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PROGRAMS FOR ANALYSIS OF
SCATTERING ANGULAR DISTRIBUTIONS

by

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ABSTRACT

This report describes FORTRAN programs written to aid in the analysis of neutron elastic-scattering angular distributions. The SAD program consists of subroutines used to obtain Legendre expansion coefficients by least-squares fitting of input angular data, to produce Calcomp plots of angular distribution data, to transform expansion coefficients from the laboratory system to the center-of-mass system, and to change the normalization of the expansion coefficients. Another program, DRIVER, plots expansion coefficients as a function of energy.

I. INTRODUCTION

Angular-distribution data for elastic scattering of neutrons from many materials are needed for inclusion in a library of neutron cross sections for use in reactor calculations. The SAD and DRIVER programs were written to aid in the acquisition of such data. Both programs are in CDC-3600 FORTRAN and involve the use of the Calcomp 580 plotter.

Sections II and III give detailed descriptions of programs SAD and DRIVER, including the input specifications. Section IV discusses the difficulties involved in least-squares fitting, followed by a comparison (Section V) of the least-squares and integration methods for obtaining Legendre coefficients. The appendixes contain FORTRAN listings for both SAD and DRIVER, as well as listings of input cards, printed and punched output, and examples of Calcomp plots.

II. PROGRAM SAD

A. Description of SAD Subroutines

The SAD code has a choice of five possible main paths. Program SAD itself merely reads as input a variable IPATH = 1, 2, 3, 4, and 5, thereby choosing the paths through subroutines LEGENDRE, POLYWOLY, OSCAR, COAGOGO, and RENORM, respectively.

1. Subroutine LEGENDRE

Subroutine LEGENDRE yields a least-squares fit to input angular-distribution data for up to 80 points, using as many as 20 Legendre polynomials. Several orders of expansion may be used with one set of input data.

The original version of LEGENDRE,¹ without the plotting features described below, was written by G. J. Duffy of the ANL Applied Mathematics Division.

In the least-squares fitting procedure, coefficients a_ℓ must be determined such that the expansion

$$\frac{d\sigma}{d\Omega} = \sum_{\ell=0}^{L-1} a_\ell P_\ell (\cos \theta) \quad (1)$$

yields the best fit to input angular-distribution data. In Eq. 1, $d\sigma/d\Omega$ is the differential scattering cross section in millibarns/steradian, θ is the scattering angle, and P_ℓ is the Legendre polynomial of order ℓ . The quantity to be minimized with respect to the variation of the a_ℓ is

$$S = \sum_{j=1}^N w_j \left[\sum_{\ell=0}^{L-1} a_\ell P_\ell (\cos \theta_j) - \left(\frac{d\sigma}{d\Omega} \right)_j \right]^2, \quad (2)$$

where $(d\sigma/d\Omega)_j$ is the input differential cross section at angle θ_j and having weight w_j , with the summation over j including N experimental points. Differentiation of Eq. 2 with respect to a_ℓ yields

$$\sum_{\ell=0}^{L-1} a_\ell \sum_{j=1}^N w_j P_\ell (\cos \theta_j) P_k (\cos \theta_j) = \sum_{j=1}^N w_j \left(\frac{d\sigma}{d\Omega} \right)_j P_k (\cos \theta_j), \quad (3)$$

where $k = 0, 1, \dots, L-1$. In matrix notation, Eq. 3 is

$$BA = Y, \quad (4)$$

where

$$B_{k\ell} = \sum_{j=1}^N w_j P_k (\cos \theta_j) P_\ell (\cos \theta_j),$$

$$A = \begin{pmatrix} a_0 \\ a_1 \\ \vdots \\ a_{L-1} \end{pmatrix},$$

and

$$Y = \begin{Bmatrix} \sum_{j=1}^N w_j \left(\frac{d\sigma}{d\Omega} \right)_j P_0 (\cos \theta_j) \\ \vdots \\ \sum_{j=1}^N w_j \left(\frac{d\sigma}{d\Omega} \right)_j P_{L-1} (\cos \theta_j) \end{Bmatrix}$$

The coefficients a_ℓ in Eq. 4 are obtained by use of the matrix inversion subroutine MATINV described below.

The standard deviations, δa_ℓ , of the coefficients a_ℓ are calculated from²

$$\delta a_\ell = \left[\frac{B_{\ell\ell}^{-1} \sum_{j=1}^N w_j \left[\sum_{\ell=0}^{L-1} a_\ell P_\ell (\cos \theta_j) - \left(\frac{d\sigma}{d\Omega} \right)_j \right]^2}{N - L} \right]^{1/2}, \quad (5)$$

where $B_{\ell\ell}^{-1}$ is a diagonal element of B^{-1} , the inverse of matrix B. For $N = L$, Eq. 5 is used without the $N - L$ term in the denominator.

Subroutines POLYLOT and POLYP may be used when the path through LEGENDRE is followed. POLYLOT draws a graph with the differential scattering cross section determined by the expansion coefficients plotted against the cosine of the scattering angle. Subroutine POLYP plots the input points used in the fitting on the graph and can also plot other points if desired.

2. Subroutine POLYWOLY

Subroutine POLYWOLY reads punched output for several energies obtained from running LEGENDRE, OSCAR, or COAGOGO problems. This output consists of a heading card and cards containing the Legendre coefficients. POLYWOLY then uses POLYLOT to plot all the angular distributions determined by the Legendre coefficients on one graph. Each curve is labeled with the energy.

3. Subroutine OSCAR

Subroutine OSCAR reads, as input, coefficients that have been obtained by fitting experimental data. It will normalize the coefficients as in LEGENDRE, transform them from the laboratory to the center-of-mass system, and correct the first coefficient for inelastic scattering and fission assuming isotropy in the center-of-mass system. OSCAR was written for use with the data of Langsdorf and co-workers,³ who plot coefficients in the laboratory system for each ℓ in the expansion as a function of

energy. At one time, a machine called OSCAR was available to assist in reading the points off the graphs and in punching the input cards.

Two normalizations have been used by Langsdorf *et al.*³ One is

$$\frac{d\sigma}{d\Omega} = \frac{\sigma_s}{4\pi} \sum_{\ell=0}^{L-1} w_\ell P_\ell(\cos \theta) \text{ barns/steradian}, \quad (6)$$

with

$$w_0 = 1;$$

the other is that of Eq. 1, except for units of barns/steradian rather than millibarns/steradian.

To transform the coefficients from the laboratory to the center-of-mass system, the subroutine MATRIX is used. This subroutine, and function CLEB, which is used by MATRIX, were both taken from the Atomics International Code CHAD.⁴

The correction for inelastic scattering and fission is made by multiplying the coefficient for $\ell = 0$ by the factor

$$\frac{\sigma_T - \sigma_{inel} - v\sigma_f}{\sigma_T}.$$

This correction is based on the assumption that all secondary neutrons are detected without energy discrimination so that the experimental σ_s in Eq. 6 is actually the σ_T of the above factor. Also, the above factor involves the assumption that inelastically scattered and fission neutrons are produced isotropically in the center-of-mass system. The input values of σ_{inel} , v , and σ_f are based on sources other than the experiment yielding the input coefficients.

4. Subroutine COAGOGO

Subroutine COAGOGO reads expansion coefficients in the normalization and format used by Smith and co-workers⁵ and changes them to the LEGENDRE normalization. The normalization used by Smith *et al.*, is that of Eq. 6. The MATRIX subroutine is used to transform the coefficients from the laboratory to the center-of-mass system. Subroutine POLYLOT may be used to plot the angular distribution.

COAGOGO may also be used to plot graphs using POLYLOT by reading, as input, coefficients previously punched out by LEGENDRE, OSCAR, or COAGOGO. An option available in COAGOGO allows the height of the graph and the scale of the Y-axis to be determined by the code rather than by being input.

5. Subroutine RENORM

Subroutine RENORM reads coefficients punched by LEGENDRE, OSCAR, or COAGOGO in the format of Eq. 1 and changes them to the normalization of the

ENDF/B library. The ENDF/B normalization is

$$\frac{d\sigma}{d\Omega} = \frac{\sigma_s}{4\pi} \sum_{\ell=0}^{L-1} (2\ell + 1) f_{\ell} P_{\ell}(\cos \theta) \text{ barns/steradian}, \quad (7)$$

with

$$f_0 = 1.$$

6. Subroutine MATINV

Subroutine MATINV⁶ solves the matrix equation $AX = B$, where A is a square matrix of order N , and X and B are matrices with N rows and M columns. In many applications, including the present one, X and B are column vectors, so that $M = 1$. Calling the MATINV subroutine has the effect of replacing A by its inverse A^{-1} and B by X . Also, the determinant of A is returned to the calling program.

