	-1	5	2	-3	4	4	6	4	1	23	-16	18	-6	46
59	1.8023E-03	.000	-1	-1	0	-1	0	0	1	0	-2	-1	0	0	0	-1	0	0	0	0	0	0	-4	3	1	2	-5
60	1.4766E-02	.025	-10	1	1	3	0	3	-1	0	2	1	1	0	1	1	-2	1	1	2	2	0	11	-11	3	-9	16
61	7.988	.040	-10	0	1	2	0	3	-1	0	2	1	0	0	0	0	-1	2	1	2	2	0	9	-9	4	-8	14
62	0.3535	.206	0	0	0	0	0	0	1	0	-1	-1	0	0	0	0	0	0	0	0	0	0	1	-2	-2	2	2
63	2.6739E-03	.000	7	0	-2	-3	0	-4	2	0	-4	-2	0	0	-1	-1	2	-2	-1	-4	-3	0	-13	13	-5	12	-18
64	1.3958E-02	.007	0	-1	1	2	0	1	-4	1	8	3	-1	0	2	2	-2	2	1	4	3	0	-8	5	3	-3	-9
65	9.122	.010	0	0	1	1	0	1	-6	1	11	7	-1	-1	2	0	-2	2	1	3	2	0	-5	2	4	-4	-5
66	6.0753E-02	.208	-1	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	1	-2	-1	1	2
67	1.0592E-03	.000	-3	1	-1	4	0	1	9	0	-18	-13	0	1	-1	1	-1	-2	-1	2	2	0	-1	-1	2	1	2
68	2.502	.082	-4	2	-6	2	0	0	0	2	0	-1	0	1	2	3	0	-4	0	0	-1	0	1	-2	0	-1	1
69	5.0052E-03	.006	3	10	-13	3	-1	-17	-5	1	10	3	-5	1	2	3	-2	-2	1	5	4	0	-3	2	4	-4	0
70	3.399	.015	6	7	-6	-4	0	-13	-4	-1	6	4	-3	0	-1	-2	-1	2	1	3	3	0	-4	4	1	-1	-2
71	8.5524E-02	.191	0	0	2	1	0	2	-1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	-1	-1	1	-1
72	5.4468E-04	.000	-2	-2	0	1	0	-5	1	1	-4	-2	1	1	1	2	0	-3	0	0	0	0	-3	2	0	7	-4
73	0.4532	.016	-12	1	6	8	0	-12	2	5	-1	-6	1	4	6	12	-1	-15	0	0	-3	0	0	-1	0	-1	0
74	3.5271E-02	.005	-6	0	3	7	0	-7	-1	3	1	-3	1	2	1	8	-1	-7	0	1	0	0	0	-1	0	-2	0
75	1.929	.026	1	6	-7	-6	0	-6	-17	0	35	25	-2	-2	2	-3	-1	7	3	1	1	0	2	-1	9	-9	3
76	2.069	.073	4	-7	3	2	0	11	16	-2	-34	-23	3	1	-4	-1	0	0	-3	0	1	0	-1	0	-3	7	0

[a]Part of the correlation matrix obtained in the energy range 0.3 to 20 eV SAMMY fit. The standard deviations on parameters are also given in column 2 and 3 of the Table (absolute and relative values). The parameter numbers are given in line 1 and column 1 (see Table 9b).

Table 9b. Partial list of ^{241}Pu input resonance parameters[a]

SPIN GROUP NUMBER 1 WITH SPIN= 3.0, ABUNDANCE= 1.0000, AND G-FACTOR=0.5833

ENERGY (EV)	GAMMA-GAMMA (MILLI-EV)	GAMMA-CHANNEL 1 L=0 SPIN=3.0 (MILLI-EV)	GAMMA-CHANNEL 2 L=0 SPIN=0.0 (MILLI-EV)	GAMMA-CHANNEL 3 L=0 SPIN=0.0 (MILLI-EV)
5.74390E-01(1)	4.7200E+01	7.7498E-04(2)	0.0000E+00	0.0000E+00
1.05650E+00(3)	3.3716E+01(4)	1.4668E-01(5)	0.0000E+00	0.0000E+00
1.26967E+00(6)	4.8900E+01	2.7352E-03(7)	0.0000E+00	0.0000E+00
1.92029E+00(8)	4.4600E+01	1.0824E-03(9)	0.0000E+00	0.0000E+00
2.67680E+00(10)	2.7324E+01(11)	8.6554E-02(12)	0.0000E+00	0.0000E+00
4.28194E+00(13)	3.0731E+01(14)	5.7561E-01(15)	2.6803E+01(16)	0.0000E+00
6.93218E+00(17)	3.0250E+01(18)	6.1947E-01(19)	-1.0442E+02(20)	4.5173E-01(21)
8.61452E+00(22)	2.9325E+01(23)	7.7938E-01(24)	8.1770E-01(25)	6.0040E+01(26)
1.34305E+01(27)	3.3765E+01(28)	2.3820E+00(29)	3.6897E-04(30)	2.2959E+01(31)
1.66739E+01(32)	2.4641E+01(33)	1.0735E+00(34)	2.0644E+02(35)	1.5440E+00(36)
1.78530E+01(37)	3.6041E+01(38)	2.5250E+00(39)	5.9507E-01(40)	1.8731E+01(41)
1.82689E+01(42)	4.0000E+01	1.3010E-01(43)	-3.2455E+01(44)	1.5573E-01(45)

SPIN GROUP NUMBER 2 WITH SPIN= 2.0, ABUNDANCE= 1.0000, AND G-FACTOR=0.4167

ENERGY (EV)	GAMMA-GAMMA (MILLI-EV)	GAMMA-CHANNEL 1 L=0 SPIN=2.0 (MILLI-EV)	GAMMA-CHANNEL 2 L=0 SPIN=0.0 (MILLI-EV)	GAMMA-CHANNEL 3 L=0 SPIN=0.0 (MILLI-EV)
1.73500E+00(46)	4.0000E+01	2.0798E-03(47)	6.8219E+01(48)	2.7418E+02(49)
4.58233E+00(50)	3.1280E+01(51)	4.7835E-01(52)	-1.9686E+01(53)	1.2489E+02(54)
5.81069E+00(55)	6.3570E+01	2.7728E+00(56)	-1.1390E+03(57)	2.1007E+02(58)
9.62075E+00(59)	3.9289E+01	5.9155E-01(60)	2.0009E+02(61)	1.7131E+00(62)
9.92260E+00(63)	8.8500E+01	1.8935E+00(64)	8.6900E+02(65)	2.9278E-01(66)
1.27925E+01(67)	3.0553E+01(68)	8.7576E-01(69)	-2.3286E+02(70)	4.4892E-01(71)
1.47537E+01(72)	2.8977E+01(73)	7.6085E+00(74)	7.3749E+01(75)	2.8291E+01(76)
1.59871E+01(77)	4.0000E+01	1.7456E+00(78)	-4.3441E+02(79)	8.3513E+00(80)

[a]Identification of the variable parameters in the energy range 0.3 to 20 eV SAMMY fit; to be used for the interpretation of Table 9.

Table 10a. Partial correlation matrix of ^{241}Pu resonance parameters[a]

			76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
77	3.846	.172	-12	100																							
78	1.7478E-02	.000	-6	11	100																						
79	7.0853E-02	.039	16	12	24	100																					
80	2.760	.221	-2	3	20	10	100																				
81	26.48	.137	13	2	-49	15	0	100																			
82	9.9348E-03	.000	12	-10	-22	-6	-5	20	100																		
83	0.3962	.030	-2	4	-11	-28	0	-15	12	100																	
84	33.65	.187	-9	10	22	6	-8	6	-23	22	100																
85	46.47	.077	5	-6	-29	-29	6	-14	23	59	-58	100															
86	2.2961E-02	.000	7	-5	-3	6	0	5	4	-25	-11	-11	100														
87	9.5795E-02	.057	0	1	-6	-13	-2	-2	21	20	-1	9	-8	100													
88	28.46	.200	-1	2	0	-4	-1	0	6	6	-6	8	-29	30	100												
89	25.77	.195	-1	-1	-5	-9	0	0	-6	-1	4	-6	8	29	-12	100											
90	6.4414E-02	.087	2	2	-3	-5	0	-3	21	17	-9	17	0	33	-3	13	100										
91	6.8569E-02	.000	1	-3	-2	1	0	6	-7	-15	0	-12	0	-20	-6	-8	-21	100									
92	0.3651	.111	2	-1	-4	-2	0	-1	14	-8	-4	1	25	19	4	6	18	9	100								
93	10.58	.211	-1	1	1	-1	-1	2	-5	-4	-2	-2	8	0	1	-2	10	-18	1	100							
94	129.0	.088	2	0	-10	-18	0	-5	-9	9	-10	12	6	6	-4	10	-24	43	6	3	100						
95	1.4638E-02	.000	-1	1	3	2	1	2	-8	5	9	-5	-14	-4	1	-2	-6	-4	-27	13	8	100					
96	0.1679	.036	5	-2	-2	6	1	3	2	-7	-4	-3	-1	-7	-5	-1	-5	-28	-47	-13	-28	-18	100				
97	17.47	.220	1	-1	0	2	1	-1	-3	3	2	2	-6	2	1	3	-1	-25	-8	-2	-3	55	12	100			
98	33.08	.138	2	-1	1	4	0	2	4	-5	2	-6	-2	-5	-1	-4	-2	-17	-42	-2	-37	-34	79	-17	100		
99	4.3224E-02	.178	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	-4	-1	1	4	1	0	1	100	
100	4.0681E-02	.000	1	-1	0	3	0	2	3	-5	-2	-2	0	-5	-2	-2	-2	-3	-4	-2	-6	5	2	8	-2	-2	100
101	0.1251	.111	1	-1	-2	1	0	1	1	-5	-2	0	10	1	1	1	2	4	13	1	5	-4	7	0	5	9	-24
102	35.55	.178	0	0	0	0	-1	1	0	-3	-3	0	3	-2	-1	-1	0	1	1	-2	0	-2	7	3	2	1	-32
103	31.53	.186	0	-1	-2	-2	0	0	-2	-2	-1	0	2	-1	-1	0	-2	2	1	0	-3	1	3	1	3	1	-18
104	3.1115E-02	.000	-1	1	0	-3	0	-2	-5	7	5	2	-2	5	4	3	1	1	7	6	10	-4	-8	-8	-3	1	-20
105	9.3639E-02	.043	0	-1	0	4	1	1	-5	0	-1	1	-1	0	-1	0	2	-6	4	-2	-1	0	0	2	0	2	-19
106	44.31	.149	0	-1	0	2	1	0	-4	1	3	-1	-2	1	1	1	0	-1	2	1	-1	3	-2	-2	1	1	-23
107	25.86	.189	0	0	1	0	0	0	-6	1	0	1	-1	0	0	0	2	-6	1	-1	3	-4	-5	1	-3	0	-11
108	1.8151E-02	.000	0	-1	1	2	0	1	-6	1	2	-1	-3	0	1	0	1	-4	-1	1	1	2	-4	0	-2	0	-17
109	7.9328E-02	.025	0	-1	-2	1	0	1	3	-2	-3	1	4	-1	-1	0	-1	3	2	-1	-1	0	6	3	2	1	10
110	10.62	.182	0	0	0	1	0	1	-1	-2	-2	0	0	-1	-1	-1	0	-1	-1	-1	0	0	2	2	0	0	1
111	23.67	.141	1	-1	-2	0	0	1	-1	-2	-1	-1	1	-2	-1	0	-2	1	-2	0	-4	3	3	2	2	0	1
112	1.2634E-02	.000	-2	1	0	-3	0	-1	-2	4	3	1	-1	2	2	2	0	1	4	4	5	-3	-4	-3	-3	0	-3
113	0.5617	.043	-1	0	0	1	0	0	-1	1	0	0	-2	-1	0	-1	0	-2	0	0	-3	0	0	1	-1	0	0
114	19.35	.120	0	-1	-1	2	1	0	-1	0	4	-3	-2	0	1	0	-1	1	-1	2	-4	5	1	-1	2	0	-6
115	15.98	.166	1	0	1	2	0	1	-4	-1	-3	1	-1	-1	-1	-1	2	-7	-1	-2	3	-3	-3	3	-4	0	-5
116	3.4725E-02	.000	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
117	0.4965	.042	-1	1	0	0	0	-1	-1	3	0	1	0	-2	0	0	-2	2	2	1	0	-1	2	0	0	0	1
118	103.6	.056	-1	0	0	0	0	0	-1	1	1	0	0	-2	0	0	-2	2	1	1	-1	-1	1	0	0	0	1
119	6.308	.233	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
120	1.5919E-02	.000	1	-1	0	1	0	1	1	-2	0	-1	1	2	1	0	2	-2	1	0	0	0	0	1	0	1	0
121	0.4001	.018	0	0	-1	0	0	-1	0	3	0	1	1	1	0	0	1	0	4	0	0	-2	3	0	0	0	1

