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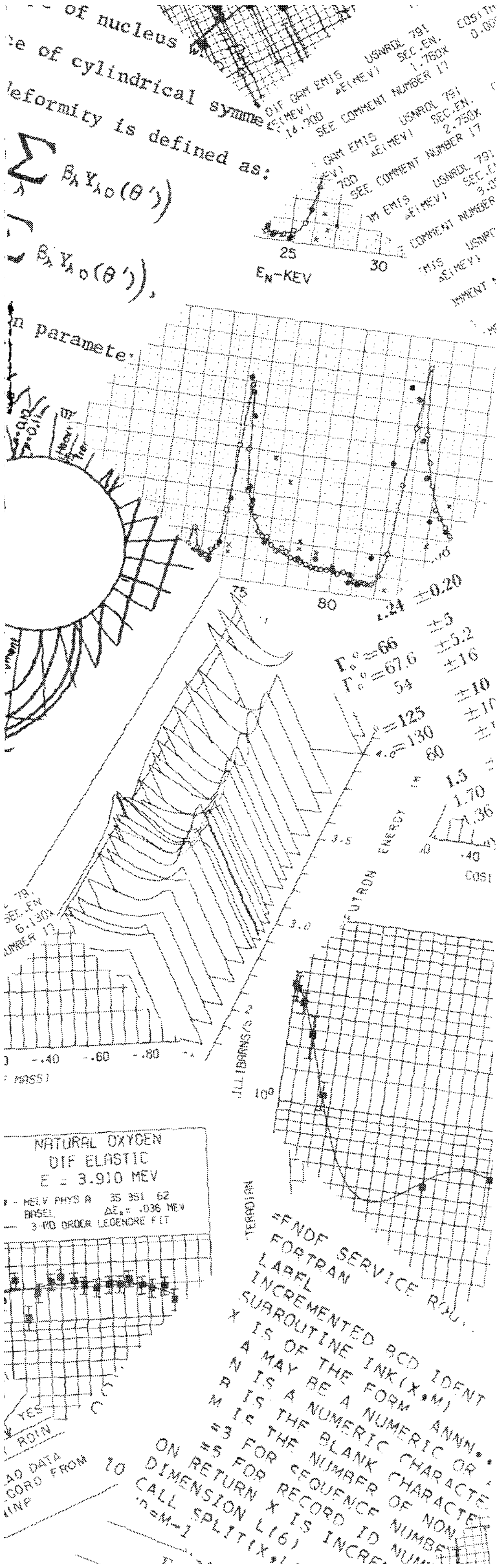

NEUTRON CROSS SECTIONS OF ^{59}Co BELOW 100 keV

S.F. MUGHABGHAB AND T.J. KRIEGER

April 1975

INFORMATION ANALYSIS CENTER REPORT

NATIONAL NEUTRON CROSS SECTION CENTER
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

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(Physics, Nuclear – TID-4500)

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UNDER CONTRACT NO. E(30-1)-16 WITH THE
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy, Domestic \$5.50;
Foreign \$8.00; Microfiche \$2.25

December 1975 600 copies

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ACKNOWLEDGMENTS

We would like to acknowledge the assistance of D. I. Garber, R. R. Kinsey, and A. J. Fuoco in the computer production of the figures in this evaluation and to B. A. Magurno and F. Scheffel for the operation of computer codes.

with the evaluation (and in most instances measurements) in the energy range 0.1 - 20 MeV. In this report we present the analysis, evaluation, and documentation of the data below 100 keV.

The present evaluation differs basically from the previous ENDF/B III (MAT 1118) (in the resonance region) in the following respects: (1) the resonance energy region have been extended from 35 keV to 100 keV, (2) to describe the thermal capture, scattering, total cross section and the polairzation data single s-wave bound level with spin 3 was invoked. In the previous evaluation two bound levels with respective spins 3 and 4 were used. The necessity to invoke in ENDF/B III a bound level with spin 4 is attributed to adoption of a radiative width of 0.4 eV for the resonance at 132 eV with spin 4. The present evaluation adopts a radiative width of 0.48 eV for this resonance, i.e. as recommended in BNL 325 (1973).

Above neutron energy of 100 keV, the differences between ENDF/B IV and ENDF/B III are well described by Guenther et al[3].

with a weighted average experimental value of 74.9 ± 0.8b and with a value of 75.5 ± 1.5 b recommended[4] in BNL 325 (1973). The Wescott g factor for capture calculated here is determined as 0.99996. The thermal cross sections are as follows:

Thermal Capture Cross Section	=	37.22 b
Thermal Elastic Scattering Cross Section	=	6.62 b
Thermal Total Cross Section	=	43.84 b

After the completion of this evaluation Koester et al[55] reported measurements of the total free-atom scattering cross section σ_{sc} and the coherent scattering amplitude. The values are:

$$\sigma_{sc} = 5.95 \pm 0.65 \text{ b}$$
$$b_c = 2.78 \pm 0.04 \text{ fm}$$

From these quantities, the scattering amplitudes b_+ and b_- corresponding to spin I + 1/2 and I - 1/2 states are calculated[55]. The results are:

$$b_+ = -2.78 \pm 0.04 \text{ fm}$$
$$b_- = +9.91 \pm 0.06 \text{ fm}$$

These quantities are in strong disagreement with the values reported by Ito and Shull[16]. In addition, these results imply that 91 ± 1% of the scattering is due to (I-1/2) spin states in the second edition of BNL 325[7] provides an adequate summary of the data prior to 1966. Since that time, new measurements have been carried out. These are indicated in Table 1.

Table 1

Recent Thermal Capture Measurements

Capture Cross Section (b)	Technique	Author
37.24 ± 0.11	pulsed neutron technique	Silk et al[8]
37.14 ± 0.24	activation	Merritt et al[9]
36.6 ± 0.5	activation	DeWorm[10
37.75 ± 0.4	activation	Kim[11]

A total capture and a free-atom scattering cross sections of 37.2 ± 0.2b and 6.7 ± 0.3b are recommended in BNL 325, third edition[4]. After the completion of this evaluation a very recent measurement by Dilg et al[12] using slow neutrons energies between 0.0399 and 2.608 meV appeared in the literature. These authors determined σ_{γ} (2200 m/sec) = 37.15 ± .08b for ^{59}Co. Because of the widely discrepant scattering cross sections measured by Bernstein et al[5] and Wu et al[6] and mentioned previously (σ_s = 5 band 6.7b), Dilg crried out total cross section measurement at 1.25 eV. By subtracting the capture cross section at this energy from the total cross section, he derived a value of 6.3b for the scattering cross section of ^{59}Co. This is in good agreement, within the stated error, with the value recommended[4]

Table IX

Comparison of the Calculation with
the Experimental Polarization Data

Capture at 0.0725 eV	Into J=4 States
Experimental	78.7 ± 1.0%*
Present Evaluation	79.2%
Capture at 2.11 eV	
Experimental	85.5 ± 5.4%*
Present Evaluation	79.6%
Scattering at 0.0725	By J=3 Resonance
Experimental	87 ± 1%
Present Evaluation	85.1%

*Value renormalized to σ_γ (2200 m/sec) = 37.2b to neutron threshold.

In addition, by assuming a total free scattering cross section of 6.7b and a coherent scattering amplitude of 2.5 fm, Schermer[16] obtained two sets of solutions for b_+ and b_- with the aid of the following relations:

$$\sigma_s = 4\pi g_+ b_+^2 + 4\pi g_- b_-^2$$

$$b_{coh} = g_+ b_+ + g_- b_-$$

In these relations g_+ and g_- are the statistical weight factors and b_+ and b_- are the bound coherent scattering amplitudes due to I + 1/2 and I - 1/2 resonances respectively; σ_s is the <u>bound</u> scattering cross section and is related to the free scattering cross section by

$$\sigma_s \text{ (bound)} = \sigma_s \text{ (free)} \left(\frac{A+1}{A}\right)^2$$

The two solutions for b_+ and b_- are presented in Table 2.

Table II

	b_+ (fm)	b_- (fm)
Case 1	+ 8.5 ± 0.2	- 5.3 ± 0.3
Case 2	-3.5 ± 0.2	+10.3 ± 0.3

Schermer[16] deduced that the second set satisfies his

IV. Comparison with Polarization Data

As pointed out previously, at the completion of the evaluation, two data files for each spin state were prepared. Calculations of capture and scattering cross sections were carried out with the aid of the code INTER[47]. The scattering cross sections at thermal energies due to spin 3 and 4 resonances are found to be 12.94b and 1.71b respectively. From these values, one calculates bound coherent scattering amplitudes of 10.32 fm and -3.75 fm for J=3 and J=4 resonances. These values are in excellent agreement with the measurements of Ito and Shull[17]. The results of the scattering data are summarized in Table VII.