Subroutine MATINV was written by B. S. Garbow of the ANL Applied Mathematics Division.

7. Subroutine POLYPLOT

Subroutine POLYPLOT uses the Calcomp-580 plotter to plot a graph of the curve determined by the Legendre expansion coefficients. A linear scale for $\mu = \cos \theta$ extending from 1 to -1 is used along the X-axis. Either a linear or a logarithmic scale may be used along the Y-axis in plotting $d\sigma/d\Omega$ in millibarns. The logarithmic scale is suitable for high-energy angular distributions, which typically have a high peak at $\mu = 1$ and rather low peaks over the rest of the angular range. The angular distribution is computed from the coefficients at 101 equally spaced values of μ for the plotting. If a portion of the curve lies above or below the range of the Y-axis, it is drawn on the top or bottom edge of the graph, respectively.

The name of the material and the mass number are drawn below the X-axis, and the number of terms in the expansion is drawn within the lower left-hand corner of the graph, except when POLYPLOT is called by POLYWOLY. The curve determined by the coefficients is labeled with the energy. When POLYPLOT is called by POLYWOLY, more than one curve may be drawn on the same graph.

The Calcomp plotting package is used in conjunction with POLYPLOT and the other subroutines that involve plotting. This package consists of a set of binary subroutines for the CDC-3600, described in Ref. 7.

8. Subroutine POLYP

Subroutine POLYP is called by LEGENDRE to plot the points used in the fitting if KPLOTS = 2 or 3 in the LEGENDRE input. Triangular symbols are used in the plotting. POLYP plots NEX other sets of points read in by the LEGENDRE subroutine for KPLOTS = 3 or 4. Different symbols are used in plotting the extra points. Also, POLYP draws NEX + 1 legends for KPLOTS = 3 or NEX legends for KPLOTS = 4. The legends are drawn to the right of the graph parallel to the Y-axis.

9. Subroutine MATRIX

Subroutine MATRIX calculates the transformation matrix, T^{-1} , used in transforming coefficients from the laboratory to the center-of-mass system. It can also calculate the inverse matrix, T , required for going from the center-of-mass to the laboratory system, although this option is not involved in the SAD program.

The equations used for the calculation of T^{-1} are given below. Reference 4 presents a detailed derivation of the equations. The normalization of the transformation matrix in the following equations is that necessary for transforming the f_ℓ of Eq. 7. Thus,

$$f_\ell^C = \sum_{m=0}^{\infty} T_{\ell m}^{-1} f_m^L, \quad (8)$$

where the f_ℓ^C and f_m^L are coefficients in the center-of-mass and laboratory systems, respectively.

The first row of the transformation matrix is simply

$$T_{0k}^{-1} = \delta_{0k}, \quad (9)$$

where δ_{0k} is the Kronecker delta; the second row is computed from

$$T_{10}^{-1} = -\frac{2}{3} \gamma, \quad (10)$$

$$T_{12}^{-1} = \frac{2}{3} \gamma, \quad (11)$$

$$T_{1,2n+4}^{-1} = 0, \quad n = 0, 1, \dots, \quad (12)$$

and

$$T_{1,2n+1}^{-1} = \frac{4n+3}{2} \left[\frac{4(-r)^n}{\sqrt{1+r}} \sum_{\ell=0}^{\infty} \frac{(-1)^\ell [(2\ell+2n+1)!]^2 (\ell+2n+1)! r^\ell}{2^{2\ell} [(\ell+n)!]^2 (2\ell+4n+3)! [1-4(\ell+n)^2] \ell!} \right]. \quad (13)$$

In Eqs. 10 and 11, γ is the ratio of the neutron mass to the mass of the atom, while $r = \gamma^2/(1-\gamma^2)$. The remaining rows of the matrix are found from the recursion formula

$$T_{\ell+1,k}^{-1} = \frac{2\ell+1}{\ell+1} \left[\sum_{n=0}^{\infty} T_{1n}^{-1} \sum_{m=|n-k|}^{n+k} C^2(nmk;000) T_{\ell m}^{-1} \right] \frac{-\ell}{\ell+1} T_{\ell-1,k}^{-1}, \quad (14)$$

where the $C(nmk;000)$ are Clebsch-Gordan coefficients.

In the calculation of the inverse transformation from the center-of-mass to the laboratory system, Eqs. 9 and 14 can be used with T^{-1} replaced by T . Equations 10-13 are replaced by

$$T_{1k} = \frac{k}{2k-1} (-\gamma)^{k-1} - \frac{k+2}{2k+3} (-\gamma)^{k+1}, \quad k = 0, 1, \dots \quad (15)$$

Subroutine MATRIX and function CLEB were taken from the CHAD code⁴ with only those changes necessary for adaption to CDC-3600 FORTRAN and for transforming coefficients in the normalization of Eq. 1 rather than that of Eq. 7.

10. Function CLEB

Function CLEB calculates the Clebsch-Gordan coefficients $C(nmk;000)$ required by subroutine MATRIX. Equation 3.32 of Ref. 8 is used in this calculation.

B. Input and Output Descriptions for SAD Paths

In the following input descriptions, the information is given in four columns. These are, respectively, the card type number, the format used for the variables, the variable FORTRAN names and a description of the meanings and ranges of the input quantities. Standard FORTRAN format designations are used.

1. LEGENDRE Path

No.	Format	FORTTRAN- Name	Description
1	(I3)	IPATH	IPATH = 1 to choose LEGENDRE path in SAD.
2	(I3)	IFCAL	IFCAL > 0 if plotting is desired.

The following two cards are read for each set of MP problems:

1	(12A6)	(RECORD(I), I = 1,12)	Hollerith title to be used in printout describing this set of MP problems.
2	(6I3)	MP, MPE, MPWGTs,	Number of problems with the above title card. If = 0, no angular distributions are calculated from the fitted coefficients and printed out. If = 1, angular distributions are calculated from the fitted coefficients for each point in the input. If = 0, weights w_j are input. If = 1, $w_j = 1/(d\sigma/d\Omega)_j$. If = 2, $w_j = 1$. If = 3, $w_j = 1/\epsilon_j^2$, where ϵ_j are input.

No.	Format	FORTRAN Name	Description
		MRADEG,	If = 0, angle input is in radians. If = 1, angle input is in degrees. If = 2, cosines of angles are input.
		MORADG,	If = 0, angle output is in radians. If = 1, angle output is in degrees. If = 2, cosines of angles are output.
		MERROR	If = 0, no error matrix is printed. If = 1, error matrix is printed.

The following card types are read for each problem:

1	(A3, I5, F8.3, 2X, 6I3, 4F10.0, I4)	MATERIAL	Chemical symbol of material (e.g., FE).
		NUM,	Mass number (or atomic number if preferred).
		ENERGY,	Energy in MeV.
		LMIN,	Minimum number of terms in fit. Expansion includes P_0 through P_{LMIN-1} .
		LMAX,	Maximum number of terms in fit.
		N,	Number of points to be fit.
		NX,	If = 0, no extra values of $\cos \theta$ are input. If > 0, NX extra values of $\cos \theta$ are input and $d\sigma/d\Omega$ will be calculated from the coefficients at these values.
		NPLOTS,	If = 0, don't plot. If = 1, plot best fit of those involving from LMIN to LMAX terms. If = 2, plot fit for each L used from LMIN to LMAX.

No.	Format	FORTTRAN Name	Description
		KPLOTS,	<p>If = 1, plot no experimental (input) points.</p> <p>If = 2, plot input points used in fitting.</p> <p>If = 3, plot input points used in fitting, NEX other sets of points, and NEX + 1 legends.</p> <p>If = 4, don't plot input points used in fitting. Plot NEX other sets of points and NEX legends.</p>
		XLEN,	Length of X-axis in inches.
		YO,	Minimum values on Y-axis in millibarns. If logarithmic plotting is used, YO must be a number that is a power of 10.
		SCALEY,	Y-axis scale in inches/millibarn for linear plotting, or inches/decade for log plotting.
		YLEN,	Length of Y-axis in inches.
		ILOG	<p>If = 0, a linear Y-axis is desired.</p> <p>If = 1, a logarithmic Y-axis is desired.</p>
2	(I3)	LDELTA	Fits are made for $L = L_{MIN}$, $L_{MIN} + L_{DELTA}$, $L_{MIN} + 2(DELTA)$, ..., L_{MAX} .
3 (for MPWGTS = 1 or 2) or 3 (for MPWGTS = 0 or 3)	(10F8.0) (9F8.0)	(THETA(I), Y(I), I = 1,N) (THETA(I), Y(I), W(I), I = 1,N)	<p>Pairs of angles or cosines and $d\sigma/d\Omega$ to be fit. The $d\sigma/d\Omega$ must be in millibarns/steradian.</p> <p>Triplets of angles or cosines, $d\sigma/d\Omega$, in millibarns/steradian, and weight factors, w_j or ϵ_j, to be used in fitting.</p>
4 (for NX>0)	(5E14.8)	(XTHETA(I), I = 1, NX)	Extra values of $\cos \theta$ at which $d\sigma/d\Omega$ will be calculated.
5 (for KPLOTS = 3 or 4)	(I3)	NEX	Number of extra sets of points to be read in.