[a]Part of the correlation matrix obtained in the energy range 200 to 300 eV SAMMY fit. The standard deviations on parameters are also given in column 2 and 3 of the table (absolute and relative values). The parameter numbers are given in column 1 and line 1 (see Table 10b.)

Table 10b. Partial list of ^{241}Pu input resonance parameters[a]

SPIN GROUP NUMBER 1 WITH SPIN= 3.0, ABUNDANCE= 1.0000, AND G-FACTOR=0.5833

ENERGY (EV)	GAMMA-GAMMA (MILLI-EV)	GAMMA-CHANNEL 1 L=0 SPIN=3.0 (MILLI-EV)	GAMMA-CHANNEL 2 L=0 SPIN=0.0 (MILLI-EV)	GAMMA-CHANNEL 3 L=0 SPIN=0.0 (MILLI-EV)
1.95868E+02(1)	4.1434E+01	1.3834E+01(2)	9.7972E+01(3)	-4.5750E+02(4)
1.97975E+02(5)	4.2316E+01	3.8421E+00(6)	1.6848E+02(7)	-3.9370E+01(8)
2.00765E+02(9)	4.0000E+01	6.9065E-01(10)	1.7436E+02(11)	-6.6644E+00(12)
2.05900E+02(13)	4.0000E+01	6.7763E+00(14)	3.4575E+01(15)	-1.5822E+02(16)
2.07498E+02(17)	4.0000E+01	2.8334E+00(18)	-2.5375E+01(19)	7.1649E-01(20)
2.10450E+02(21)	4.0000E+01	1.6518E+00(22)	1.7031E+02(23)	7.8267E+01(24)
2.14551E+02(25)	4.0000E+01	5.9128E+00(26)	-3.2334E+02(27)	6.4688E-01(28)
2.17556E+02(29)	4.0000E+01	1.9290E+01(30)	1.6075E+03(31)	5.2714E+01(32)
2.25877E+02(33)	4.0000E+01	4.3323E+00(34)	2.5464E+02(35)	-2.1297E+02(36)
2.33263E+02(37)	4.0000E+01	2.9326E+01(38)	3.9610E-02(39)	1.6721E+01(40)
2.34624E+02(41)	4.0000E+01	3.2999E+00(42)	-2.2628E+00(43)	3.4707E+01(44)
2.43353E+02(45)	4.0000E+01	1.0184E+01(46)	7.9892E+02(47)	9.4993E+02(48)
2.44919E+02(49)	4.0000E+01	4.7201E+00(50)	2.2056E+01(51)	-3.0528E+02(52)
2.48568E+02(53)	4.0000E+01	1.3815E+01(54)	2.8302E+00(55)	5.2321E+01(56)
2.55183E+02(57)	4.0000E+01	4.4782E+00(58)	3.3964E+01(59)	4.4677E+02(60)
2.53347E+02(61)	4.0000E+01	2.0676E+01(62)	-7.7728E+00(63)	1.4605E+02(64)
2.63764E+02(65)	4.0000E+01	1.8396E+00(66)	5.5364E+01(67)	5.8831E+02(68)
2.66467E+02(69)	4.0000E+01	2.2345E+00(70)	-3.0270E+01(71)	1.3389E+02(72)
2.69480E+02	4.0000E+01	3.9266E-01(73)	5.0000E+00	0.0000E+00
2.71590E+02(74)	4.0000E+01	1.0096E+01(75)	-3.5366E+02(76)	-2.2421E+01(77)
2.74073E+02(78)	4.0000E+01	1.8288E+00(79)	1.2464E+01(80)	1.9347E+02(81)
2.77040E+02(82)	4.0000E+01	1.3141E+01(83)	1.7962E+02(84)	-5.9995E+02(85)
2.80033E+02(86)	4.0000E+01	1.6759E+00(87)	1.4235E+02(88)	-1.3201E+02(89)
2.81500E+02	4.0000E+01	7.4008E-01(90)	1.5898E+02	1.4970E+02
2.83676E+02(91)	4.0000E+01	3.4756E+00(92)	5.0048E+01(93)	-1.4606E+03(94)
2.85543E+02(95)	4.0000E+01	4.6969E+00(96)	-7.9397E+01(97)	-2.3900E+02(98)
2.88400E+02	4.0000E+01	2.4324E-01(99)	1.2687E+00	-1.0028E+01
2.90994E+02(100)	4.0000E+01	1.1254E+00(101)	1.9940E+02(102)	-1.6916E+02(103)
2.93425E+02(104)	4.0000E+01	2.1867E+00(105)	-2.9736E+02(106)	1.3714E+02(107)
2.94347E+02(108)	4.0000E+01	3.1242E+00(109)	5.8327E+01(110)	-1.6747E+02(111)
2.97499E+02(112)	4.0000E+01	1.2996E+01(113)	-1.6237E+02(114)	9.6391E+01(115)

SPIN GROUP NUMBER 2 WITH SPIN= 2.0, ABUNDANCE= 1.0000, AND G-FACTOR=0.4167

ENERGY (EV)	GAMMA-GAMMA (MILLI-EV)	GAMMA-CHANNEL 1 L=0 SPIN=2.0 (MILLI-EV)	GAMMA-CHANNEL 2 L=0 SPIN=0.0 (MILLI-EV)	GAMMA-CHANNEL 3 L=0 SPIN=0.0 (MILLI-EV)
1.97444E+02(116)	3.9434E+01	1.1965E+01(117)	1.8420E+03(118)	2.7066E+01(119)
1.99447E+02(120)	4.0000E+01	2.2235E+01(121)	1.9328E+03(122)	-2.2174E-02(123)
2.02693E+02(124)	4.0000E+01	3.0163E+01(125)	-3.8215E+01(126)	1.2616E+02(127)
2.09255E+02(128)	4.0000E+01	6.6600E+00(129)	9.9392E+02(130)	2.8513E+02(131)
2.11846E+02(132)	4.0000E+01	7.6726E+00(133)	5.6918E+02(134)	3.0969E+02(135)
2.17633E+02(136)	4.0000E+01	1.9471E+01(137)	2.0413E+03(138)	-2.6501E+00(139)
2.19134E+02(140)	4.0000E+01	4.8904E+00(141)	1.0198E+02(142)	-1.4795E+02(143)
2.19084E+02(144)	4.0000E+01	4.9410E+00(145)	8.3706E+03(146)	1.2975E+01(147)
2.27836E+02(148)	4.0000E+01	2.0246E-01(149)	-1.9260E+02(150)	1.5062E+02(151)
2.28072E+02(152)	4.0000E+01	1.5072E+01(153)	6.4959E+00(154)	8.3970E+00(155)
2.29875E+02(156)	4.0000E+01	1.3146E+01(157)	4.5675E+02(158)	7.8766E+00(159)
2.31581E+02(160)	4.0000E+01	6.0006E+00(161)	4.3882E+02(162)	2.2855E+02(163)
2.35989E+02(164)	4.0000E+01	4.4297E+00(165)	1.6972E+01(166)	3.0616E+02(167)
2.38345E+02(168)	4.0000E+01	3.6882E+00(169)	2.5900E+01(170)	2.2391E+02(171)
2.40956E+02(172)	4.0000E+01	1.1023E+01(173)	1.4720E+01(174)	-4.5513E+02(175)
2.43834E+02(176)	4.0000E+01	1.3018E+01(177)	3.6419E+01(178)	1.6449E+02(179)
2.46793E+02(180)	4.0000E+01	2.2568E+00(181)	1.4354E+02(182)	3.2459E+01(183)
2.49587E+02(184)	4.0000E+01	5.4929E+00(185)	4.5941E+00(186)	1.2773E+01(187)
2.56605E+02(188)	4.0000E+01	2.6523E+00(189)	3.6226E+02(190)	-9.3726E+01(191)
2.59510E+02(192)	4.0000E+01	6.3320E+00(193)	6.4678E+01(194)	-3.1398E+02(195)
2.63550E+02	4.0000E+01	7.9111E-01(196)	-2.5962E+03	1.5229E+02
2.64192E+02(197)	4.0000E+01	3.3510E-01(198)	8.0643E+01(199)	-2.8026E+02(200)
2.68054E+02(201)	4.0000E+01	1.5433E+00(202)	1.8045E+02(203)	7.8908E+02(204)
2.69869E+02(205)	4.0000E+01	1.5176E+01(206)	-3.1063E+01(207)	-2.3241E+03(208)
2.75676E+02(209)	4.0000E+01	3.7926E+00(210)	-4.6169E+01(211)	3.2498E+02(212)
2.78410E+02(213)	4.0000E+01	6.5256E+00(214)	1.0763E+03(215)	1.1265E+02(216)
2.84311E+02(217)	4.0000E+01	1.5763E+01(218)	-5.0679E+02(219)	3.6650E+01(220)
2.87133E+02(221)	4.0000E+01	5.2175E+00(222)	2.0943E+01(223)	8.2074E+01(224)
2.90280E+02(225)	4.0000E+01	1.0029E+01(226)	-7.9894E+02(227)	6.6676E+02(228)
2.96544E+02(229)	4.0000E+01	3.3461E+00(230)	-3.4589E+01(231)	2.3555E+01(232)
2.97835E+02(233)	4.0000E+01	4.7692E+00(234)	3.3008E+01(235)	-1.1971E+02(236)