Table VII

Scattering Cross Sections Due to Two Spin States 3 and 4

	J=3	J=4
Free σ_{sc} (b)	12.94	1.71
Free a_{coh} (fm)	10.15	-3.69
Bound b_{coh} (fm)	10.32	-3.75
Exp. b_{coh} (fm)	10.60 ± 0.70	-3.80 ± 0.54

In addition, the capture and scattering cross sections at the following energies, 0.0253, 0.0725, and 2.11 eV for both spin states were determined. The results are presented in Table VIII.

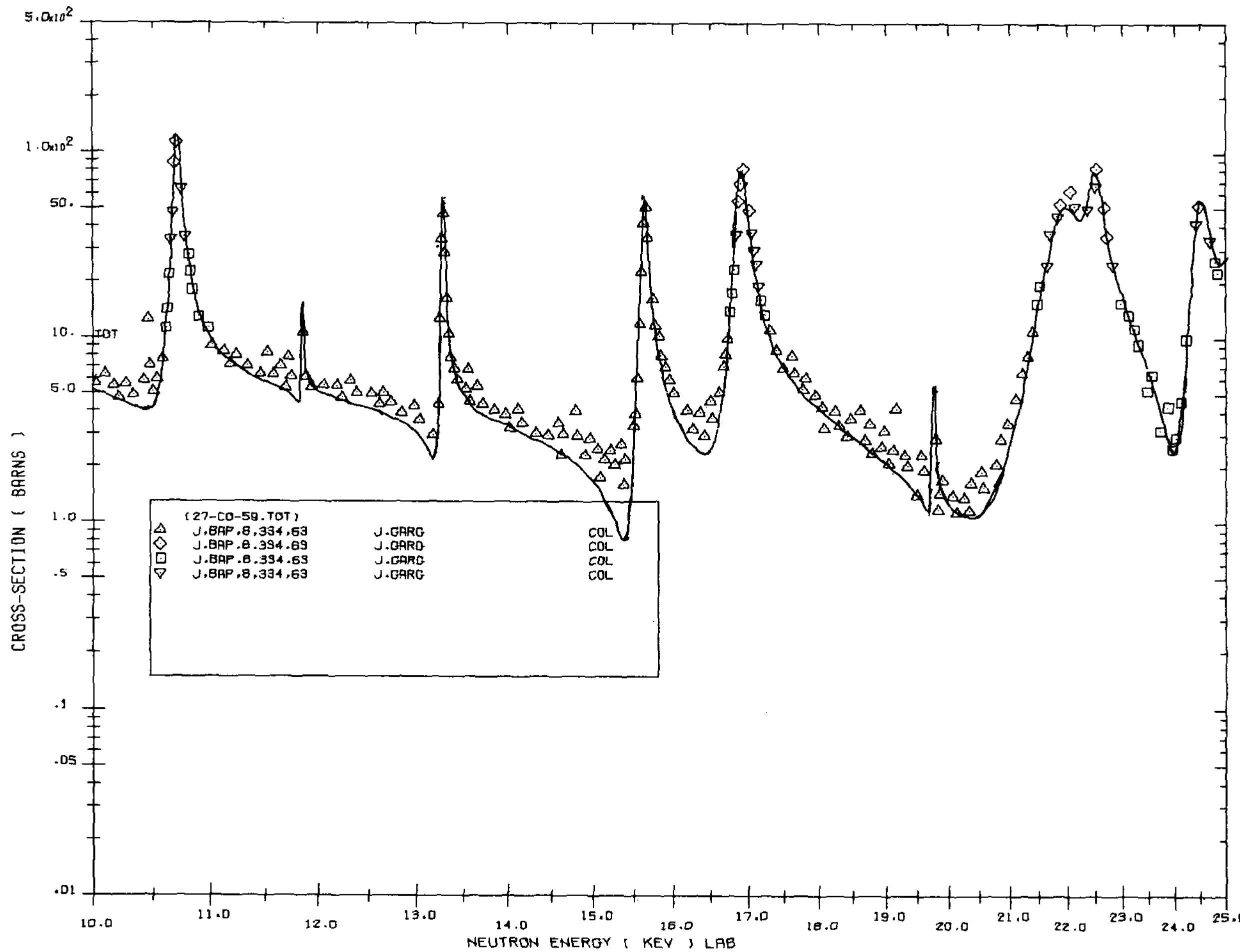
III. Parameters of the 132 eV Resonance and the Absorption Resonance Integral of ^{59}Co

The resonance parameters of the 132 eV resonance are particularly important because this resonance dominates thermal capture and gives the largest contribution to the absorption resonance integral. In addition ^{59}Co is used as a flux monitor in the energy region below 132 eV. In 1948, Seidl[18] studied the 132 eV resonance by the transmission method. Applying the Breit-Wigner formula, he obtained two sets of solutions: $\Gamma = 2.0 \pm 0.1$ eV and $J = 4$ or $\Gamma = 5.0 \pm 0.5$ eV and $J = 3$. The measured peak cross section of the resonance, $\sigma_o = 12{,}500 \pm 1250$b, favored a spin assignment of 4 in accordance with the relation

$$\sigma_o = 4\pi \lambda\!\!\!^{-2} g \left(\frac{A+1}{A} \right)^2$$

Subsequently, Seidl et al[19] used the BNL fast chopper facility to remeasure the resonance parameters of the 132 eV resonance. Values of $\Gamma = 5.0 \pm .07$ eV and $\sigma_o = 9700 \pm 1800$b were obtained.

More accurate and detailed determination of the parameters of the resonance were carried out by Jain et al[20]. Based on a comparison of the measured $2g\Gamma_n$ and Γ values, these authors deduced a spin assignment of 4 for this resonance. Measurement of the γ ray intensity[20] determined the value of the radiative width for the first time i.e. $\Gamma_\gamma = 0.40 \pm 0.04$ eV. Observa-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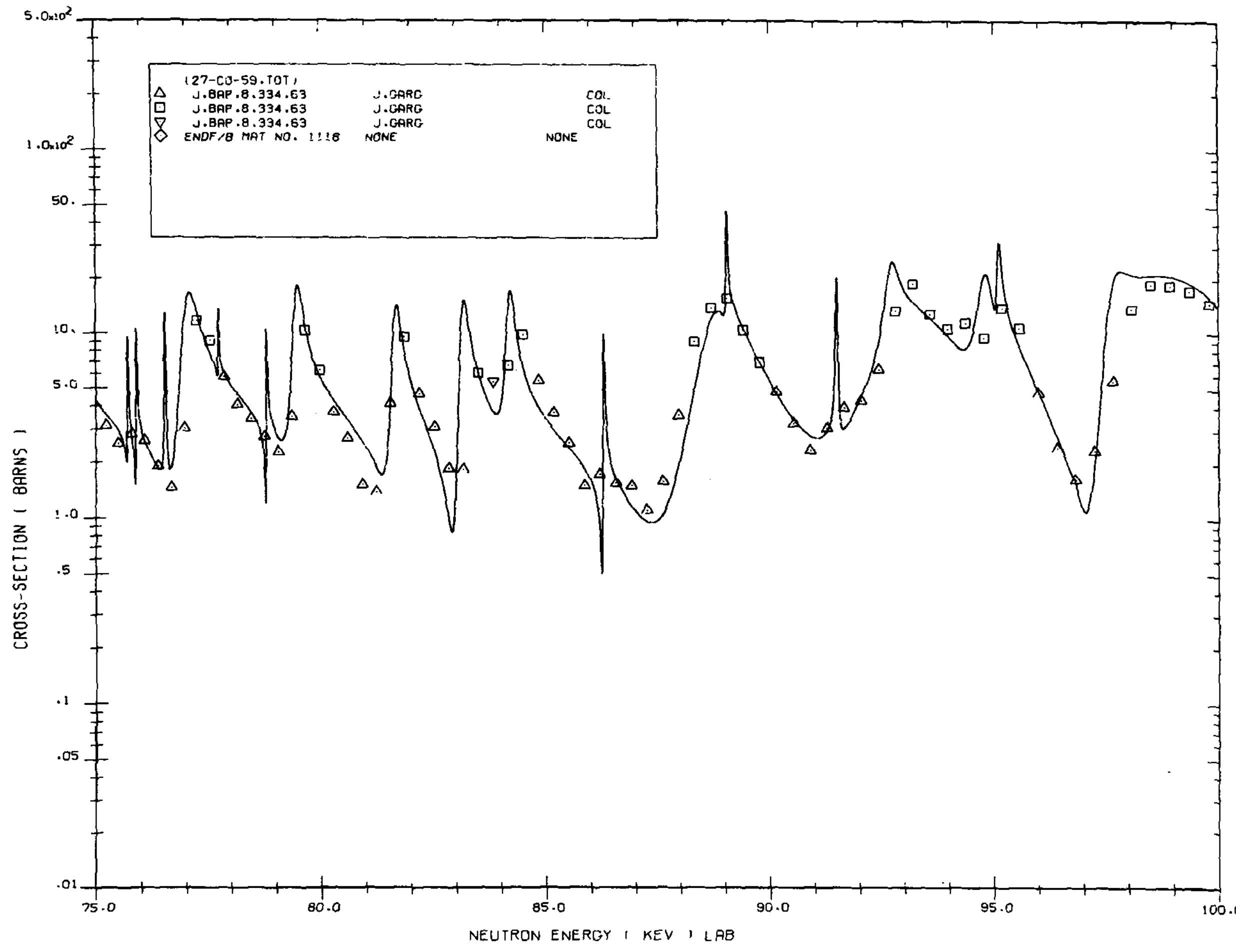
NEUTRON ENERGY (KEV) LAB