No.	Format	FORTTRAN Name	Description
6 (for KPLOTS = 3)	(10A6)	(LMESS(1,I), I = 1, 10)	Legend describing points used in fit that will be drawn using POLYP.

The following three card types occur for $I = 1, 2, \dots, NEX$:

7 (for KPLOTS = 3 or 4)	(10A6)	(LMESS(I,J), J= 1,10)	Legend describing Ith set of extra experimental points.
8 (for KPLOTS = 3 or 4)	(I3)	NEXPTS(I)	Number of pairs of $\cos \theta_j$ and $(d\sigma/d\Omega)_j$ for Ith set of extra experimental points.
9 (for KPLOTS = 3 or 4)	(10F8.0)	(ANGLE(I,J), BARNS(I,J), J = 1, JJ)	Pairs of $\cos \theta_j$ and $(d\sigma/d\Omega)_j$ in millibarns/steradian for Ith set of extra experimental points. Here JJ = NEXPTS(I).

The printed output for the LEGENDRE path begins with the title card and the control parameters for the set of MP problems. For each problem, the output begins with the material identification, energy, and control parameters. For each number of terms, L, used in the problem, the Legendre coefficients determined by the fit are output, followed by a table containing the input values of θ_i or $\cos \theta_i$, the experimental $(d\sigma/d\Omega)_i$, the $(d\sigma/d\Omega)_i$ as calculated from the coefficients, and the differences of experimental and calculated $(d\sigma/d\Omega)_i$. If $NX > 0$, the extra values of $\cos \theta$ and the corresponding calculated $d\sigma/d\Omega$ are then output. The standard deviations of the Legendre coefficients are given, followed by the sum of the squares of the differences between the input and calculated $(d\sigma/d\Omega)_i$. If MERROR = 1, the error matrix, B^{-1} , is printed out. Output quantities are labeled for easy identification. All Legendre coefficients and differential cross sections are in millibarns/steradian.

The punched output from LEGENDRE for each L value in each problem starts with a heading card giving the quantities MATERIAL, NUM, ENERGY, N, and L in an (A3, I5, F8.3, 2I5) format. Then the following card or cards contain the Legendre coefficients $a_0, a_1, \dots, a_{L-1}$ in a (5E16.8) format.

Appendix B-1 lists the input cards for a sample LEGENDRE problem. In this problem, experimental data of Towle and Gilboy⁹ for aluminum at 3.01 MeV are fit, using five-, seven-, and nine-term Legendre expansions. Calcomp plots with a linear Y-axis are obtained. The printed output, punched output, and plots are given in Appendixes C-1 and D-1 and Figs. 1-3 of Appendix E, respectively.

Figure 4 of Appendix E is a Calcomp plot illustrating the use of the logarithmic option for the Y-axis. This plot was obtained by fitting the output of an Abacus-2 problem¹⁰ for gadolinium using a 15-term Legendre expansion.

2. POLYWOLY Path

No.	Format	FORTTRAN Name	Description
1	(I3)	IPATH	IPATH = 2 to choose POLYWOLY path in SAD.
The following cards are read for each graph desired:			
2	(I3)	NPLOT	Number of curves to be plotted on one graph.
3	(4F10.0, I3)	XLEN, YO, SCALEY, YLEN, ILOG	Length of X-axis in inches. Minimum value on Y-axis in millibarns. If logarithmic plotting is used, YO must be a number that is a power of 10. Y-axis scale in inches/millibarn for linear plotting or inches/decade for logarithmic plotting. Length of Y-axis in inches. If = 0, a linear Y-axis is desired. If = 1, a logarithmic Y-axis is desired.

The following cards occur NPLOT times. These cards may be the punched output obtained from the LEGENDRE, OSCAR, or COAGOGO paths.

1	(A3, I5, F8.3, 5X, I5)	MAT, NUM, EN, L,	Chemical symbol of material. Mass number or atomic number of material. Energy in MeV. Number of Legendre coefficients.
2	(5E16.8)	(B(I), I = 1, L)	Expansion coefficients $a_0, a_1, \dots, a_{L-1}$ in normalization of Eq. 1.

The printed output from POLYWOLY consists merely of MAT, NUM, EN, and L as read from each of the NPLOT heading cards corresponding to each graph. There is no punched output.

Input cards for a sample POLYWOLY problem are listed in Appendix B-2. This problem produces a Calcomp graph with angular-distribution curves for sodium at six energies. The input coefficients were based on fitting English data in ENDF/A¹¹ using the LEGENDRE path. The printed output for this problem is in Appendix C-2; the Calcomp plot is Fig. 5 of Appendix E.

3. OSCAR Path

No.	Format	FORTTRAN Name	Description
1	(I3)	IPATH	IPATH = 3 to choose OSCAR path in SAD.
2	(4I3)	NCOORD, NCOEFF, INEL, KSIG	If = 0, do not transform input coefficients to the center-of-mass system. If = 1, transform input coefficients to the center-of-mass system. If = 0, input coefficients are normalized as in Eq. 1. If = 1, change to normalization of Eq. 1 from the normalization of Eq. 6. If = 0, no correction is made for inelastic scattering and/or fission. If = 1, correct first coefficient for inelastic scattering and/or fission. If = 0 or 1, σ_T is input as SIGSCAT(I). If = 2, $\sigma_T/4\pi$ is input as SIGSCAT(I).
3	(A3, I3, F10.5, 2I3, 2F5.0)	MAT, NO, AMASS, NLEVLs, L, XSCALE, GAMF	Chemical symbol of material. Mass number or atomic number. Mass of material/neutron mass. Number of energies. Number of terms in Legendre expansion. Divide input energies, EN(I), by XSCALE to get correct energy. (This quantity referred to a scale factor on the graph-reading machine, OSCAR.) Number of neutrons per fission.

No.	Format	FORTTRAN Name	Description
4		Blank Card	
5		Blank Card	
6	(10F8.0)	(EN(I), SIGSCAT(I), I = 1, NLEVL5)	Pairs of energies in MeV and σ_T (or $\sigma_T/4\pi$) in barns.

The following two card types occur for $K = 2, 3, \dots, L$:

1		Blank Card	
2	(10F8.0)	(BLAB(K,I), I = NLEVL5)	Coefficients w_{K-1} of Eq. 6 at energy EN(I) if NCOEFF = 1. For NCOEFF = 0, these are the coefficients a_{K-1} of Eq. 1 in millibarns/ steradian.

The following card type occurs if INEL = 1:

1	(10F8.0)	(SIGIN(K), SIGF(K), K = 1, NLEVL5)	Pairs of inelastic scatter- ing and fission cross sec- tions (σ_{inel} and σ_f) in barns at energy EN(K).
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The printed output from OSCAR begins with identification and control parameters, followed by the expansion coefficients with the normalization of Eq. 1 in both laboratory and center-of-mass systems for each energy in the input. If the input coefficients were in the center-of-mass system, no laboratory system coefficients are given in the output. Then a table is given of the cross sections σ_T , σ_{inel} , σ_f , and σ_{el} (elastic scattering) in barns at the input energies.

The OSCAR punched output for each energy consists of a heading card with the quantities MAT, NO, EN(K), and L in an (A3, I5, F8.3, 5X, I5) format, followed by a card or cards with the coefficients $a_0, a_1, \dots, a_{L-1}$ in a (5E16.8) format. Thus the punched output is the same as that for the LEGENDRE path, except that the number of points to be fit, which is irrelevant here, is omitted.

Input cards for a sample OSCAR problem are listed in Appendix B-3. In this problem, Legendre coefficients in the normalization of Eq. 1 are read for oxygen at five energies and are transformed to the center-of-mass system. No correction for inelastic scattering is made as the energies involved are below the inelastic threshold. The input data were derived from graphs in Ref. 3. Appendixes C-3 and D-2 present the printed and punched output, respectively.