[a]Identification of the variable parameters in the energy range 200 to 300 eV SAMMY fit; to be used for the interpretation of Table 10a.

s-wave level spacing	$< D > = 0.83 \pm 0.08$ eV
s-wave strength function	$S_o = (1.23 \pm 0.09) \times 10^{-4}$
radiative width	$< \Gamma_\gamma > = (36 \pm 6)$ meV
total fission width	$< \Gamma_f >_{2+} = (600 \pm 100)$ meV
	$< \Gamma_f >_{3+} = (100 \pm 20)$ meV

The proposed level spacing is 9% lower than the lowest estimate of 0.90 eV obtained from the examination of the neutron width distribution in the energy range 0 to 200 eV. This correction of 9% is meant to take into account the effect of the unresolved multiplets and was given by Blons and Derrien in Ref. 19.

5. THE CROSS SECTIONS

5.1 THE THERMAL RANGE

Special care was taken for the analysis of the thermal range. First, one should reproduce by the resonance parameters the 2200 m/s cross sections proposed by the ENDF/B-VI standard evaluation group;[21] second, one should try to explain the discrepancy on the 0.26-eV resonance capture cross-section found by Weston and Wright[12] For this purpose, a consistent SAMMY fit was performed in the energy range 0.001 to 3 eV, using as input all the parameters obtained by fitting the higher energy ranges and by varying only the parameters of the 0.26-eV resonance and the parameters of the bound levels. The experimental data base (see Table 5) was renormalized in the energy range 0.02 to 0.03 eV to be consistent with the new standard values at 0.0253 eV.

A preliminary fit, including all the selected experimental data, has shown some inconsistencies between Wagemans and Deruytter and Weston and Todd fission data. When Wagemans and Deruytter and Weston and Todd data are normalized to the same value in the energy range 0.02 to 0.03 eV, there is a disagreement of 2.5% over the energy range 0.02 to 0.45 eV (326.0 b·eV for Wagemans and Deruytter and 334.2 b·eV for Weston and Todd). The origin of this discrepancy can be seen in Fig. 5. The shape of the Weston and Todd data deviates from the shape of the Wagemans and Deruytter data in the energy range below 0.03 eV and a consistent normalization cannot be obtained by using the energy range 0.02 to 0.03 eV. The Wagemans and Deruytter data have the expected 1/v shape; this is not the case for the Weston and Todd data. The Weston and Todd data should be normalized on the Wagemans and Deruytter data in the energy range above 0.05 eV; the Weston and Todd data should not be taken into account in the energy range below 0.05 eV (see Table 12).

The final SAMMY fit included only Young and Smith[14] and Simpson and Shuman[15] total cross sections and Wagemans and Deruytter fission cross sections. The results of the fit are shown in Fig. 8. The 2200 m/s cross sections obtained are given in Table 11. They are in agreement with the proposed standard values. The calculated capture cross sections are shown in Figs. 6 and 7; the same deviation in shape noted above is observed for the Weston and Todd experimental capture data; like the fission data, they should be normalized over the 0.26-eV resonance and not in the energy range 0.02 to 0.03 eV. The renormalized fission cross sections of Seppi *et al.*[24] are also shown in Fig. 8. They agree quite well with the calculated cross sections.

The cross-section values integrated over the energy ranges 0.02 to 0.03 eV and 0.02 to 0.45 eV are shown in Table 12. Renormalizing the Weston and Todd absorption data to the absorption inferred from the Simpson and Shuman total cross section in the energy range 0.05 to 0.45 eV and the Weston and Todd fission to the Wagemans and Deruytter fission in the same energy range, results in capture cross sections in agreement with the calculated values. This renormalization process

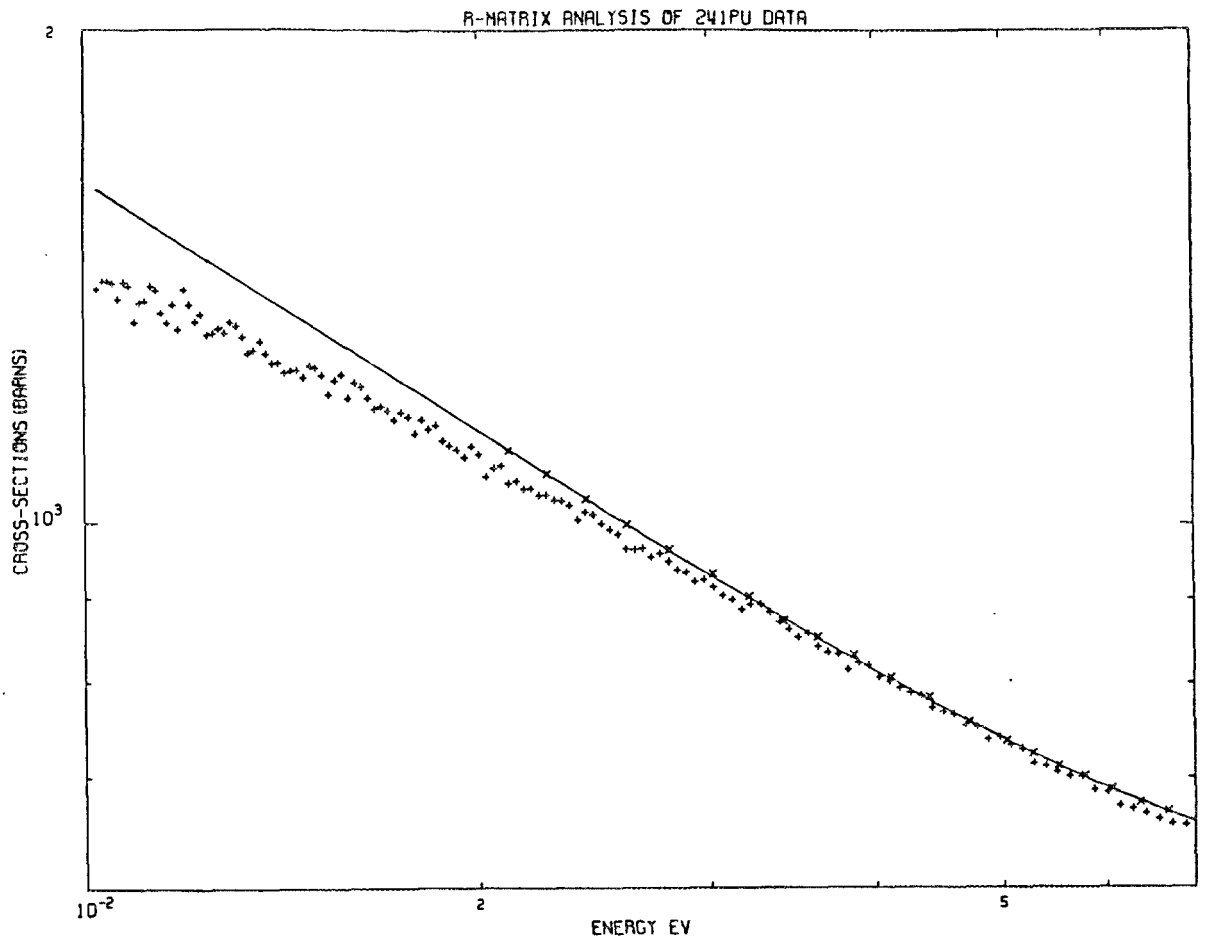

Fig. 5. Pu-241 fission cross sections in the energy range 0.01 to 0.07 eV. The solid line represents the cross sections calculated from the resonance parameters obtained by fitting the data of Wagemans and Deruytter (x). The data of Weston and Todd (+), normalized to the Wagemans and Deruytter data in the energy range 0.05 to 0.45 eV, deviate strongly from the calculated values below 0.03 eV.

leads to a 1.6% decrease in the 1978 Weston and Todd fission and to a 10% decrease in the 1978 Weston and Todd capture over the 0.26-eV resonance.

The dip in the fission cross section observed at 2 eV in the Weston and Todd experimental data (Figs. 6 and 10) is due to a strong interference effect between a small resonance at 1.735 eV and the large resonance at 5.81 eV. The resonance at 1.735 eV was not given in previous resonance parameter sets.

Table 11. Pu-241 thermal cross sections[a]

	Standard at 0.0253 eV[b] (barn)	Energy range 0.02 to 0.03 eV (barn)	Calculated at 0.0253 eV (barn)
Fission	1012.68 ± 6.58	1023.9	1011.88 (−0.1%)
Capture	361.29 ± 4.95	366.0	362.95 (+0.5%)
Scattering	12.17 ± 2.62	12.2	11.16 (−9.1%)
Total	1386.14 ± 8.64	1402.1	1386.0 (−0.0%)

[a]Column 2 gives the average values in the energy range 0.02 to 0.03 eV corresponding to the standard values at 0.0253 eV. The calculated values are obtained from the resonance parameters at 0°K. The figures between parentheses are the percentage deviation from the standard values.

[b]See Ref. 21.

5.2 THE RESOLVED RESONANCE REGION

Table 13, taken from Weston and Todd[5] is an illustration of the large discrepancies existing in the ^{241}Pu experimental fission data. Therefore, a consistent fit of the data could not be obtained without allowing large local renormalization or residual background corrections in most of the experimental data. The problem of the renormalization of the data was also considered by Wagemans and Deruytter[6] who have shown (Table 14) that a good agreement can be obtained, in the energy range below 50 eV, between the fission cross-section data of Wagemans and Deruytter, Blons, and Migneco *et al.* if the normalization is performed in the energy range 12 to 20 eV assuming an integral value of 1350 b·eV corresponding to an average cross section of 1024 b in the 0.02- to 0.03-eV thermal normalization range (i.e. 1012.7 b at 0.0253 eV). The Weston and Todd data renormalized to the Wagemans and Deruytter data over the 0.26-eV resonance, as stated above, gives 1349 b·eV in the 12- to 20-eV energy range. The value calculated from the resonance parameters is 1342 b·eV only 0.5% below the Wagemans and Deruytter normalization value.