Figure 9.

Table III

Resonance Parameters of the 132 eV Resonance

E_o	J	Γ(ev)	Γ_n(ev)	Γ_γ(ev)	Author
131.2			5.32±.05	0.46±.05	Bockhoff[25]
132			5.15±0.30		Garg[26]
132.0±0.5		6.0 ±0.2	5.15±.06		Nakajimo[27]
132.0±0.5	4	5.35±0.10	5.13±0.07	0.40±0.04	Jain[20]
130				0.44	Moxon[23]
132				0.67±0.15	Block[24]
134±2		5.2 ±0.7			Seidl[19]
132				0.48±.04	Wall[22]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90.0
95.0
100.0
CROSS-SECTION (BARNS)
NEUTRON ENERGY (KEV) LAB

Figure 7.

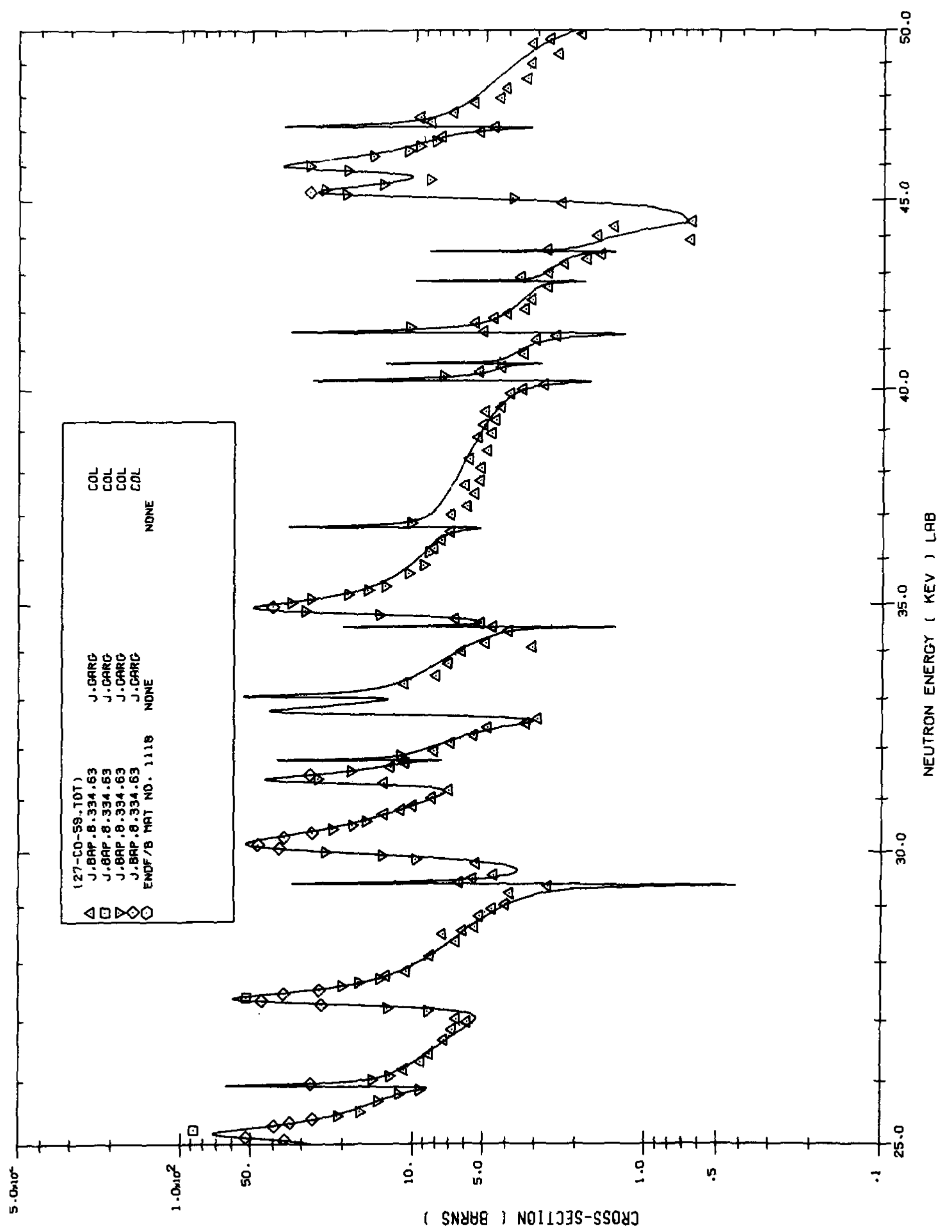
$$I\ (1/v) = 0.45\ \sigma_\gamma\ (2200\text{m/sec})$$

for a low energy cut off of 0.5 eV.

The values were normalized to a ^{197}Au absorption resonance integral of 1565 b. A weighted average value:

$$I_o(^{59}\text{Co}) = 74.9 \pm 0.8\ b$$

is obtained.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NEUTRON ENERGY (KEV) LAB
CROSS-SECTION (BARNS)

Figure 5.

(b) In the unresolved energy region, averaging the Breit-Wigner total cross section for s-wave resonances over an energy region containing many resonances, one obtains

$$<\sigma_T> = 4\pi (R')^2 + 2\pi^2 \lambda\!\!\!^{-2} \sqrt{E}\, S_o + 0\ (S_o)^2$$

Usually, the contribution of higher order terms $0(S_o)^2$ in the keV energy range is small and can be neglected. By carrying out a least square fit to the average total cross section one can derive R' and S_o.