4. COAGOGO Path

<u>No.</u>	<u>Format</u>	<u>FORTTRAN Name</u>	<u>Description</u>
1	(I3)	IPATH	IPATH = 4 to choose the COAGOGO path in SAD.
2	(I3)	IFCAL	If = 0, no plotting. If = 1, plotting with graph dimensions and scales calculated internally. If = -1, plotting with dimensions and scale as input.
3	(4I3)	NCOORD,	If = 0, do not transform input coefficients to the center-of-mass system. If = 1, transfer input coefficients to the center-of-mass system.
		NCOEF,	If = 0, input coefficients have normalization of Eq. 1. If = 1, input coefficients have normalization of Eq. 6.
		INEL,	If = 0, 1, don't correct for inelastic scattering. If = 2, first coefficient is corrected for inelastic scattering.
		L	Number of terms in expansion.
4	(2A3, F10.5, I3)	MAT,	Chemical symbol of material.
		NO,	Mass number or atomic number.
		AMASS,	Mass of material/neutron mass.
		NLEVLS	Number of energies.

The following five card types occur if NCOEF = 1:

- 1 Blank Card (once)

Card types 2 through 5 occur NLEVLS times.

- 2 (6X, F4.3, EN, Energy in MeV.
F4.2,
6(F5.3,4X)) SIGEL, Elastic scattering cross
section in barns.

No.	Format	FORTRAN Name	Description
		(A(J), J = 1,6)	$w_1, w_2, \dots, w_6$ coefficients in normalization of Eq. 6.
(The format of card type 2 is the one used by Smith <i>et al.</i> , ⁵ in storing experimental results.)			
3 (if INEL=2)	(F10.5)	SIGIN	Inelastic scattering cross section, σ_{inel} , in barns.
4 (if INEL=2)	(F10.5)	SIGTOT	σ_T in barns.
5 (if IFCAL=-1)	(4F10.0, I4)	XLEN, YO, SCALEY, YLEN, ILOG	Length of X-axis in inches. Minimum value on Y-axis in millibarns. If logarithmic plotting is used, YO must be a number that is a power of 10. Y-axis scale in inches/ millibarn for linear plot- ting, or inches/decade for log plotting. Length of Y-axis in inches. If = 0, a linear Y-axis is desired. If = 1, a logarithmic Y-axis is desired.

The following cards replace the above five types if NCOEF = 0, and occur
NLEVLs times:

1	(8X, F8.3, 5X, I5)	EN	Energy in MeV.
		L	Number of terms in expansion.
2	(5E16.8)	(B(K), K = 1, L)	Coefficients $a_0, a_1, \dots,$ a_{L-1} in normalization of Eq. 1.
3 (if INEL=2)	(F10.5)	SIGIN	Inelastic scattering cross section, σ_{inel} , in barns.
4 (if INEL=2)	(F10.5)	SIGTOT	σ_T in barns.
5 (if IFCAL=-1)	(4F10.5, I4)	XLEN, YO, SCALEY, YLEN, ILOG	Definitions are as for card type 5 for NCOEF = 1.

Note that logarithmic plotting is available only for IFCAL = -1. For IFCAL = 1, linear plotting is obtained with the dimensions and scales determined by the program.

The printed output for COAGOGO begins with the identification and control parameters. On a separate page for each energy are given the energy, σ_{el} and σ_{inel} , the input coefficients in both the Eq. 6 normalization (if used) and the Eq. 1 normalization, and the coefficients in the center-of-mass system in the Eq. 1 normalization. Then values of $d\sigma/d\Omega$, calculated from the center-of-mass coefficients, are presented for 11 equally spaced values of $\cos \theta$ from -1 to +1.

The punched output from COAGOGO is exactly the same as that from OSCAR.

Input cards for a sample COAGOGO problem are listed in Appendix B-4. Here input coefficients for chromium at five energies are read in the normalization of Eq. 6, transformed to the center-of-mass system and changed to the normalization of Eq. 1. The input coefficients were obtained from Smith.⁵ Calcomp plots are obtained at each energy, the graph dimensions and scales being determined by the program. Appendixes C-4 and D-3 list the printed and punched outputs, respectively. One of the five Calcomp plots obtained is presented as Fig. 6 in Appendix E.

5. RENORM Path

No.	Format	FORTTRAN Name	Description
1	(I3)	IPATH	IPATH = 5 to choose RENORM path in SAD.
2	(A3, I5, F8.3, 5X, I5)	MAT,	Chemical symbol of material.
		NUM,	Mass number or atomic number.
		ENERGY,	Energy in MeV.
		L	Number of terms in expansion.
3	(5E16.8)	(B(I), I = 1, L)	Coefficients $a_0, a_1, \dots, a_{L-1}$ of Eq. 1.

The following two card types are read for each energy:

Printed output from RENORM at each energy consists of the energy, σ_{el} , and the Legendre coefficients in both the input normalization of Eq. 1 and the normalization of Eq. 7. The normalization of Eq. 1 is referred to as the MC² normalization in the printout because the Argonne MC² code uses this normalization.

The RENORM punched output begins with a heading card with MAT, NUM, ENERGY, L, and σ_{el} in an (A3, I5, F8.3, 5X, I5, F10.5) format. The remaining cards contain the coefficients $f_1, f_2, \dots, f_{L-1}$ in a (6E13.5) format.

Appendix B-5 lists input cards for a sample RENORM problem. Legendre coefficients at five energies, obtained by fitting English iron data in ENDF/A¹¹ using LEGENDRE, are changed from the normalization of Eq. 1 to the ENDF/B normalization of Eq. 7. The printed output is in Appendix C-5; the punched output is in Appendix D-4.

III. PROGRAM DRIVER

A. Description of Program DRIVER and Associated Subroutines

1. Program DRIVER

Program DRIVER reads expansion coefficients for a series of energies as punched by LEGENDRE, OSCAR, or COAGOGO in the LEGENDRE normalization, or as punched by RENORM in the ENDF/B normalization. Several orders of expansion may be used at a given energy. A Calcomp graph is drawn for each ℓ in the expansion in which the coefficients a_ℓ or f_ℓ are plotted on a linear scale against the energy on a logarithmic scale. For $\ell = 0$ in the ENDF/B normalization, σ_s is plotted against the energy. The symbols used in the plotting are determined by the number of terms in the expansion. The axes are labeled with the material identification, the ℓ value, and input Hollerith information.

The input coefficients are scanned by the program to determine a suitable scale on the Y-axis for a graph 10 in. high. The minimum energy and number of inches per energy decade are furnished in the input to specify the X-axis.

The FORTRAN subroutines LNGRID, LNAXIS, LINAXIS, LNLABEL, and LINLABEL are used in drawing the axes, hash marks, grid lines, and numbers along the axes. These are general-purpose plotting routines, described below, which were originally written by John Zenor of the Reactor Physics Division and later slightly modified by Phyllis Walker of the Applied Mathematics Division.¹² These subroutines, as well as the DRIVER program itself, use the binary plotting package for the Calcomp-580 plotter.⁷

2. Subroutine LINAXIS (ITYPE, BEGIN, EEND, POS, CYCLEL, TA, TB, AXLAST)

Subroutine LINAXIS is used to draw an axis with hash marks according to a linear scale. ITYPE = 1 produces an X-axis; ITYPE = 2 yields a Y-axis. For ITYPE = 1, the X-axis starts with coordinates (BEGIN, POS) and ends with coordinates (AXLAST, POS), where BEGIN, POS, and AXLAST are in inches. There are ten equal intervals separated by hash marks in every CYCLEL inches. If the difference between BEGIN and EEND is an integral multiple of CYCLEL, the value calculated and returned for AXLAST will equal EEND. Otherwise, AXLAST will be the first integral multiple of CYCLEL greater than EEND. In drawing the hash marks, the Y-coordinate of the pen goes from POS, to POS + TA, to POS + TB, and back to POS.

For ITYPE = 2, the Y-axis goes from (POS, BEGIN) to (POS, AXLAST). In drawing the hash marks, the X-coordinate of the pen goes from POS, to POS + TA, to POS + TB, and back to POS. Other features are the same as for drawing an X-axis.

3. Subroutine LNAXIS (ITYPE, BEGIN, EEND, POS, CYCLEL, TA, TB, AXLAST)

Subroutine LNAXIS is used to draw an axis with hash marks according to a logarithmic scale. The description of this subroutine parallels that of subroutine LINAXIS, except that there are nine intervals separated by hash marks based on a logarithmic scale in every CYCLEL inches.