Table 15 shows the average fission cross sections in 17 energy intervals in the incident neutron energy range 3 to 300 eV. The Weston and Todd data renormalized to the Wagemans and Deruytter data are compared to the values calculated from the resonance parameters. The agreement is excellent.

Table 16 shows the capture cross sections and the α values in the neutron energy range 10 to 300 eV. The α values calculated from the resonance parameters are compared to the Weston and Todd experimental values. The calculated values are on average 14.3% smaller; the discrepancies are very large (20% to 60%) in the

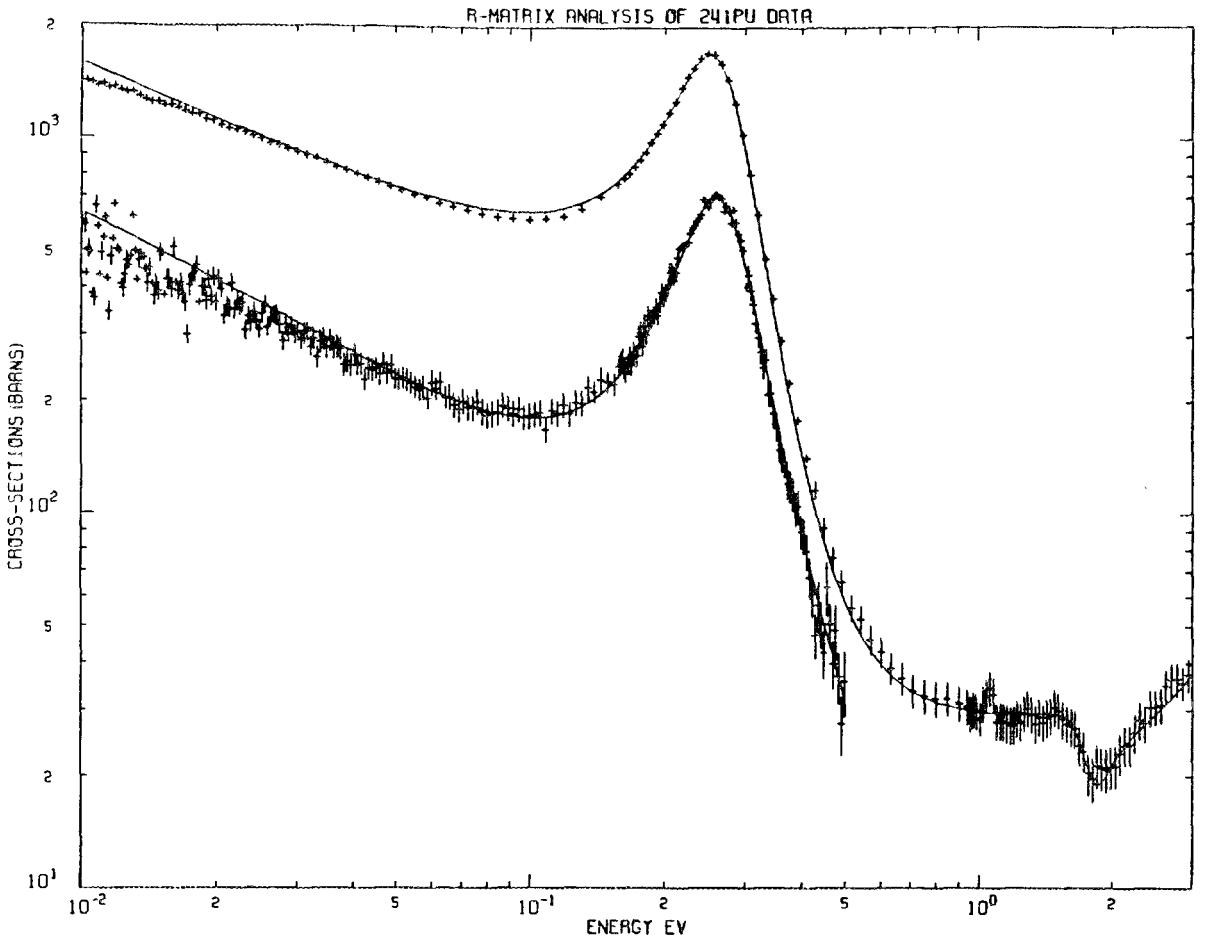

Fig. 6. Pu-241 fission and capture cross sections in the energy range 0.01 to 3 eV. The curves represent the cross sections calculated from the resonance parameters obtained by fitting the fission data of Wagemans and Deruytter, the total cross-section data of Simpson and Shuman and Young and Smith The experimental data are Weston and Todd fission cross sections normalized to Wagemans and Deruytter fission in the energy range 0.05 to 0.45 eV, and Weston and Todd capture normalized via the absorption cross sections inferred from Simpson and Shuman total cross section in the energy range 0.05 to 0.45 eV.

regions where the capture cross sections are small. The experimental capture data were included in the SAMMY fits only in the energy range 3 to 20 eV (Fig. 11) and a correction of 15% to the normalization was obtained. The large Γ_γ values obtained for the broad resonances at 5.81 and 9.62 eV suggest that an important experimental background could also remain in the experimental capture data. The absorption cross sections were normalized by Weston and Todd to values inferred from the Kolar and Carraro total cross sections in the energy range 5 to 50 eV. It has been shown[2] that the Kolar and Carraro total cross sections could be too large and therefore the Weston and Todd absorptions could also be too large. Renormalizing

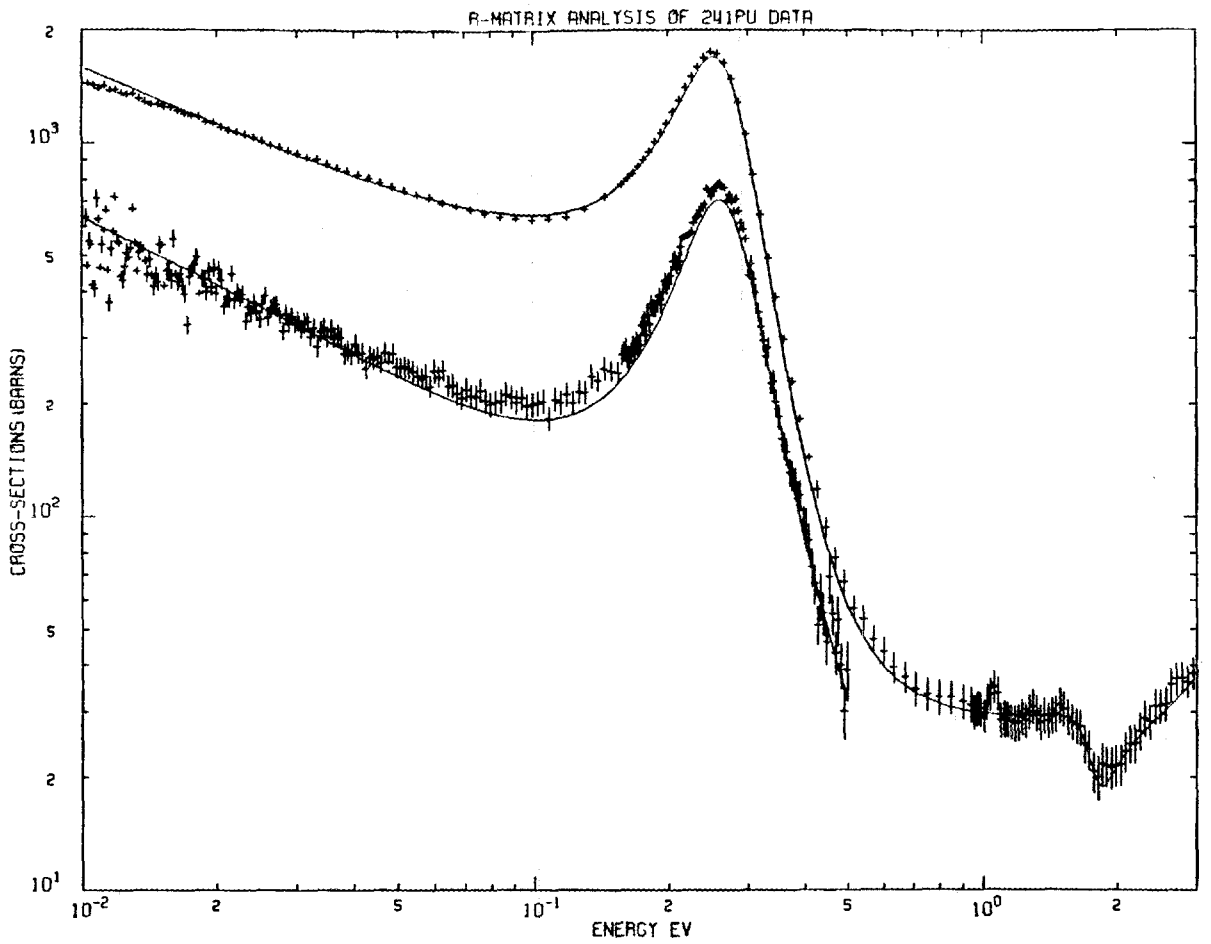

Fig. 7. Pu-241 fission and capture cross sections in the energy range 0.01 to 3 eV. The curves represent the cross sections calculated from the resonance parameters obtained by fitting Wagemans and Deruytter fission, Young and Smith total and Simpson and Shuman total. The experimental data are Weston and Todd data normalized on the standard values between 0.02 and 0.03 eV. Note the dip in Weston and Todd fission cross section at 2 eV which is well represented by a strong interference effect between a small resonance at 1.735 eV and the broad resonance at 5.810 eV.

the Weston and Todd absorptions to the absorptions inferred from the Harvey and Simpson transmission data should remove the discrepancy with the capture and α values.