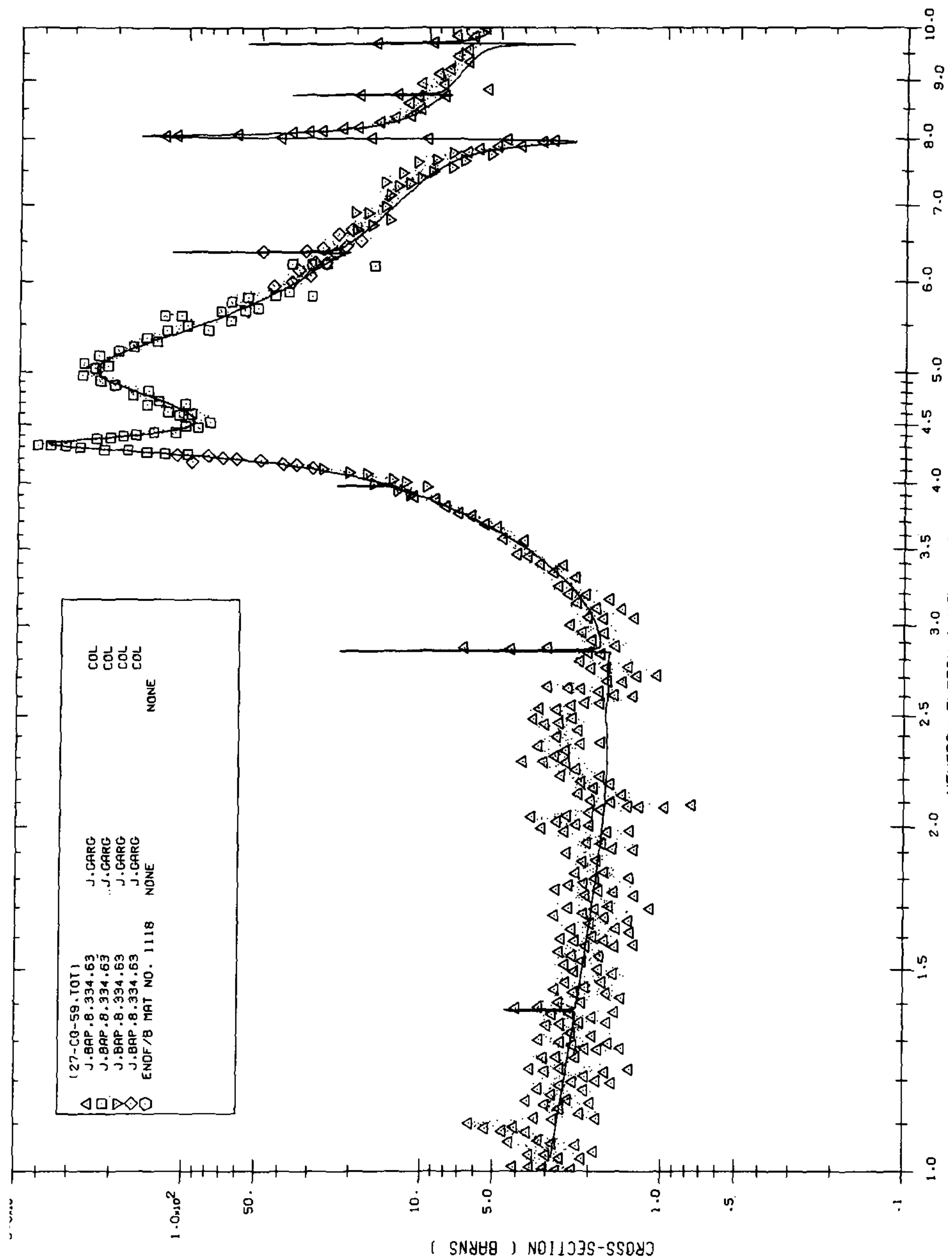
(c) A variation on the above method is to measure the variation of average transmission <T> at one neutron energy versus sample thickness. With the aid of the relation

$$<T> = \left(1 - \frac{\Gamma n}{D}\ \frac{A}{\Gamma}\right) e^{-n\sigma_p}$$

one obtains R' through the potential scattering cross section σ_p where

$$\sigma_p = 4\pi (R')^2$$

Shape analysis of the ^{59}Co transmission data below neutron energy of 77 keV by Morgenstern et al [40] gave R' = 5.4 ± 0.5 fm. In an effort to search for a spin dependence of the scattering data, Morgenstern et al [40] fitted the transmission data in an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CROSS-SECTION (BARNS)

Figure 3.

V. The Total Cross Section of ^{59}Co and the Evaluation Procedure

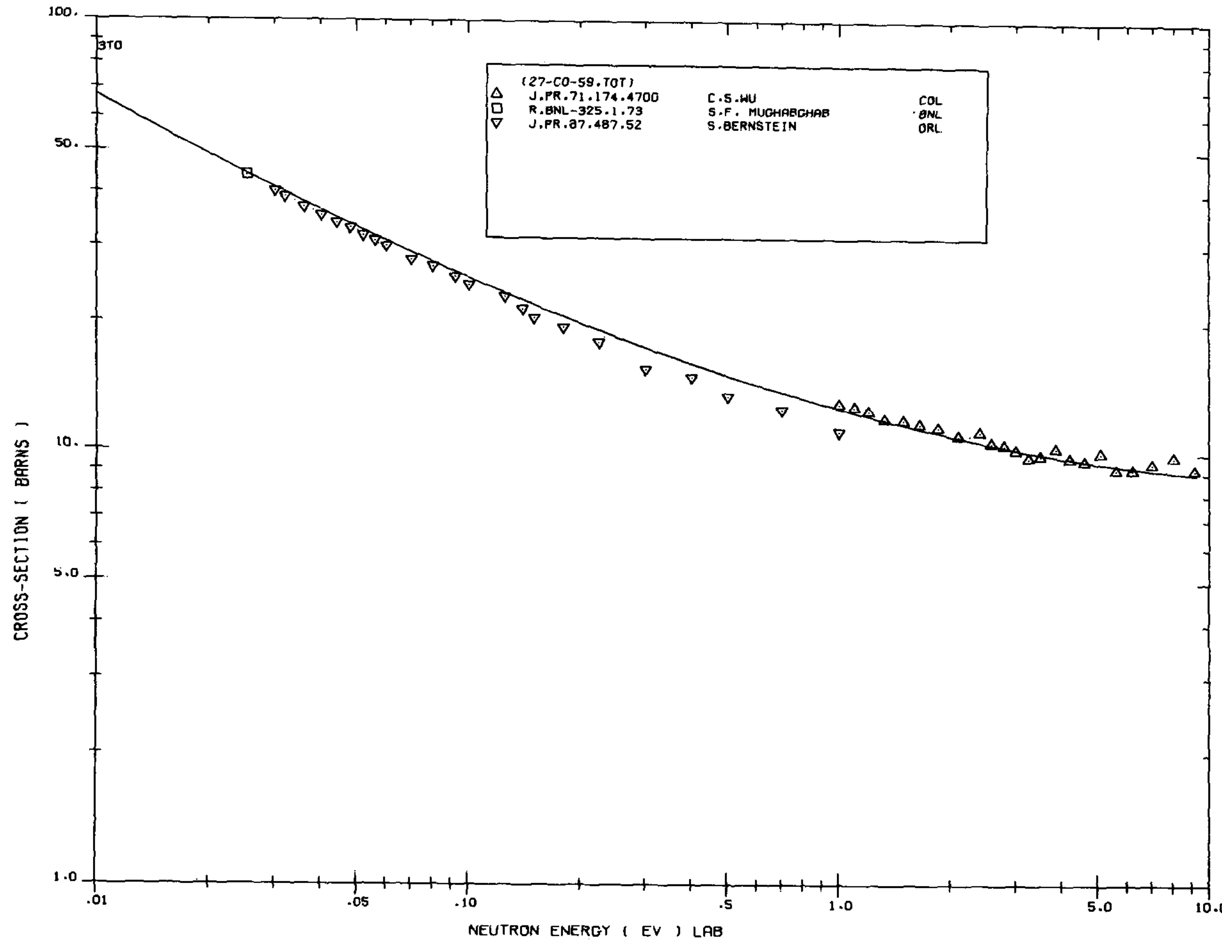
There are several measurements of the total cross section of ^{59}Co below 100 keV. Of these, two high resolution measurements reported in the literature are due to Garg et al(45) and Morgenstern et al(40-41) in the respective energy regions 0.14-128 keV and 1.38-500 keV. The total cross section measured by Garg et al(45) is available in the SCISRS Library. Unfortunately, the data of Morgenstern et al(40-41) is in transmission form, was not converted to total cross section by the authors, and is not available. In view of these considerations we applied the multilevel Breit-Wigner formalsim for a fitting of the data of Garg et al(45).

The technique of evaluating the total cross section from thermal energy to 100 keV proceeded along the following lines. As a starting point, the resonance parameters, the scattering radius, and the 2200 m/sec capture and scattering cross sections recommended(4) in BNL 325 were adopted. A multilevel Breit-Wigner total cross section curve was calculated using code RESEND(46). The initial calculation showed that the fit to cross section between resonances is poor, thus indicating that the potential scattering cross section is not adequately described.

As a result, the following modifications were subsequently made:

(1) The effective scattering radius R' was increased from 5.3 fm to 6.8 fm.

(2) The change in R' necessitated a change in the bound state parameters. Those in BNL 325 (1973) are based on a scatter-



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CROSS-SECTION (BARNS)
NEUTRON ENERGY (EV) LAB

Figure 1.