4. Subroutine LINLABEL (IDIR, BEGIN, END, POS, DELTAL, ORGVAL, DELTAV, NFORM)

Subroutine LINLABEL is used for plotting numbers along an axis on a linear scale. BEGIN and END are the coordinates in inches of the positions on the axis defining the range over which labeling is desired. DELTAL is the separation in inches of successive numbers to be drawn. ORGVAL is the number to be plotted at the position defined by BEGIN; DELTAV is the difference between successive numbers. IDIR = 1 places numbers below the X-axis; IDIR = 2 yields numbers to the left of the Y-axis. The numbers are 0.07 in. high and are plotted in the format given by NFORM. For example, 5HE10.3 or 2HI3 would be possible values of NFORM. For IDIR = 1, POS is the distance in inches of the bottom of the number below the X-axis; for IDIR = 2, POS is the distance in inches of the bottom of the numbers to the left of the Y-axis.

5. Subroutine LNLABEL (IDIR, BEGIN, END, POS, DELTAL, ORGVAL, DELTAV, NFORM)

Subroutine LNLABEL is used for plotting numbers along an axis on a logarithmic scale. The description of LNLABEL parallels that of LINLABEL except for the definitions of ORGVAL and DELTAV. In LNLABEL, ORGVAL must be a number that is a power of 10, since it is the power that is actually plotted. For example, ORGVAL = 1000 would produce the number 3 at the BEGIN position, while ORGVAL = 0.01 would yield the number -2. DELTAV is a number that is a positive power of 10 such that $\text{DELTAV} = 10^n$ will yield a number greater by n than the previous number plotted.

6. Subroutine LNGRID (ITYPE, BEGIN, FEND, POSBEG, POSEND, DELTAL, DELTAX, CYCLEL, AXLAST, AAXIS)

Subroutine LNGRID draws two axes with hash marks either on a linear or a logarithmic scale, along with grid lines parallel to the axes between them. ITYPE = 1 yields axes and grid lines in the X-direction; ITYPE = 2 produces lines in the Y-direction. AAXIS is the name of either subroutine LINAXIS or subroutine LNAXIS. These subroutines are called by LNGRID when the axes are to have hash marks on a linear or a logarithmic scale, respectively. Thus both LINAXIS and LNAXIS must be declared in an EXTERNAL statement in the program that calls LNGRID.

When AAXIS is called the first time, the values ITYPE, BEGIN, FEND, POSBEG, CYCLEL, 0., 0.125, and EEND are given to the variables ITYPE, BEGIN, EEND, POS, CYCLEL, TA, TB, and AXLAST in the subroutine AAXIS. After the first axis is drawn, grid lines are drawn parallel to the axis at intervals of DELTAL inches, with the grid lines extending from BEGIN to EEND. The final axis is drawn by assigning the values ITYPE, BEGIN, FEND, POSEND, CYCLEL, -0.125, 0., and XXXXX to the variables ITYPE, BEGIN, EEND, POS,

CYCLEL, TA, TB, and AXLAST in the subroutine AAXIS. The value EEND is returned as AXLAST when return is made from LNGRID. The variable DELTAX is used to control hash marks on the grid lines between the two axes. Hash marks are drawn on grid lines occurring at distances that are multiples of DELTAX inches from the first axis. These hash marks extend 0.125 in. on each side of the grid line in question, and are spaced the same as the hash marks on the initial and final axes.

B. Input and Output Description for DRIVER

<u>No.</u>	<u>Format</u>	<u>FORTTRAN Name</u>	<u>Description</u>
1	(I3)	INORM	If = 0, read and plot coefficients in Eq. 1 normalization. If =1, read and plot coefficients in Eq. 7 normalization.
2	(I2, 7A8)	LDAYSQ	Length of a Hollerith statement in an I2 format, followed by the Hollerith statement identifying day and sequence number of the problem providing the coefficients to be plotted. The statement is drawn outside the Y-axis.
3	(2I6, 2A8, A3, 37X, I2)	NNN, LMESS, NOENG	Number of sets of coefficients to be plotted. Thus NNN is the sum of the number of orders used at each energy. Length of a Hollerith statement in an I6 format, followed by the statement describing the data. The statement is drawn outside the Y-axis. Number of energies.
4	(3E12.0)	XO, SCALEXX, XEGG	Minimum energy on X-axis in MeV. XO should be a number that is a power of 10. Inches/decade for X-axis. Hash marks are drawn on the vertical grid lines every XEGG inches from the Y-axis.

The following two card types occur NNN times for INORM = 0:

1	(A3, I5, F8.3, 5X, I5)	NAME, NATOM,	Chemical symbol of material. Mass number or atomic number.
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No.	Format	FORTTRAN Name	Description
		X(I),	Energy in MeV.
		NX	Number of terms in expansion.
2	(5E16.8)	(Y(K,I), K=1, NX)	Legendre coefficients a_0 , a_1 , ..., a_{NX-1} .

The following two card types occur NNN times in place of the above two types for INORM = 1:

1	(A3, I5, F8.3, 5X, I5, F10.5)	NAME, NATOM, X(I), NX Y(1,I)	Chemical symbol of material. Mass number or atomic number. Energy in MeV. Number of terms in the expansion. Elastic scattering cross section in barns.
2	(6E13.5)	(Y(K,I), K=2, NX)	Legendre coefficients f_1 , f_2 , ..., f_{NX-1} .

The following card type occurs NOENG times:

1	(14X, F7.3, 3A8, 5A7)	ENERGY(KK), (SOURCE(KK,I) I=1, 3), (ORDER(KK,I), I = 1, 5)	Energy in MeV. Hollerith information de- scribing data source at this energy. List of orders, NX, used at this energy in a Hollerith format for printout.
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The printed output from DRIVER for each ℓ value lists the energies, the sources of data, and the various orders of expansion used at each energy. Then a table follows containing in each line the energy, the coefficient with the ℓ value in question, the order of expansion, and the X- and Y-coordinates, in inches, of the plotted point. If a coefficient is zero at a particular energy, the corresponding line of the table is omitted.

The input cards for a DRIVER sample problem are listed in Appendix G. In this problem, coefficients in the normalization of Eq. 1 are plotted for 18 energies and 46 orders of expansion. The coefficients were obtained by fitting data for aluminum in Ref. 9 using the LEGENDRE path in SAD. The printed output for $\ell = 0$ and $\ell = 10$ is presented in Appendix H as being typical of the complete output. Figures 7 and 8 in Appendix I are the Calcomp plots for $\ell = 0$ and $\ell = 10$, respectively.

IV. DIFFICULTIES INVOLVED IN LEAST-SQUARES FITTING

Care must be taken in fitting experimental data using the LEGENDRE path in SAD. Although the least-squares technique can be used without having input values of $d\sigma/d\Omega$ at the ends of the angular interval, i.e., for $\mu = +1$ and -1 , such a procedure may yield bad results. This is because the curve determined by the fitted coefficients may fit the data rather well over the range of the experimental points, but may behave wildly near $\mu = \pm 1$. Such wild behavior may include negative values of $d\sigma/d\Omega$ over part of the angular range. Thus it is desirable to add "experimental" points at or near $\mu = \pm 1$ in the input, determined by visually inspecting the trend of the actual experimental values. The extra points are especially necessary for high-order fits or when the angular-distribution curve has a local minimum or maximum near $\mu = -1$. At times, the Wick limit may be used as a guide in determining the value of $d\sigma/d\Omega$ for $\mu = 1$. According to this limit,

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mu=1} \geq \frac{k^2 \sigma_T^2}{(4\pi)^2}, \quad (16)$$

where k is the wave number of the neutron-nucleus system, and σ_T is the total cross section at the energy in question. If the energy at which the angular distribution is measured is in a resonance region, the Wick limit may be of little use because σ_T would be an average of values near the experimental energy weighted with the resolution function appropriate to the measurements.

Sometimes a fit will be satisfactory over most of the angular range, but have a spike between two successive experimental points. Use of higher-order fits does not always yield better coefficients since this may cause small fluctuations in the curve which are merely following experimental errors. Because of this effect, the fit to the aluminum data at 3.01 MeV in the sample LEGENDRE problem using nine terms in the expansion is not quite as good as the fits using five or seven terms. This is shown in Figs. 1-3 of Appendix E.