Figures 9 to 15 provide a detailed graphical comparison between the results of several measurements and the corresponding quantities as computed from the resonance parameters. The curves represent the calculated data; the crosses or the vertical bars (error bars) represent the experimental values. Figure 10 shows the Weston and Todd, Blons, and Migneco *et al.* fission cross sections in the energy range 0.3 to 20 eV; the Weston and Todd and the Blons data were displaced by 2

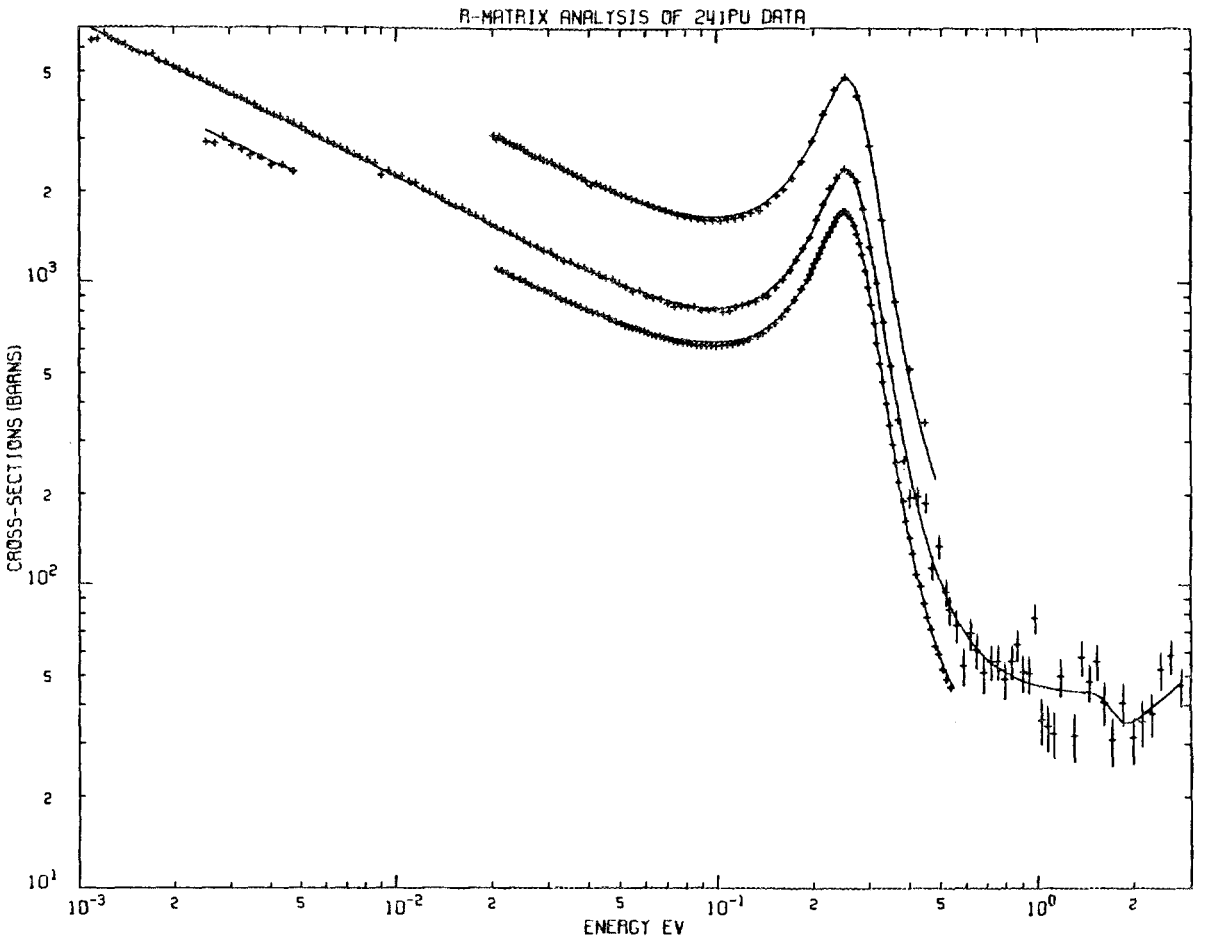

Fig. 8. Pu-241 fission and total cross sections in the energy range 0.001 to 3 eV. The curves represent the cross sections calculated from the resonance parameters. The experimental data are the Simpson and Shuman total cross sections in the energy range 0.02 to 0.5 eV (displaced by a factor os three), the Young and Smith total cross sections in the energy range 0.001 to 3 eV, the Wagemans and Deruytter fission cross sections in the energy range 0.02 to 0.5 eV and the renormalized Seppi fission data in the energy range 0.002 to 0.006 eV.

and 1 decades respectively for clarity of the display. Figure 9 shows the Harvey and Simpson transmission data in the same energy range; the medium and thin sample data were displaced by 0.25 and 0.5, respectively.

Figure 11 shows Weston and Todd fission and capture in the energy range 0.3 to 20 eV.

Figures 12 and 13 show the data in the energy range 45 to 73 eV and 73 to 100 eV. The upper part of the figure represents the total cross sections obtained from Harvey and Simpson thick sample transmission displaced by three decades.

Table 12. Pu-241 cross sections in the energy range below 0.45 eV[a]

References	Energy range 0.02 to 0.03 eV (barn)		Energy range 0.02 to 0.45 eV (barn · eV)		
	EXP 1	EXP 2	EXP 1	EXP 2	THE
Young and Smith total	1401.8		455.01		456.19
Simpson and Shuman total	1401.9		458.97		459.12
Wagemans and Deruytter fission	1024.3		326.03		327.74
Weston and Todd fission	1024.9	999.9	334.18	326.03	327.80
Weston and Todd capture	366.2	338.8	137.43	127.74	126.49
Simpson and Shuman absorption	1389.7		453.77		453.92
Weston and Todd absorption	1391.1	1338.7	471.61	453.77	454.29
Scattering					5.20

[a]EXP 1 are the average experimental values (or the integral values) obtained when the data are normalized at 0.0253 eV on the standard data.[21] EXP 2 are the experimental values obtained when Weston and Todd fission and Weston and Todd absorption are normalized to Wagemans and Deruytter fission and Simpson and Shuman absorption respectively, in the energy range 0.02 to 0.45 eV. Simpson and Shuman absorption was obtained by substracting the calculated scattering value to the total value. THE are the values calculated from the resonance parameters. They are in excellent agreement with EXP 2.

Table 13. Fission cross-section integrals

Energy interval (eV)	Average value (b·eV)	Ratio (data/average)							
		Weston and Todd (Ref. 5)	Wagemans and Deruytter (Ref. 6)	Blons (Ref. 4)	Migneco *et al.* (Ref. 7)	Simpson *et al.* (Ref. 8)	James (Ref. 9)	Moore *et al.* (Ref. 10)	Carlson and Behrens (Ref. 11)
3.0 – 4.9	350.8	1.048	1.029	0.991	1.021		1.020 1.002	0.899	
4.9 – 8.0	876.8	1.009	0.994	1.006	1.024		0.991 1.010	0.967	
8.0 – 9.0	237.6	1.017	1.010	0.992	0.997		1.026 0.958	1.040 0.930	1.006
9.0 – 12.0	311.1	1.028	1.001	0.975	1.029		0.973 1.076	1.031 0.971	0.942
12.0 – 14.0	284.8	0.995	1.018	0.960	1.007		0.988 1.007	1.052 0.992	
14.0 – 17.4	928.0	1.022	1.015	1.000	0.972		1.033 0.928	1.026 0.996	0.954
17.4 – 20.0	143.8	1.010	0.948	0.930	0.973		1.013 1.051	1.190 1.021	
20.0 – 25.0	232.2	1.035	1.010	0.937 1.044	1.027	0.881	0.968 1.077	1.000 1.070	
25.0 – 27.2	274.1	1.040	1.043	0.985 0.993	0.995	0.894	1.011	1.071 0.988	0.950
27.2 – 30.0	324.2	1.034	1.000	0.966 0.970	0.977	0.859	1.075	1.016 1.148	
30.0 – 36.1	326.3	1.055	1.034	0.986 0.982	0.988	0.988	1.104	1.005 1.068	
36.1 – 44.0	254.8	1.116	1.070	0.989 0.993	0.953	0.810	0.998	1.084 1.040	
44.0 – 52.0	332.5	1.012	(1.002)	0.946 0.923		0.871	0.929	1.221 1.281	
50 – 60	173.1	1.010		0.921	0.971	0.930	1.170		
60 – 70	559.1	1.049		0.962	1.010	0.924	1.055		
70 – 80	278.3	0.925		0.982	1.039	1.111	1.032		
80 – 90	685.9	1.075		0.956	0.999	1.030	0.940		
90 – 100	279.2	0.973		0.980	0.992	1.024	1.121		
100 – 200	2660.	1.000		0.861	0.939	1.087	1.207		
200 – 300	2780.	1.037		0.930	0.938	1.146	1.056		
300 – 400	2129.	1.076		0.963	0.855	1.101	1.008		

Table 14. Comparison of ^{241}Pu fission integrals (b·eV)[a]

Energy interval (eV)	Wagemans and Deruytter	Blons	Migneco *et al.*	Calculated value
3.0 – 8.0	1216.3	1243.7	1276.4	1196.9
8.0 – 9.0	236.7	238.5	240.6	234.4
9.0 – 12.0	307.2	306.7	325.2	292.0
12.0 – 14.0	286.1	276.6	291.3	279.4
14.0 – 17.4	929.4	938.3	916.7	922.2
17.4 – 20.0	134.5	135.2	142.1	139.8
20.0 – 25.0	231.4	245.1	242.4	
25.0 – 27.2	282.1	275.2	277.0	
27.2 – 30.0	319.7	317.9	321.8	
30.0 – 36.1	330.8	324.0	327.5	
36.1 – 44.0	269.0	255.9	246.6	
44.0 – 52.0	328.8	310.8		
12 – 20	1350.0	1350.0	1350.0	1341.0

[a]The ^{241}Pu fission integrals (b·eV) renormalized at σ_f (2200 m/s) = 1012.7 b via the Wagemans and Deruytter integral of 1350.0 b·eV in the energy range 12 to 20 eV. These data were taken from Ref. 6 with 1% correction for normalization on the ENDF/B-VI standard at 2200 m/s. The values calculated from the resonance parameters are also given in the energy range 3 to 20 eV.