Table VI

Resonance Parameters of ^{59}Co

E_o (kev)	J	Γ (eV)	Γ_n (eV)	Γ_γ (eV)
-0.521	3	50.15	49.67	0.48
0.132	4	5.60	5.12	0.48
1.380	3	0.4856	.0056	0.48
2.850	4	0.585	0.105	0.48
3.980	3	0.570	0.09	0.48
4.322	4	110.48	110.00	0.48
5.015	3	652.00	651.00	1.00
6.380	4	2.22	2.00	0.22
8.050	3	37.30	37.00	0.30
8.750	4	1.14	0.82	0.32
9.690	3	3.26	2.70	0.56
10.700	4	65.53	64.90	0.63
11.850	3	2.75	2.50	0.25
13.280	4	21.65	21.00	0.65
15.640	3	74.57	74.10	0.47
16.920	4	165.52	165.00	0.52
19.750	4	3.28	2.80	0.48
21.940	3	745.48	745.00	0.48
22.510	4	253.48	253.00	0.48
24.460	3	360.48	360.00	0.48
25.150	4	184.48	184.00	0.48
25.920	4	25.48	25.00	0.48

al's [45] data was generally good. However, for further improvements, a small background contribution no large than ± 1b in energy regions 1-95 keV to the elastic scattering cross was introduced in File 3 in small, selected energy regions. The solid curve in Figure 1, which is a doppler broadened RESEND[46] calculation, shows the evaluated total cross section in the energy range from 0.01 to 10.0 eV. As shown, it passes close to the data points of Bernstein et al[5] at the low energy end and in the energy region 0.1-1.0 eV there are significant deviations from the data points of Bernstein et al[5]. However, at higher energies 1-10 eV the calculated cross section well describes the data points of Wu et al[6].

Figure 2 describes the doppler broadened cross section in the energy range 10-1000 eV, comprising the important 132 eV resonance, and compares it with the measurements of Cote et al[49], Wu et al[6], Seidl et al[19], and Merrison et al[50].

Figures 3-7 show the evaluated total cross section in the respective following regions 1.0-10.0 keV, 10.0-25.0 keV, 25.0-50.0 keV, 50.0-75.0 keV, and 75.0-100.0 keV. As shown, the fit to the data of Garg et al[45] is generally good except for the thin sharp resonances. This is mainly due to the fact that resolution broadening was not applied in these calculations. Subseqent calculations taking into account resolution broadening indicated substantial improvement in the fit to the thin sharp resonances, examples of which are at energies of 6.38, 8.75, 9.69, 11.85, 19.75, 25.92, 29.4 keV in Figures 8, 9, 10. At the completion of

Table VI (Cont.)

E_o (keV)	J	Γ (eV)	Γ_n (eV)	Γ_γ (eV)
59.760	4	100.08	99.60	0.48
61.080	3	91.48	91.00	0.48
62.800	4	39.48	39.00	0.48
66.040	3	87.48	87.00	0.48
69.510	4	20.48	20.00	0.48
69.960	4	210.48	210.00	0.48
71.870	3	416.48	416.00	0.48
72.310	3	219.48	219.00	0.48
74.470	4	4.48	4.00	0.48
74.730	4	36.48	36.00	0.48
75.700	3	11.48	11.00	0.48
75.890	4	9.48	9.00	0.48
76.530	3	21.48	21.00	0.48
77.000	3	400.48	400.00	0.48
77.720	4	9.48	9.00	0.48
78.780	3	11.48	11.00	0.48
79.450	4	249.48	249.00	0.48
81.650	3	229.48	229.00	0.48
83.140	3	219.48	219.00	0.48
84.200	4	212.48	212.00	0.48
86.290	3	23.48	23.00	0.48
88.800	4	1156.48	1156.00	0.48
89.050	4	27.48	27.00	0.48
91.510	3	36.50	35.00	1.50

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16.920	4	165.52	165.00	0.52
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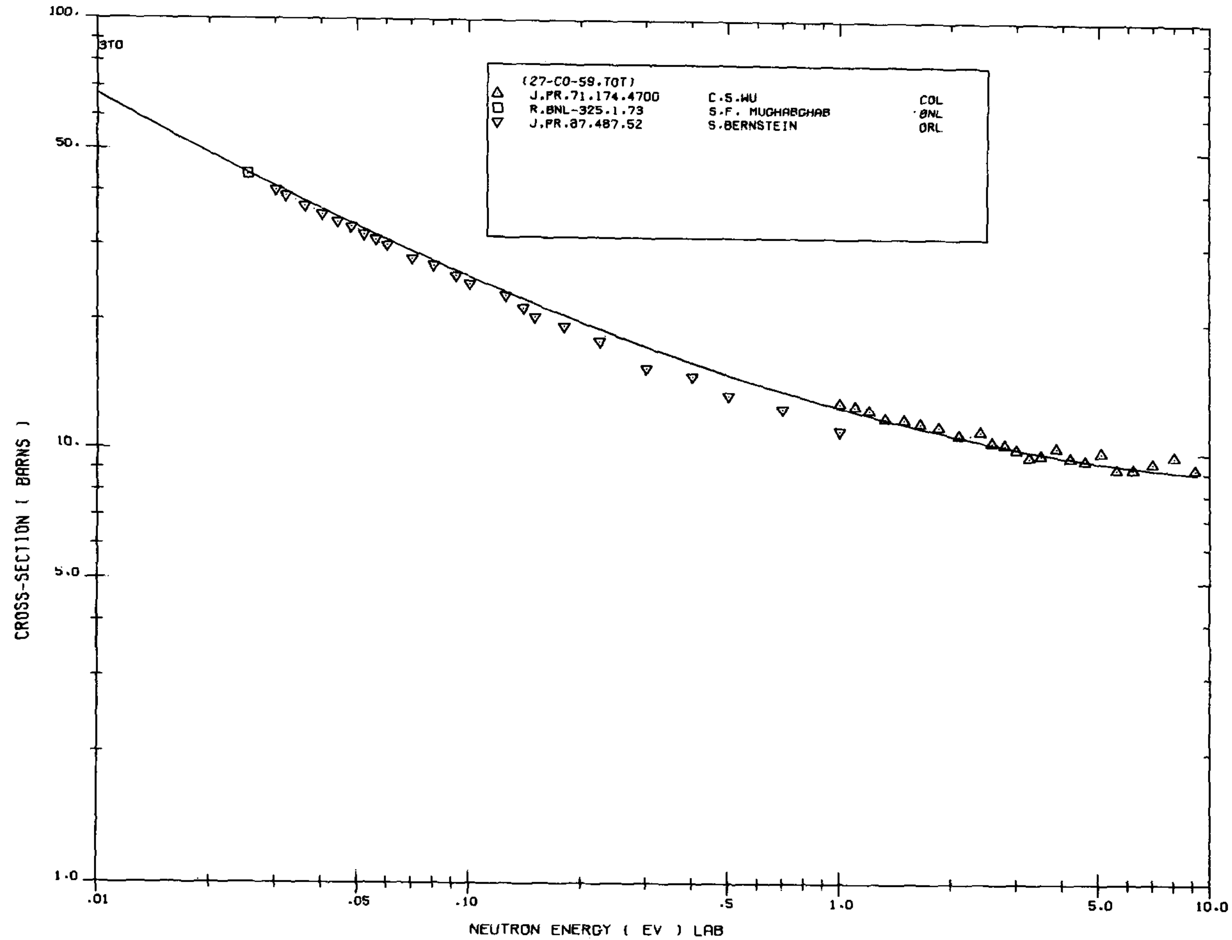

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NEUTRON ENERGY (EV) LAB

Figure 1.