The difficulties with least-square fitting mentioned above show the desirability of using POLYLOT to plot the angular distribution determined by the coefficients. Since POLYLOT calculates values of $d\sigma/d\Omega$ at 101 points for the plotting, it will illustrate any undesirable behavior. A number of cases of badly behaved coefficients were noted in Smith's data⁵ covering the energy range from about 0.3 to 1.5 MeV. The Smith coefficients were transformed to the center-of-mass system and plotted using the COAGOGO path in SAD. For heavy materials, such as U^{235} in the portion of Smith's energy range above about 1.0 MeV, the angular distributions often took sharp negative excursions near $\mu = -1$. The coefficients were obtained by fitting experimental data covering the angular range of approximately 25 to 150°. For heavy materials in this energy range, the differential cross section is decreasing near $\mu = -1$. Thus negative excursions are more probable than for lower energies or lighter materials for which $d\sigma/d\Omega$ is increasing near $\mu = -1$.

It is desirable to have a rough prescription giving the appropriate number of terms in the Legendre expansion for a given material at a given energy. In the optical model codes, Abacus-1 and Abacus-2,¹⁰ the prescription

$$\ell = (1.5kR) + 1 \quad (17)$$

is used to determine the maximum ℓ value of the phase-shift calculations where the notation (x) means the greatest integer less than x . Here k is the wave number of the neutron-nucleus system, and R is the nuclear radius. Since the maximum ℓ value in the angular-distribution expansion in Legendre polynomials is twice the maximum ℓ of the phase-shift calculations, it is reasonable to perform fitting including polynomials through ℓ values about twice as high as those given by Eq. 17. To illustrate such values, consider nuclei of mass numbers $A = 15$ and 240 scattering neutrons of energies 1 and 10 MeV. If the nuclear radius is calculated from $R = 1.5 \times 10^{-13} A^{1/3}$ cm, the above prescription suggests terms through $\ell = 4$ and $\ell = 8$ at 1 and 10 MeV, respectively, for the nucleus with $A = 15$. For the nucleus with $A = 240$, terms through $\ell = 8$ at 1 MeV and through $\ell = 20$ at 10 MeV are suggested.

V. A COMPARISON OF LEAST-SQUARES AND INTEGRATION FITTING

Two methods have been commonly used for the determination of Legendre-expansion coefficients from input angular-distribution data. One method is the least-squares fitting technique as exemplified by the LEGENDRE path in the SAD code. The other method may be referred to as the integration method and is used, for example, in the CHAD code.⁴ In this method, the Legendre coefficients are calculated by multiplying the differential cross section, $d\sigma/d\Omega$, by each $P_\ell(\mu)$ in turn, and integrating between $\mu = -1$ and $\mu = +1$ on the assumption that $d\sigma/d\Omega$ is linear between successive input values of μ . As will be demonstrated numerically below, this method is inaccurate for highly peaked distributions unless many closely spaced pairs of $d\sigma/d\Omega$ and μ are used in the input. The least-squares method, on the other hand, finds coefficients that minimize the sum of the squares of the differences of the experimental and calculated values of $d\sigma/d\Omega$ for the input values of μ , and so does not involve any such linearity assumption.

In principle, the least-squares method does not require input values of $d\sigma/d\Omega$ for $\mu = +1$ and -1 , whereas the integration method must have such values in order to perform the integration. However, as discussed in Section IV above, the fit sometimes behaves wildly near $\mu = +1$ or -1 if such input values are not provided. Another difference between the two methods is that coefficients already determined do not change when a higher-order fit is made in the integration method, whereas the lower-order coefficients do change when a higher-order least-squares fit is made.

Table I compares expansion coefficients determined by the least-squares procedure of LEGENDRE and the integration method of CHAD. Cases I and II used as input the English data for sodium at 0.220 and 15.0 MeV, respectively, from ENDF/A.¹¹ There were 11 points in the input at 0.220 MeV and 21 points at 15.0 MeV, equally spaced in μ . Cases III, IV, and V are artificial cases in which the input data for 21 equally spaced points were calculated and punched by a CDC-160A program. Case III involves the expansion

$$\mu^4 = \frac{1}{5} P_0(\mu) + \frac{4}{7} P_2(\mu) + \frac{8}{35} P_4(\mu), \quad (18)$$

multiplied by 10,000 for convenience. Case IV is 200 times the first ten terms of the expansion of $\delta(\mu - 1)$ in Legendre polynomials, which is

$$\delta(\mu - 1) = \sum_{\ell=0}^{\infty} \frac{2\ell + 1}{2} P_{\ell}(\mu); \quad (19)$$

Case V is 1000 times the first ten terms of the expansion

$$\frac{1}{\sqrt{2(1 - \mu)}} = \sum_{\ell=0}^{\infty} P_{\ell}(\mu), \quad |\mu| < 1. \quad (20)$$

The coefficients are all normalized as in Eq. 1.

TABLE I. A Comparison of LEGENDRE and CHAD Expansion Coefficients

ℓ	Case I		Case II		Case III		Case IV		Case V	
	$a_{\ell}(L)^*$	$a_{\ell}(C)^*$	$a_{\ell}(L)^*$	$a_{\ell}(C)^*$	$a_{\ell}(L)^*$	$a_{\ell}(C)^*$	$a_{\ell}(L)^*$	$a_{\ell}(C)^*$	$a_{\ell}(L)^*$	$a_{\ell}(C)^*$
0	357.541	358.010	52.201	55.616	2000.46	2033.32	100.47	180.63	1000.41	1057.12
1	8.704	8.456	106.998	116.222	1.20	0.00	301.49	641.48	1001.30	1216.03
2	-1.323	0.253	136.092	148.187	5715.60	5780.46	502.40	840.23	1001.91	1230.84
3	0.812	0.425	150.072	161.833	0.80	-0.00	703.13	1314.04	1002.28	1369.58
4	15.053	14.727	153.450	161.649	2285.92	2283.33	903.52	1282.52	1002.46	1242.27
5	-2.162	-2.031	133.999	137.587	-0.00	0.00	1103.84	1632.51	1002.49	1298.70
6	0.202	-0.312	86.090	85.758	-0.01	-5.71	1303.84	1462.28	1002.34	1091.08
7	0.115	0.294	38.777	36.346	-	-	1503.36	1611.10	1001.88	1046.66
8	-0.368	-0.943	12.157	8.392	-	-	1702.11	1524.98	1001.15	889.42
9	-0.062	0.202	2.671	-1.966	-	-	1900.64	1496.19	1000.37	769.15
10	-	-	-	-	-	-	0.00	-237.40	-0.06	-151.28
11	-	-	-	-	-	-	-0.13	-488.55	-0.11	-282.16

* $a_{\ell}(L)$ and $a_{\ell}(C)$ refer to the coefficients obtained from LEGENDRE and CHAD, respectively.

Table I indicates that the CHAD and LEGENDRE results are not very different for distributions that are not too strongly peaked. For highly peaked distributions, especially that of Case IV, the coefficients differ considerably. The LEGENDRE values are quite close to the exact ones for Cases III, IV, and V, for which the exact coefficients are known.