Table 15. Comparison of ^{241}Pu integral fission cross sections (b·eV)[a]

Energy range (eV)	Average	Weston and Todd	Calculated
3.0 – 4.9	350.8	361.6	359.2 (−0.7%)
4.9 – 8.0	876.8	870.0	836.7 (−4.3%)
8.0 – 9.0	237.6	237.9	234.4 (−1.5%)
9.0 – 12.0	311.1	313.6	292.0 (−7.4%)
12.0 – 14.0	284.8	279.3	279.4 (+0.0%)
14.0 – 17.4	928.0	929.9	922.2 (−0.8%)
17.4 – 20.0	143.8	142.6	139.8 (−2.0%)
20.0 – 30.0	795.3	845.0	842.9 (−0.2%)
30.0 – 40.0	452.0	480.7	485.9 (+1.0%)
40.0 – 50.0	390.9	426.0	408.9 (−4.1%)
50.0 – 60.0	173.1	171.8	175.5 (+2.2%)
60.0 – 70.0	559.1	576.7	570.4 (−1.1%)
70.0 – 80.0	278.3	263.8	267.6 (+1.4%)
80.0 – 90.0	685.9	715.2	722.0 (+1.0%)
90.0 – 100.0	279.2	271.7	282.7 (+4.0%)
100.0 – 200.0	2660.0	2621.0	2626.0 (+0.2%)
200.0 – 300.0	2780.0	2791.3	2828.0 (+1.3%)
3.0 – 300.0	12186.7	12298.1	12273.5 (−0.2%)

[a]Pu-241 integral fission cross sections calculated from the resonance parameters and compared to Weston and Todd experimental data normalized to Wagemans and Deruytter data in the energy range 0.02 to 0.45 eV. The percentage deviations between Weston and Todd and the calculated values are given. The average values are those obtained from all the experimental data appearing in Table 13.

Table 16. average capture cross sections and alpha values[a]

Energy range (eV)	Calculated capture (barn)	Calculated alpha	Experimental alpha	Deviation %
10 – 20	74.72	0.509	0.559	10.0
20 – 30	15.46	0.183	0.213	16.4
30 – 40	9.78	0.201	0.216	7.5
40 – 50	5.45	0.133	0.184	38.0
50 – 60	2.16	0.123	0.198	61.0
60 – 70	12.90	0.226	0.279	23.0
70 – 80	14.62	0.546	0.572	4.8
80 – 90	22.89	0.317	0.337	6.3
90 – 100	5.75	0.203	0.207	2.0
100 – 200	5.87	0.226	0.268	18.6
200 – 300	6.62	0.237	0.264	11.4
10 – 300		0.244	0.279	14.3

[a]Pu-241 capture cross sections and α values in the energy range 10 to 300 eV. The percentage deviations between the α values calculated from the resonance parameters and Weston and Todd experimental values are given.

The other curves represent Migneco *et al.* fission multiplied by 10, Weston and Todd fission, and Blons fission multiplied by 0.1.

Figures 14 and 15 show the data in the energy range 200 to 250 eV and 250 to 300 eV. The upper part of the figure represents the total cross sections obtained from Harvey and Simpson thick sample transmission displaced by three decades. The other curves represent Blons fission multiplied by 10, Migneco *et al.* fission, and Weston and Todd fission multiplied by 0.1.

The resonances of the isotope impurities (^{239}Pu, ^{240}Pu, ^{242}Pu, ^{241}Am) were not removed from the figures.

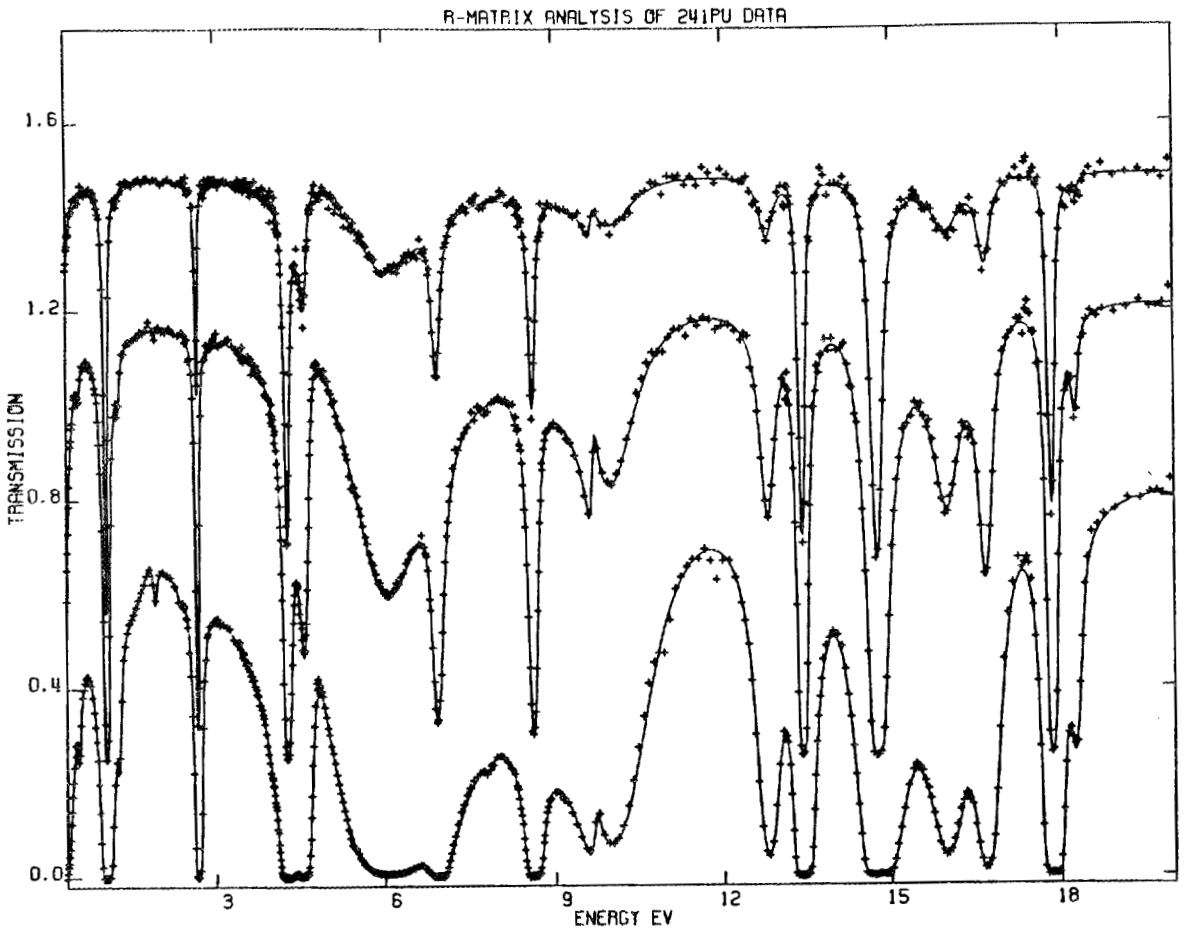

Fig. 9. Pu-241 transmission ratio in the energy range 0.3 to 20 eV. The experimental data (crosses) are the results of Harvey and Simpson measurements of 5.19×10^{-4} at/b, 2.27×10^{-3} at/b and 1.12×10^{-2} at/b samples. The solid lines represent the values calculated from the resonance parameters. The data for the thin and medium samples are displaced by 0.25 and 0.5, respectively for clarity of the display. The resonances of the isotopes ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{241}Am were not removed from the data and were included in the fit.

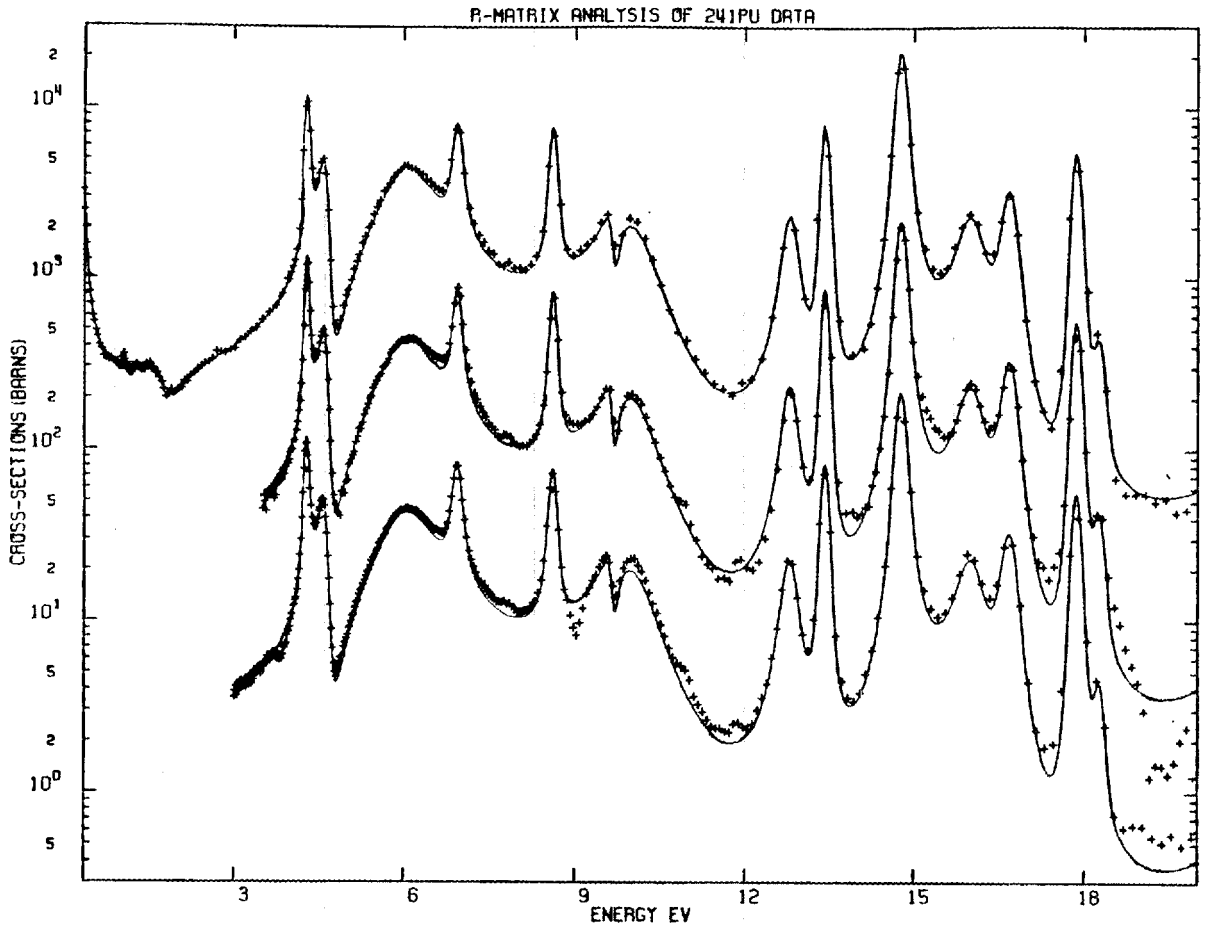

Fig. 10. Pu-241 fission cross sections in the energy range 0.3 to 20 eV. The experimental data (crosses) are from Weston and Todd (multiplied by 10), Blons, and Migneco *et al.* (multiplied by 0.1). The solid lines represent the cross sections calculated from the resonance parameters including residual background and renormalization parameters.