V. The Total Cross Section of ^{59}Co and the Evaluation Procedure

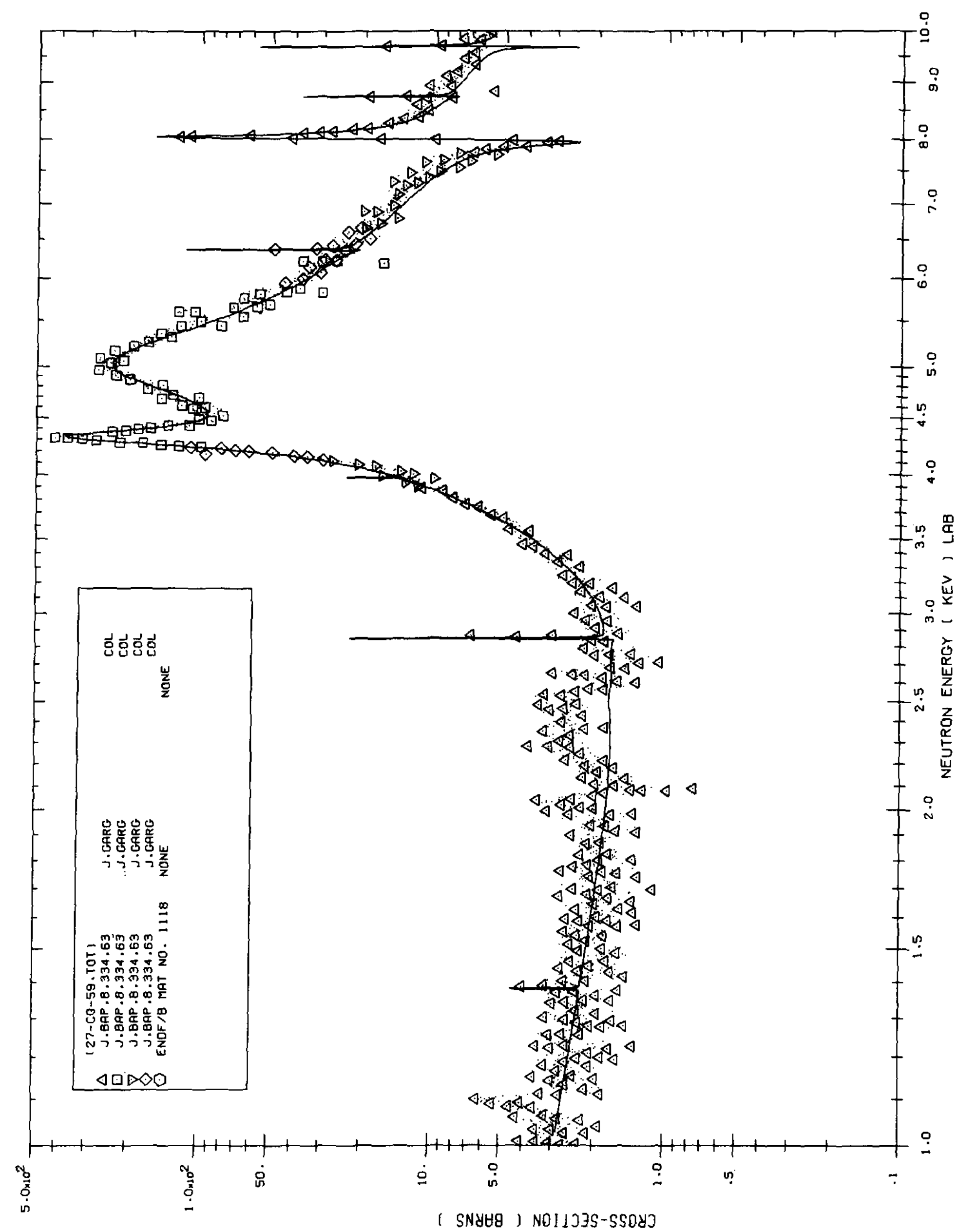
There are several measurements of the total cross section of ^{59}Co below 100 keV. Of these, two high resolution measurements reported in the literature are due to Garg et al(45) and Morgenstern et al(40-41) in the respective energy regions 0.14-128 keV and 1.38-500 keV. The total cross section measured by Garg et al(45) is available in the SCISRS Library. Unfortunately, the data of Morgenstern et al(40-41) is in transmission form, was not converted to total cross section by the authors, and is not available. In view of these considerations we applied the multilevel Breit-Wigner formalsim for a fitting of the data of Garg et al(45).

The technique of evaluating the total cross section from thermal energy to 100 keV proceeded along the following lines. As a starting point, the resonance parameters, the scattering radius, and the 2200 m/sec capture and scattering cross sections recommended(4) in BNL 325 were adopted. A multilevel Breit-Wigner total cross section curve was calculated using code RESEND(46). The initial calculation showed that the fit to cross section between resonances is poor, thus indicating that the potential scattering cross section is not adequately described.

As a result, the following modifications were subsequently made:

(1) The effective scattering radius R' was increased from 5.3 fm to 6.8 fm.

(2) The change in R' necessitated a change in the bound state parameters. Those in BNL 325 (1973) are based on a scatter-


(27-CO-59.TOT)
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ENDF/B MAT NO. 1118 NONE NONE
CROSS-SECTION (BARNS)
NEUTRON ENERGY (KEV) LAB
5.0x10^2
1.0x10^2
50.
10.
5.0
1.0
.5
.1
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
6.0
7.0
8.0
9.0
10.0

Figure 3.

(b) In the unresolved energy region, averaging the Breit-Wigner total cross section for s-wave resonances over an energy region containing many resonances, one obtains

$$\langle\sigma_T\rangle = 4\pi (R')^2 + 2\pi^2 ƛ^2 \sqrt{E}\, S_o + 0\ (S_o)^2$$

Usually, the contribution of higher order terms $0(S_o)^2$ in the keV energy range is small and can be neglected. By carrying out a least square fit to the average total cross section one can derive R' and S_o.

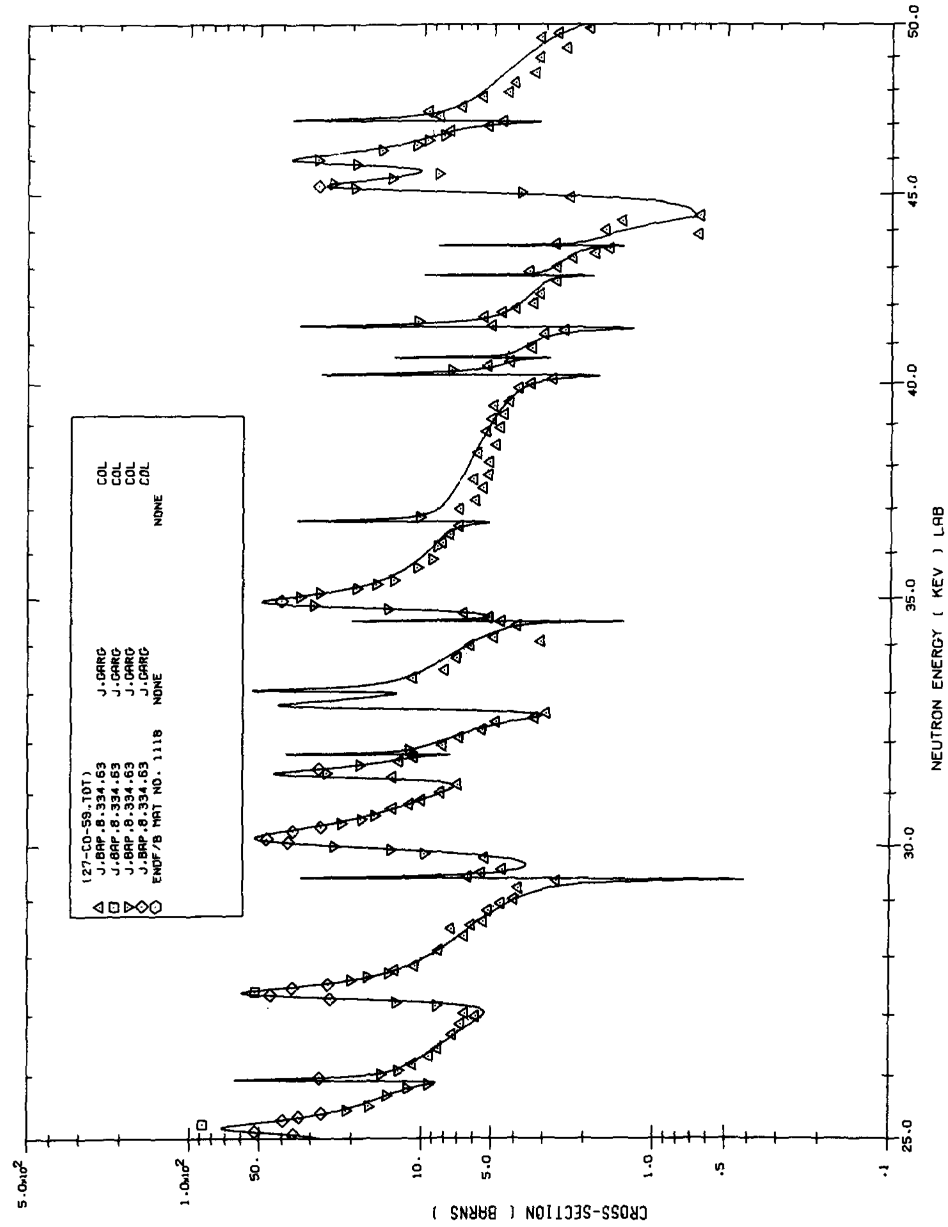
(c) A variation on the above method is to measure the variation of average transmission <T> at one neutron energy versus sample thickness. With the aid of the relation

$$\langle T\rangle = \left(1 - \frac{\Gamma n}{D}\ \frac{A}{\Gamma}\right) e^{-n\sigma_p}$$

one obtains R' through the potential scattering cross section σ_p where

$$\sigma_p = 4\pi (R')^2$$

Shape analysis of the ^{59}Co transmission data below neutron energy of 77 keV by Morgenstern et al[40] gave R' = 5.4 ± 0.5 fm. In an effort to search for a spin dependence of the scattering data, Morgenstern et al[40] fitted the transmission data in an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J.BAP.8.334.63 J.GARG COL
ENDF/B MAT NO. 1118 NONE NONE
NEUTRON ENERGY (KEV) LAB
CROSS-SECTION (BARNS)
25.0
30.0
35.0
40.0
45.0
50.0
5.0x10^2
1.0x10^2
50.
10.
5.0
1.0
.5
.1

Figure 5.