APPENDIX A

Listing of Program SAD and Associated Subroutines

```

PROGRAM SAD
C
C SCATTERING ANGULAR DISTRIBUTIONS
C
2 READ 5,IPATH
5 FORMAT(I3)
GO TO (10,15,20,25,30)IPATH
10 CALL LEGENDRE
GO TO 35
15 CALL POLYWOLY
GO TO 35
20 CALL OSCAR
GO TO 35
25 CALL COAGOGO
GO TO 35
30 CALL RENORM
35 CONTINUE
END

SUBROUTINE LEGENDRE
C
C LEAST SQUARES LEGENDRE POLYNOMIAL FIT TO SCATTERING ANGULAR
C DISTRIBUTIONS
C FITS OF ORDERS UP TO 20 MAY BE MADE ALSO FITS OF VARIOUS ORDERS
C MAY BE MADE TO A SINGLE ANGULAR DISTRIBUTION
C A PLOT OF THE FIT DEFINED BY THE LEGENDRE COEFFICIENTS MAY BE MADE
C USING POLYPLOT
C THE POINTS USED IN THE FIT AND OTHER POINTS IF DESIRED MAY BE
C PLOTTED USING POLYP
C
C DIMENSION BP(20,80),X(80),THETA(80),W(80),Y(80),B(20,20),YCOMP(80),
X,DELTAY(80),BTHETA(80),XTHETA(25),XYCOMP(25),SIGMA(20),RECORD(12),
XSTORE(20),XP(20,80),NEXPTS(8)
COMMON/GRAPH/BLOCK(10000)
COMMON/COEFF/YMAT(20)/PRINT/MATERIAL,ENERGY,JOKE,NUM
COMMON/POINTS/ANGLE(8,80),BARN(8,80)/NAME/LMESS(8,10),KPLOTS
JOKE=1
READ 10,IFCAL
IF(IFCAL)1,1,3
C INITIALIZE TAPE 1 FOR PLOTTING
3 CALL PLOTS (BLOCK,10000,1)
1 READ 7,(RECORD(I),I=1,12)
IF(EOF,60)3000,1111
1111 PRINT 8
PRINT 7,(RECORD(I),I=1,12)
2 FORMAT(5H0 MP=I3,7H MPE=I3,10H MPWGTS=I3,10H MRADEG=I3,10H
X MORADG=I3,10H MERROR=I3)
5 READ 10,MP,MPE,MPWGTS,MRADEG,MORADG,MERROR
PRINT 2,MP,MPE,MPWGTS,MRADEG,MORADG,MERROR
2750 MPWGTS=MPWGTS+1
6 MPSTAR=1
4 FORMAT (1H1,A3,I5,F8.3,5H MEV)
7 FORMAT (12A6)
8 FORMAT (17H1PROGRAM LEGENDRE//)
9 FORMAT (A3,I5,F8.3,2I5)
10 FORMAT (20I3)
11 FORMAT(7H0 XLEN=F10,4,6H Y0=F10,4,10H SCALEY=F10,4,8H YLEN=F
X10,4,8H ILOG=I3)
12 FORMAT (I8,A8,F8,2)

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13 FORMAT (9F8.0)
14 FORMAT (10F8.0)
17 FORMAT (A3,I5,F8,3,2X,6I3,4F10.0,I4)
18 FORMAT(7H0 LMIN=I3,8H LMAX=I3,10H LDELTA=I3,5H N=I3,6H NX=
X I3,10H NPLOTS=I3,10H KPLOTS=I3)
15 READ 17,MATERIAL,NUM,ENERGY,LMIN,LMAX,N,NX,NPLOTS,KPLOTS,XLEN,Y0,
XSCALEY,YLEN,ILOG
IF(EOF,60)3000,3005
3005 READ 10,LDELTA
PRINT 4,MATERIAL,NUM,ENERGY
PRINT 18,LMIN,LMAX,LDELTA,N,NX,NPLOTS,KPLOTS
20 L=LMIN
NPLOTS=NPLOTS+1
TEST = 10.0**50.0
PRINT 11,XLEN,Y0,SCALEY,YLEN,ILOG
GO TO (25,24,24,25),MPWGTS
24 READ 14,(THETA(I),Y(I),I=1,N)
GO TO 250
25 READ 13,(THETA(I),Y(I),W(I),I=1,N)
250 IF(MRADEG-1)26,252,26
252 DO 253 I=1,N
253 THETA(I)=THETA(I)*3.141592654/180.0
26 IF (NX)27,28,27
27 READ 30,(XTHETA(I),I=1,NX)
28 GO TO (45,35,40,32),MPWGTS
30 FORMAT (5E14,8)
32 DO 33 I=1,N
33 W(I)=1.0/(W(I)*W(I))
34 GO TO 45
35 DO 36 I=1,N
36 W(I)=1.0/Y(I)
37 GO TO 45
40 DO 41 I=1,N
41 W(I)=1.0
45 IF(MRADEG-1)451,451,461
451 DO 46 I=1,N
46 X(I)=COSF(THETA(I))
GO TO 463
461 DO 462 I=1,N
462 X(I)=THETA(I)
463 GO TO(50,50,48,495)KPLOTS
48 READ 10,NEX
READ 7,(LMESS(1,I),I=1,10)
NEX = NEX+1
GO TO 496
495 READ 10,NEX
NEX=NEX+1
496 DO 498 I=2,NEX
READ 7,(LMESS(I,J),J=1,10)
READ 10,NEXPTS(I)
JJ=NEXPTS(I)
498 READ 14,(ANGLE(I,J),BARN(S(I,J),J=1,JJ)
50 DO 52 I=1,N
51 BP(1,I)=1.0
52 BP(2,I)=X(I)
55 DO 58 LPLS1=3,LMAX
56 BARL=FLOATF(LPLS1-2)
57 DO 58 I=1,N
58 BP(LPLS1,I)=((2.0*BARL+1.0)*X(I)*BP(LPLS1-1,I)-
XBARL*BP(LPLS1-2,I))/(BARL+1.0)
IF(NX)60,60,580
580 DO 582 I=1,NX
581 XP(1,I)=1.0
582 XP(2,I)=XTHETA(I)
583 DO 586 LL=3,LMAX
584 Q=FLOATF(LL-2)
585 DO 586 I=1,NX
586 XP(LL,I)=((2.0+Q+1.0)*XTHETA(I)*XP(LL-1,I)-Q*XP(LL-2,I))/(Q+1.0)

```

```

60 DO 70 K=1,L
62 DO 70 M=1,L
64 SUMJ=0.0
66 DO 68 J=1,N
68 SUMJ=SUMJ+W(J)*BP(K,J)*BP(M,J)
70 B(K,M)=SUMJ
75 DO 79 K=1,L
76 SUMJ=0.0
77 DO 78 J=1,N
78 SUMJ=SUMJ+W(J)*Y(J)*BP(K,J)
79 YMAT(K)=SUMJ
80 CALL MATINV(B,L,YMAT,1,DETERM)
86 FORMAT (22H0LEGENDRE COEFFICIENTS//)
90 FORMAT (6E19,8)
950 PRINT 86
96 PRINT 90,(YMAT(K),K=1,L)
PUNCH 9,MATERIAL,NUM,ENERGY,N,L
PUNCH 2012,(YMAT(K),K=1,L)
100 IF (MPE=1) 120,1013,101
101 PRINT 2001,MPE
CALL EXIT
1013 IF(MORADG=2)1014,1015,1014
1014 PRINT 109
GO TO 1016
1015 PRINT 110
1016 IF(MORADG=1)1020,1017,102
1017 IF(MRADG=1)1018,1018,1100
1018 DO 1019 I=1,N
1019 BTHETA(I)=57.29577951*THETA(I)
GO TO 102
1100 DO 1101 I=1,N
1101 BTHETA(I)=57.29577951*ACOSF(X(I))
GO TO 102
1020 DO 1021 I=1,N
1021 BTHETA(I)=THETA(I)
102 DO 117 J=1,N
103 SUML=0.0
104 DO 105 LPLS1=1,L
105 SUML = SUML +YMAT(LPLS1)*BP(LPLS1,J)
106 YCOMP(J)=SUML
107 DELTAY(J)=YCOMP(J)-Y(J)
109 FORMAT (69H0 THETA Y EXPER Y COMPUTED
X DELTA Y//)
110 FORMAT (69H0 COS THETA Y EXPER Y COMPUTED
X DELTA Y//)
111 IF(MORADG=1)116,116,115
115 PRINT 90,X(J),Y(J),YCOMP(J),DELTAY(J)
GO TO 117
116 PRINT 90,BTHETA(J),Y(J),YCOMP(J),DELTAY(J)
117 CONTINUE
IF(NX)120,120,1180
1180 DO 1183 I=1,NX
SUMX = 0.0
DO 1183 M=1,L
SUMX=SUMX+XP(M,I)*YMAT(M)
1183 XYCOMP(I)=SUMX
1185 FORMAT(22H0 INTERMEDIATE ANGLES)
1186 FORMAT(42H0 COS OF THETA YCOMP//)
1187 FORMAT (E19,8,10X,E19,8)
1188 PRINT 1185
1189 PRINT 1186
1190 PRINT 1187,(XTHETA(I),XYCOMP(I),I=1,NX)
120 SUMJ=0.0
122 DO 123 J=1,N
123 SUMJ=SUMJ+W(J)*(YCOMP(J)-Y(J))*(YCOMP(J)-Y(J))
1230 IF(SUMJ.LT. TEST)1231,1235
1231 KEEP=L