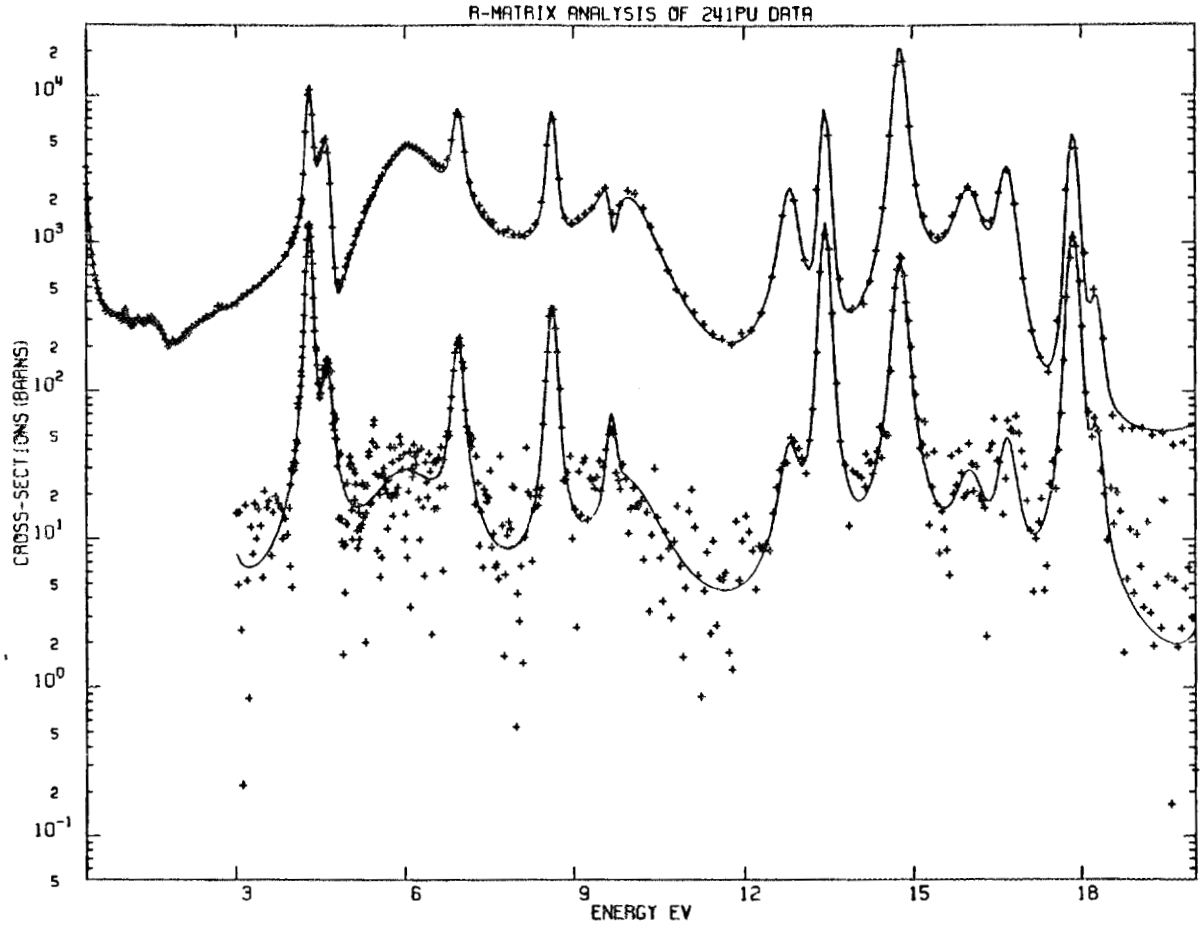

Fig. 11. Pu-241 fission and capture cross sections in the energy range 0.3 to 20 eV. The experimental data are from Weston and Todd. The solid lines represent the cross sections calculated from the resonance parameters including residual background and renormalization parameters. The fission data were displaced by one decade for clarity of the display.

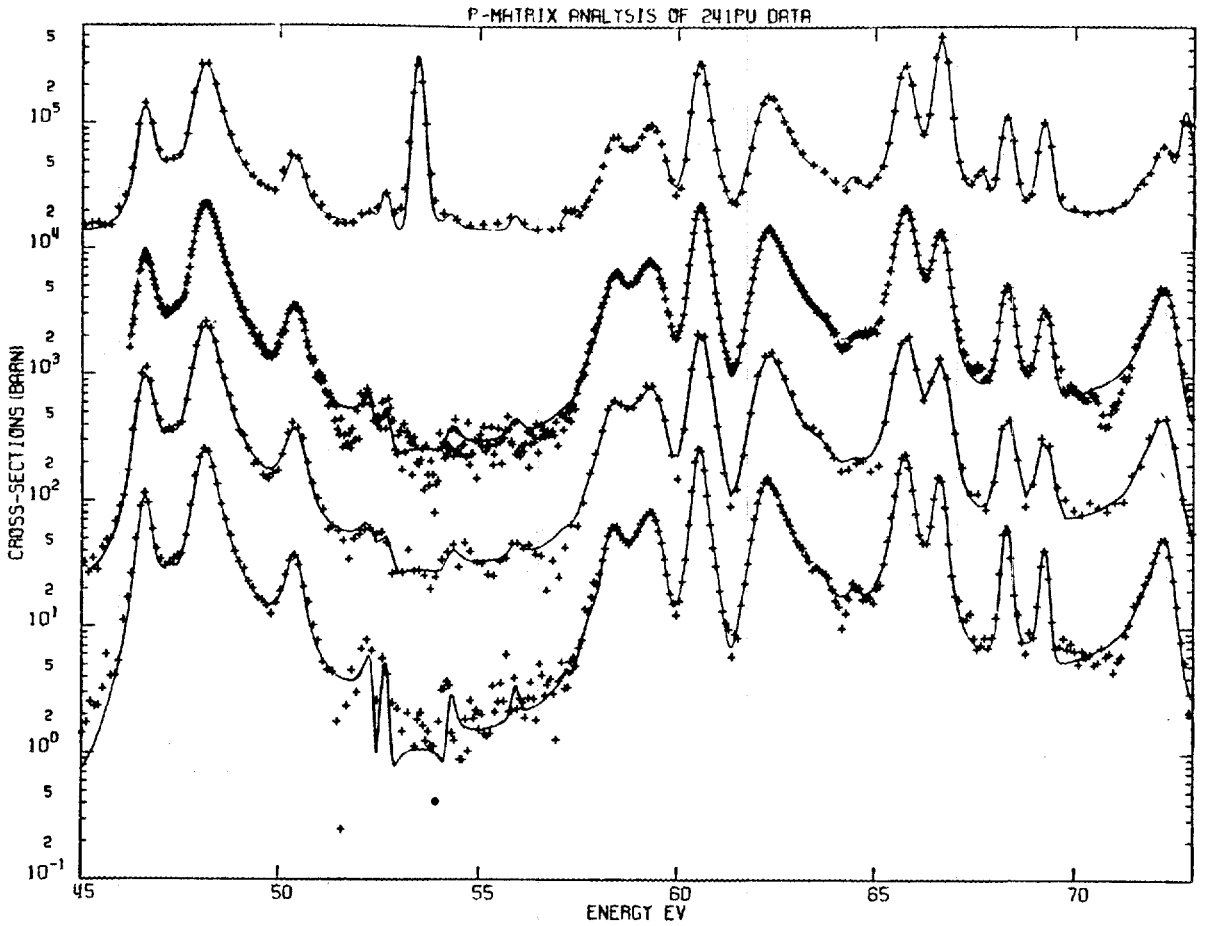

Fig. 12. Pu-241 cross sections in the energy range 45 to 73 eV. The upper curve represents the total cross sections obtained from Harvey and Simpson thick sample transmission displaced by three decades. The other curves are Migneco *et al.* fission multiplied by 10, Weston and Todd fission and Blons fission multiplied by 0.1. The solid lines represent the cross sections calculated from the resonance parameters including residual background and renormalization parameters.