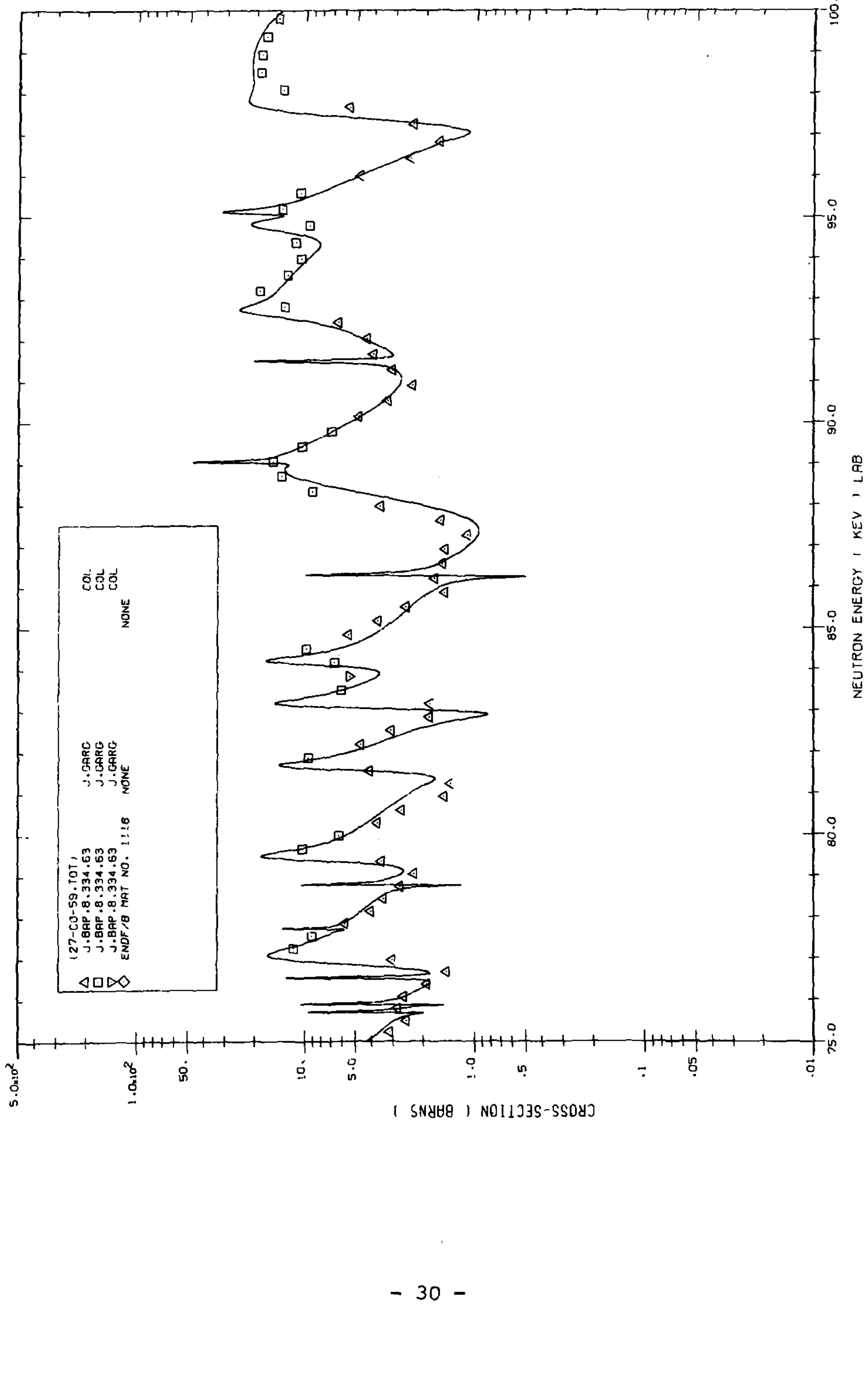
$$I\ (1/v) = 0.45\ \sigma_{\gamma}\ (2200\text{m/sec})$$

for a low energy cut off of 0.5 eV.

The values were normalized to a ^{197}Au absorption resonance integral of 1565 b. A weighted average value:

$$I_{o}(^{59}Co) = 74.9 \pm 0.8\ b$$

is obtained.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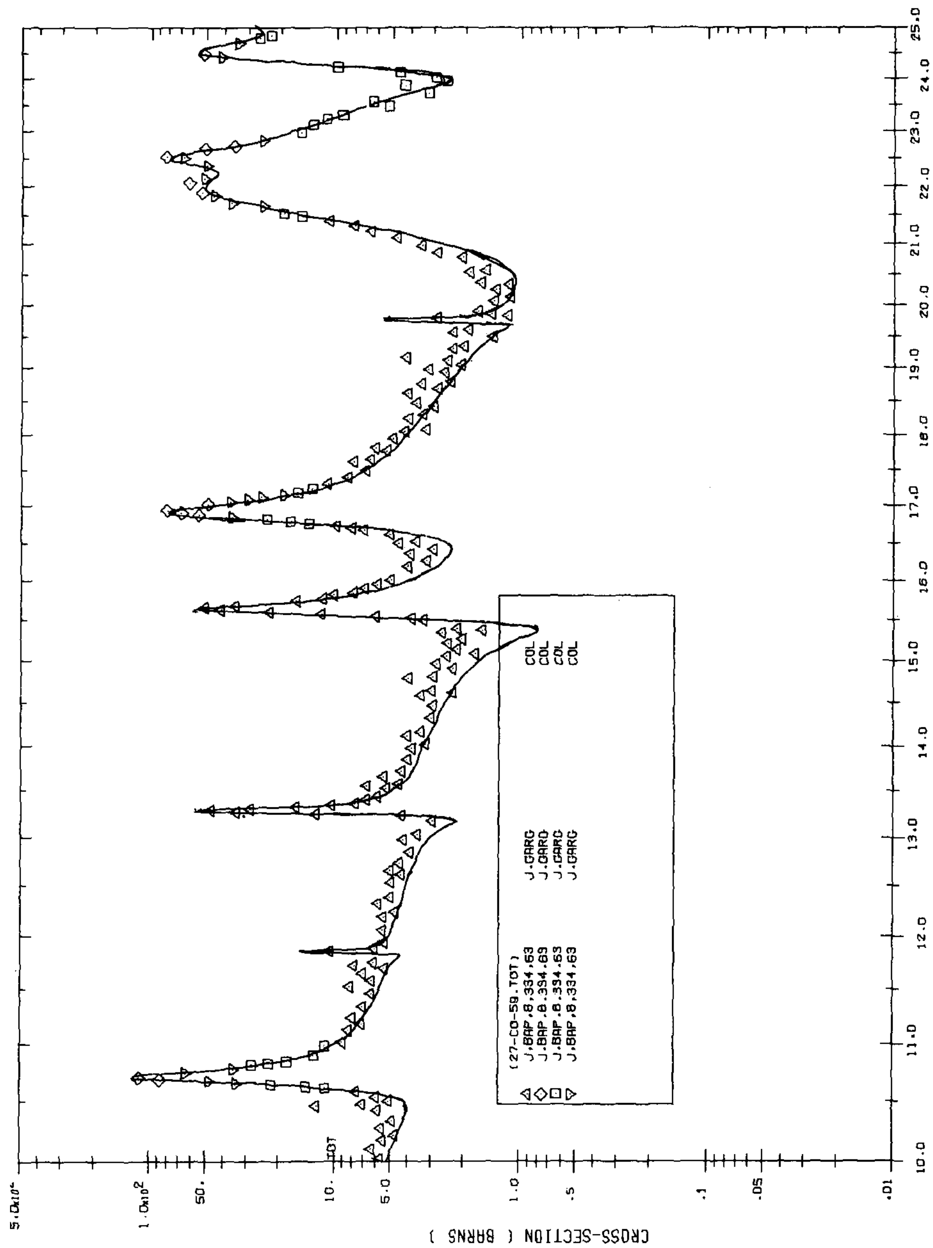
ENDF/B MAT NO. 1118 NONE NONE
CROSS-SECTION (BARNS)
NEUTRON ENERGY (KEV) LAB
5.0x10²
1.0x10²
50.
10.
5.0
1.0
.5
.1
.05
.01
75.0
80.0
85.0
90.0
95.0
100.0

Figure 7.