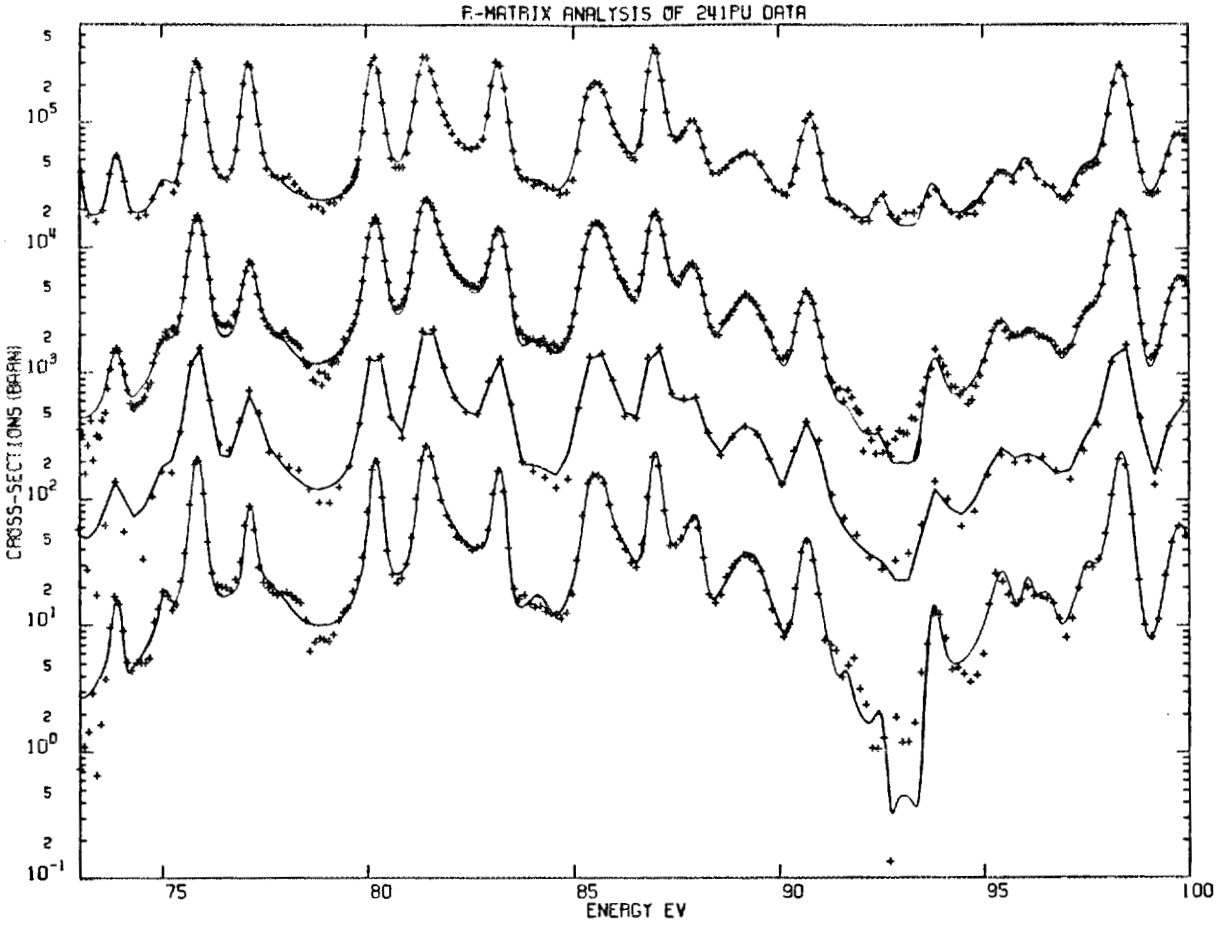

Fig. 13. Pu-241 cross sections in the energy range 73 to 100 eV. The upper curve represents the total cross sections obtained from Harvey and Simpson thick sample transmission data displaced by three decades. The other curves are Migneco *et al.* fission multiplied by 10, Weston and Todd fission, Blons fission multiplied by 0.1. The solid lines represent the cross sections calculated from the resonance parameters including residual background and renormalization parameters.

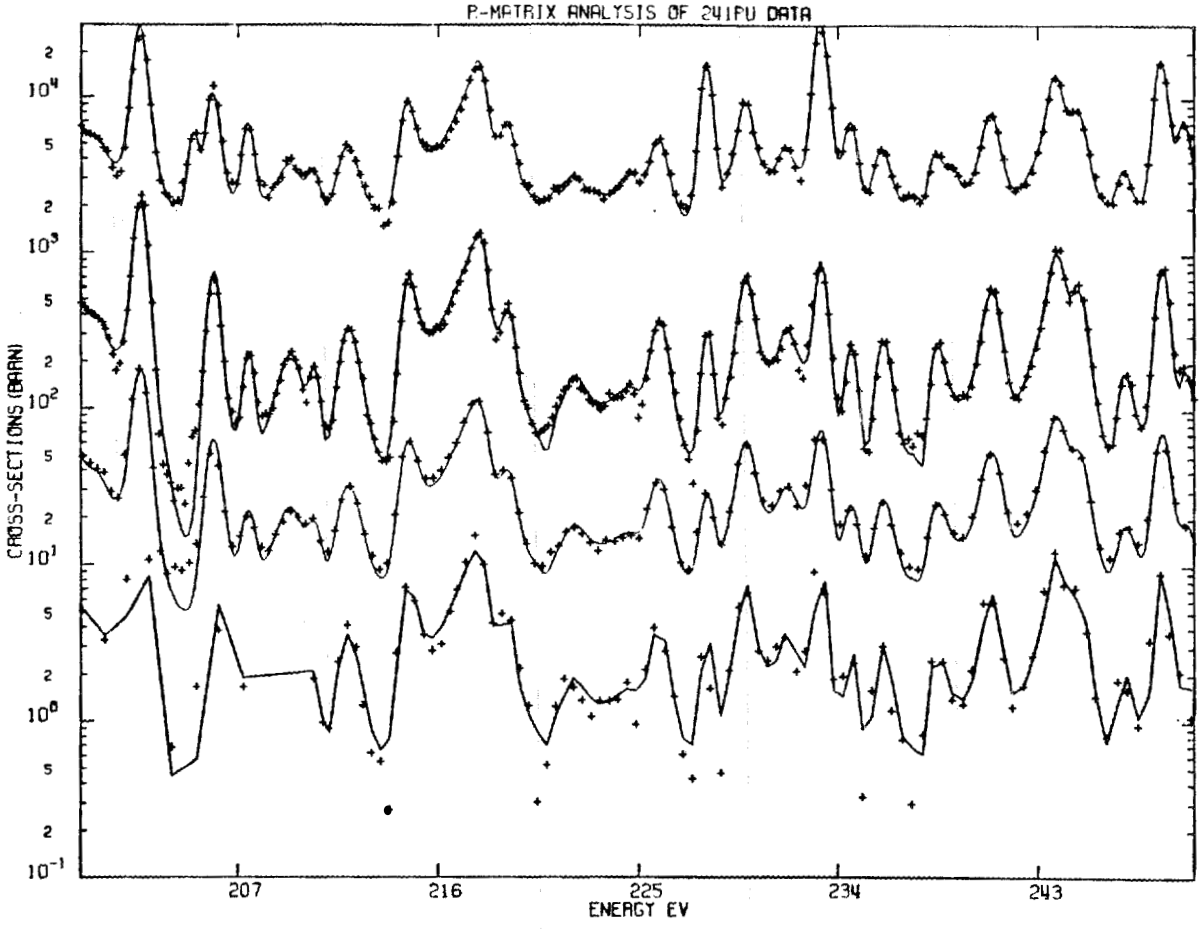

Fig. 14. Pu-241 cross sections in the energy range 200 to 250 eV. The upper curve is the total cross sections obtained from Harvey and Simpson thick sample transmission data displaced by three decades. The other curves are Blons fission multiplied by 10, Migneco *et al.* fission and Weston and Todd fission multiplied by 0.1. The solid lines represent the cross sections calculated from the resonance parameters including residual background and renormalization parameters.

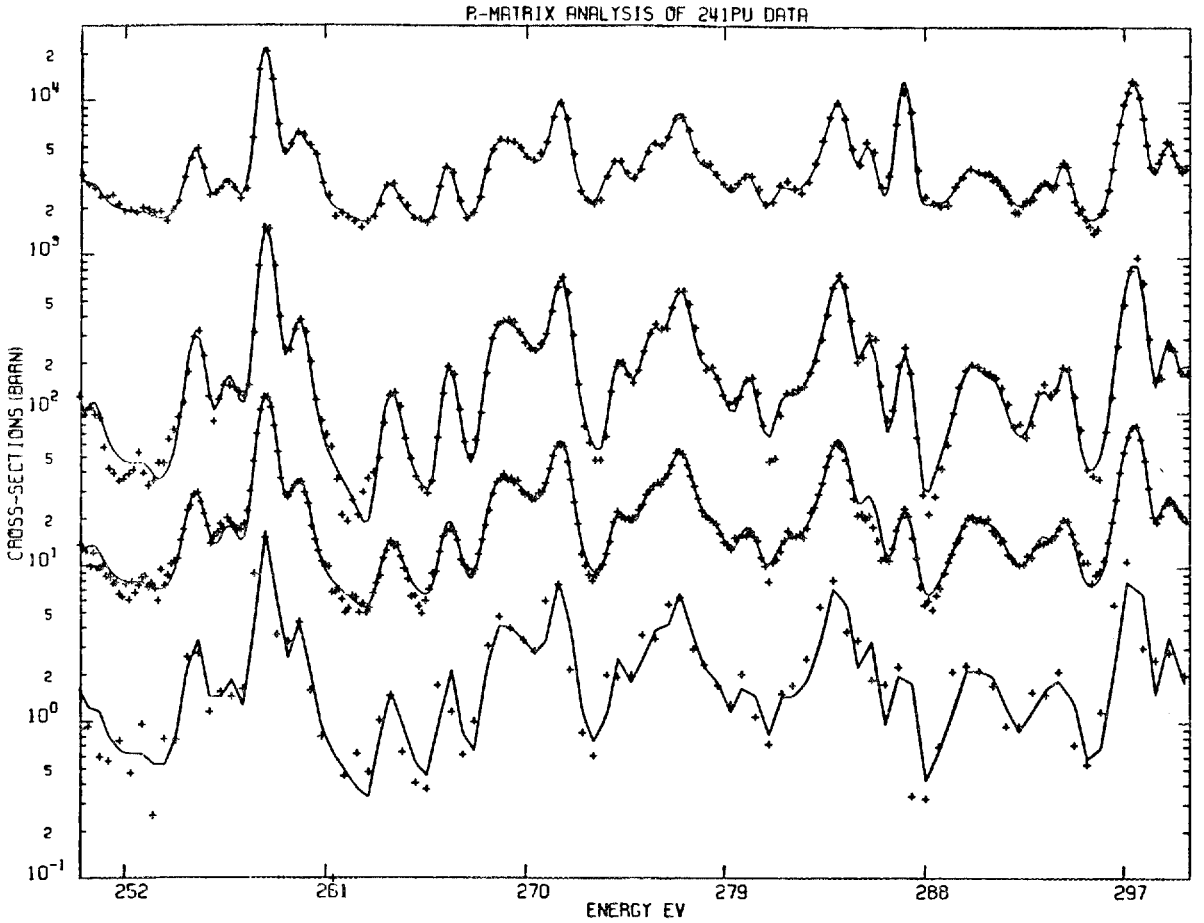

Fig. 15. Pu-241 cross sections in the energy range 250 to 300 eV. The upper curve is the total cross sections obtained from Harvey and Simpson thick sample transmission data displaced by three decades. The other curves are Blons fission multiplied by 10, Migneco *et al.* fission and Weston and Todd fission multiplied by 0.1. The solid lines are the cross sections calculated from the resonance parameters including residual background and renormalization parameters.

6. CONCLUSIONS

As it stands the present analysis is a great improvement over previous evaluations in that it includes Harvey and Simpson high resolution transmission data which were not available before. A consistent representation of the transmission and of Migneco *et al.*, Blons, and Weston and Todd fission cross sections was obtained by allowing local renormalization and residual background corrections to the experimental fission cross sections. Except in the thermal region, Weston and Todd fission data has proved to be more reliable than Migneco *et al.* and Blons data, particularly for the experimental background corrections. Similar conclusions were also obtained in ^{239}Pu and ^{235}U evaluations.[27,28] A careful examination of Weston and Todd capture and fission data in the thermal region below 0.05 eV has shown that a part of the difficulties encountered by Weston and Wright in a previous evaluation[12] was due to the deviation of the cross sections of Weston and Todd from those of Wagemans and Deruytter. It has also been shown that Weston and Todd absorption data should be renormalized to the absorption inferred from Harvey and Simpson transmission data.

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