Table III

Resonance Parameters of the 132 eV Resonance

E_o	J	Γ(ev)	Γ_n(ev)	Γ_γ(ev)	Author
131.2			5.32±.05	0.46±.05	Bockhoff[25]
132			5.15±0.30		Garg[26]
132.0±0.5		6.0 ±0.2	5.15±.06		Nakajimo[27]
132.0±0.5	4	5.35±0.10	5.13±0.07	0.40±0.04	Jain[20]
130				0.44	Moxon[23]
132				0.67±0.15	Block[24]
134±2		5.2 ±0.7			Seidl[19]
132				0.48±.04	Wall[22]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J,BAP,8,334,63 J.GARG COL
NEUTRON ENERGY (KEV) LAB
CROSS-SECTION (BARNS)

Figure 9.

III. Parameters of the 132 eV Resonance and the Absorption Resonance Integral of ^{59}Co

The resonance parameters of the 132 eV resonance are particularly important because this resonance dominates thermal capture and gives the largest contribution to the absorption resonance integral. In addition ^{59}Co is used as a flux monitor in the energy region below 132 eV. In 1948, Seidl[18] studied the 132 eV resonance by the transmission method. Applying the Breit-Wigner formula, he obtained two sets of solutions: $\Gamma = 2.0 \pm 0.1$ eV and $J = 4$ or $\Gamma = 5.0 \pm 0.5$ eV and $J = 3$. The measured peak cross section of the resonance, $\sigma_o = 12{,}500 \pm 1250$b, favored a spin assignment of 4 in accordance with the relation

$$\sigma_o = 4\pi \lambda\!\!\!^{-2} g \left(\frac{A+1}{A} \right)^2$$

Subsequently, Seidl et al[19] used the BNL fast chopper facility to remeasure the resonance parameters of the 132 eV resonance. Values of $\Gamma = 5.0 \pm .07$ eV and $\sigma_o = 9700 \pm 1800$b were obtained.

More accurate and detailed determination of the parameters of the resonance were carried out by Jain et al[20]. Based on a comparison of the measured $2g\Gamma_n$ and Γ values, these authors deduced a spin assignment of 4 for this resonance. Measurement of the γ ray intensity[20] determined the value of the radiative width for the first time i.e. $\Gamma_\gamma = 0.40 \pm 0.04$ eV. Observa-

IV. Comparison with Polarization Data

As pointed out previously, at the completion of the evaluation, two data files for each spin state were prepared. Calculations of capture and scattering cross sections were carried out with the aid of the code INTER[47]. The scattering cross sections at thermal energies due to spin 3 and 4 resonances are found to be 12.94b and 1.71b respectively. From these values, one calculates bound coherent scattering amplitudes of 10.32 fm and -3.75 fm for J=3 and J=4 resonances. These values are in excellent agreement with the measurements of Ito and Shull[17]. The results of the scattering data are summarized in Table VII.

Table VII

Scattering Cross Sections Due to Two Spin States 3 and 4

	J=3	J=4
Free σ_{sc}(b)	12.94	1.71
Free a_{coh}(fm)	10.15	-3.69
Bound b_{coh}(fm)	10.32	-3.75
Exp. b_{coh}(fm)	10.60 ± 0.70	-3.80 ± 0.54

In addition, the capture and scattering cross sections at the following energies, 0.0253, 0.0725, and 2.11 eV for both spin states were determined. The results are presented in Table VIII.

to neutron threshold.

In addition, by assuming a total free scattering cross section of 6.7b and a coherent scattering amplitude of 2.5 fm, Schermer[16] obtained two sets of solutions for b_+ and b_- with the aid of the following relations:

$$\sigma_s = 4\pi g_+ b_+^2 + 4\pi g_- b_-^2$$

$$b_{coh} = g_+ b_+ + g_- b_-$$

In these relations g_+ and g_- are the statistical weight factors and b_+ and b_- are the bound coherent scattering amplitudes due to I + 1/2 and I - 1/2 resonances respectively; σ_s is the bound scattering cross section and is related to the free scattering cross section by

$$\sigma_s \text{ (bound)} = \sigma_s \text{ (free)} \left(\frac{A+1}{A}\right)^2$$

The two solutions for b_+ and b_- are presented in Table 2.

Table II

	b_+ (fm)	b_- (fm)
Case 1	+ 8.5 ± 0.2	- 5.3 ± 0.3
Case 2	-3.5 ± 0.2	+10.3 ± 0.3

Schermer[16] deduced that the second set satisfies his

Table IX

Comparison of the Calculation with
the Experimental Polarization Data

Capture at 0.0725 eV	Into J=4 States
Experimental	78.7 ± 1.0%*
Present Evaluation	79.2%
Capture at 2.11 eV	
Experimental	85.5 ± 5.4%*
Present Evaluation	79.6%
Scattering at 0.0725	By J=3 Resonance
Experimental	87 ± 1%
Present Evaluation	85.1%

*Value renormalized to σ_γ (2200 m/sec) = 37.2b the second edition of BNL 325[7] provides an adequate summary of the data prior to 1966. Since that time, new measurements have been carried out. These are indicated in Table 1.

Table 1

Recent Thermal Capture Measurements

Capture Cross Section (b)	Technique	Author
37.24 ± 0.11	pulsed neutron technique	Silk et al[8]
37.14 ± 0.24	activation	Merritt et al[9]
36.6 ± 0.5	activation	DeWorm[10
37.75 ± 0.4	activation	Kim[11]

A total capture and a free-atom scattering cross sections of 37.2 ± 0.2b and 6.7 ± 0.3b are recommended in BNL 325, third edition[4]. After the completion of this evaluation a very recent measurement by Dilg et al[12] using slow neutrons energies between 0.0399 and 2.608 meV appeared in the literature. These authors determined σ_γ (2200 m/sec) = 37.15 ± .08b for ^{59}Co. Because of the widely discrepant scattering cross sections measured by Bernstein et al[5] and Wu et al[6] and mentioned previously (σ_s = 5 band 6.7b), Dilg crried out total cross section measurement at 1.25 eV. By subtracting the capture cross section at this energy from the total cross section, he derived a value of 6.3b for the scattering cross section of ^{59}Co. This is in good agreement, within the stated error, with the value recommended[4] with a weighted average experimental value of 74.9 ± 0.8b and with a value of 75.5 ± 1.5 b recommended[4] in BNL 325 (1973). The Wescott g factor for capture calculated here is determined as 0.99996. The thermal cross sections are as follows:

Thermal Capture Cross Section	=	37.22 b
Thermal Elastic Scattering Cross Section	=	6.62 b
Thermal Total Cross Section	=	43.84 b

After the completion of this evaluation Koester et al[55] reported measurements of the total free-atom scattering cross section σ_{sc} and the coherent scattering amplitude. The values are:

$$\sigma_{sc} = 5.95 \pm 0.65 \text{ b}$$
$$b_c = 2.78 \pm 0.04 \text{ fm}$$

From these quantities, the scattering amplitudes b_+ and b_- corresponding to spin I + 1/2 and I - 1/2 states are calculated[55]. The results are:

$$b_+ = -2.78 \pm 0.04 \text{ fm}$$
$$b_- = +9.91 \pm 0.06 \text{ fm}$$

These quantities are in strong disagreement with the values reported by Ito and Shull[16]. In addition, these results imply that 91 ± 1% of the scattering is due to (I-1/2) spin states in with the evaluation (and in most instances measurements) in the energy range 0.1 - 20 MeV. In this report we present the analysis, evaluation, and documentation of the data below 100 keV.

The present evaluation differs basically from the previous ENDF/B III (MAT 1118) (in the resonance region) in the following respects: (1) the resonance energy region have been extended from 35 keV to 100 keV, (2) to describe the thermal capture, scattering, total cross section and the polairzation data single s-wave bound level with spin 3 was invoked. In the previous evaluation two bound levels with respective spins 3 and 4 were used. The necessity to invoke in ENDF/B III a bound level with spin 4 is attributed to adoption of a radiative width of 0.4 eV for the resonance at 132 eV with spin 4. The present evaluation adopts a radiative width of 0.48 eV for this resonance, i.e. as recommended in BNL 325 (1973).

Above neutron energy of 100 keV, the differences between ENDF/B IV and ENDF/B III are well described by Guenther et al[3].

ACKNOWLEDGMENTS

We would like to acknowledge the assistance of D. I. Garber, R. R. Kinsey, and A. J. Fuoco in the computer production of the figures in this evaluation and to B. A. Magurno and F. Scheffel for the operation of computer codes.

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Printed in the United States of America
Available from
National Technical Information Service
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December 1975 600 copies