```



```

1232 TEST = SUMJ
      DO 1234 J=1,20
      IF (J-L)1234,1234,1233
1233 YMAT(J)=0.0
1234 STORE(J)=YMAT(J)
1235 DO 131 K=1,L
      124 TEMP=B(K,K)*SUMJ
125 IF (N-L) 126,127,129
126 PRINT 2003,N,L
      CALL EXIT
127 TEMP1=1.0
128 GO TO 130
129 TEMP1=FLOATF(N-L)
130 TEMP2=TEMP/TEMP1
131 SIGMA(K)=SQRTF(TEMP2)
      GO TO (155,133,132),NPLOTS
132 CALL POLYPLOT (L,XLEN,Y0,SCALEY,YLEN,ILOG,1)
      GO TO 1350
133 IF (LMAX=L)166,134,155
134 DO 135 K=1,KEEP
135 YMAT(K)=STORE(K)
      CALL POLYPLOT (KEEP,XLEN,Y0,SCALEY,YLEN,ILOG,1)
1350 GO TO (154,1351,1351,1353),KPLOTS
1351 M=1
      DO 1352 J=1,N
      ANGLE(1,J)=X(J)
1352 BARNS(1,J)=Y(J)
      CALL POLYP (XLEN,Y0,SCALEY,YLEN,N,M,ILOG)
      IF (KPLOTS=3)154,1353,1353
1353 DO 1357 M=2,NEX
1355 CALL POLYP (XLEN,Y0,SCALEY,YLEN,NEXPTS(4),M,ILOG)
1357 CONTINUE
136 FORMAT (20H0STANDARD DEVIATIONS/)
137 FORMAT (30H0SUM OF SQUARED DEVIATIONS....E19.8)
138 FORMAT (16H0DETERMINANT....E19.8)
139 FORMAT (6H0N,...I3)
140 FORMAT (6H0L,...I3)
141 FORMAT (1H1)
1500 FORMAT (1H0)
1501 FORMAT (13H0ERROR MATRIX//)
154 ORG=XLEN+5.0
      CALL PLOT (ORG,0,0,-3)
155 PRINT 136
156 PRINT 90,(SIGMA(K),K=1,L)
157 PRINT 137,SUMJ
158 PRINT 138,DETERM
159 PRINT 139,N
160 PRINT 140,L
1602 IF (MERROR=1) 161,1604,1603
1603 PRINT 2004,MERROR
      CALL EXIT
1604 PRINT 1500
1605 PRINT 1501
1606 DO 1607 I=1,L
1607 PRINT 90,(B(I,J),J=1,L)
161 PRINT 141
165 IF (LMAX-L) 166,170,167
166 PRINT 2005,LMAX,L
      CALL EXIT
167 L=L+LDELTA
168 GO TO 60
170 PRINT 2010,KEEP,TEST
1705 IF(MP-MPSTAR)171,1,172
171 PRINT 2006,MP,MPSTAR
172 MPSTAR=MPSTAR+1
173 GO TO 15
2000 FORMAT (4H0MRADEG=I5)
2001 FORMAT (5H0MPE=I5)

```

```

2002 FORMAT (8H0MORADG=I5)
2003 FORMAT (3H0N=I5,2HL=I5)
2004 FORMAT (8H0MERROR=I5)
2005 FORMAT (6H0LMAX=I5,2HL=I5)
2006 FORMAT (4H0MP=I5,7HMPSTAR=I5)
2010 FORMAT (23H BEST FIT IS GIVEN BY 14,7H ORDER/28H0 SUM OF SQUARED
X DEVIATIONS=E19,8)
2011 FORMAT (A3,I5,E15,5,I5)
2012 FORMAT (5E16,8)
3000 IF(IFCAL)3001,3001,3002
3002 CALL ENDPLOT
3001 END

```

```

SUBROUTINE MATINV(A,N,B,M,DETERM)
C
C MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
C
C DIMENSION IPIVOT(20), A(20,20), B(20,1), INDEX(20,2), PIVOT(20)
COMMON PIVOT, INDEX, IPIVOT
EQUIVALENCE (IROW,JROW), (ICOLUMN,JCOLUMN), (AMAX, T, SWAP)
C
C INITIALIZATION
C
10 DETERM=1.0
15 DO 20 J=1,N
20 IPIVOT(J)=0
30 DO 550 I=1,N
C
C SEARCH FOR PIVOT ELEMENT
C
40 AMAX=0.0
45 DO 105 J=1,N
50 IF (IPIVOT(J)-1) 60, 105, 60
60 DO 100 K=1,N
70 IF (IPIVOT(K)-1) 80, 100, 740
80 IF (ABSF(AMAX)-ABSF(A(J,K))) 85, 100, 100
85 IROW=J
90 ICOLUMN=K
95 AMAX=A(J,K)
100 CONTINUE
105 CONTINUE
110 IPIVOT(ICOLUMN)=IPIVOT(ICOLUMN)+1
C
C INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
130 IF (IROW=ICOLUMN) 140, 260, 140
140 DETERM=-DETERM
150 DO 200 L=1,N
160 SWAP=A(IROW,L)
170 A(IROW,L)=A(ICOLUMN,L)
200 A(ICOLUMN,L)=SWAP
205 IF(M) 260, 260, 210
210 DO 250 L=1, M
220 SWAP=B(IROW,L)
230 B(IROW,L)=B(ICOLUMN,L)
250 B(ICOLUMN,L)=SWAP
260 INDEX(I,1)=IROW
270 INDEX(I,2)=ICOLUMN
310 PIVOT(I)=A(ICOLUMN,ICOLUMN)
320 DETERM=DETERM*PIVOT(I)
C
C DIVIDE PIVOT ROW BY PIVOT ELEMENT
C
330 A(ICOLUMN,ICOLUMN)=1.0
340 DO 350 L=1,N
350 A(ICOLUMN,L)=A(ICOLUMN,L)/PIVOT(I)
355 IF(M) 380, 380, 360
360 DO 370 L=1,M
370 B(ICOLUMN,L)=B(ICOLUMN,L)/PIVOT(I)
C

```

C REDUCE NON-PIVOT ROWS

```
C
380 DO 550 L1=1,N
390 IF(L1-ICOLUM) 400, 550, 400
400 T=A(L1,ICOLUM)
420 A(L1,ICOLUM)=0.0
430 DO 450 L=1,N
450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
455 IF(M) 550, 550, 460
460 DO 500 L=1,M
500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T
550 CONTINUE
```

C INTERCHANGE COLUMNS

```
C
600 DO 710 I=1,N
610 L=N+1-I
620 IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630
630 JROW=INDEX(L,1)
640 JCOLUM=INDEX(L,2)
650 DO 705 K=1,N
660 SWAP=A(K,JROW)
670 A(K,JROW)=A(K,JCOLUM)
700 A(K,JCOLUM)=SWAP
705 CONTINUE
710 CONTINUE
740 RETURN
END
```

SUBROUTINE POLYPLOT (LMAX,XLEN,Y0,SCALEY,YLEN,ILOG,IPATH)

C POLYPLOT DRAWS AXES ,LABELS AND THE CURVE DETERMINED BY THE
C LEGENDRE EXPANSION COEFFICIENTS

```
C
DIMENSION CSE(101),BP(20,101),SUML(101),
XX(101),Y(101)
COMMON/COEFF/C(20)/PRINT/MAT,EN,K,NUM
DATA (YMESS = .10HILLIBARNS), (XMESS = .12HCOS OF THETA)
C     COMPUTE THE X VALUES
DO 10 I=1,101
Z=I-1
X(I)=Z*XLEN/100.
10 CSE(I)=1.0-(.02*Z)
C     COMPUTE THE Y VALUES
DO 15 I=1,101
BP(1,I)=1.0
15 BP(2,I)=CSE(I)
DO 20 LL=3,LMAX
Q=FLOAT(LL-2)
DO 20 I=1,101
20 BP(LL,I)=((2.0+Q*1.0)*CSE(I)*BP(LL-1,I)-Q*BP(LL-2,I))/(Q*1.0)
IF(ILOG)202,202,201
201 YY0=LOGF(Y0)
202 DO 25 I=1,101
SUML(I)=0.0
DO 25 LL=1,LMAX
25 SUML(I)=SUML(I)+C(LL)*BP(LL,I)
IF(ILOG)251,251,252
251 Y(I)=(SUML(I)-Y0)*SCALEY
GO TO 255
252 IF(SUML(I))23,23,253
253 Y(I)=((LOGF(SUML(I))-YY0)/2.30259)*SCALEY
255 IF(Y(I)-YLEN)22,21,21
21 Y(I)=YLEN
22 IF(Y(I))23,23,29
```

```

23 Y(1)=0.
29 CONTINUE
   IF(K=1)50,28,50
C   PLOT X AND Y AXES
28 TIC=XLEN/10.0
   CALL PLOT (0.0,0.0,0.3)
   CALL PLOT (XLEN,0.0,2)
   CALL PLOT (TIC,0.0,3)
   DO 30 J=1,9
   XX=J*TIC
   CALL PLOT (XX,.10,2)
   XXX=XX+TIC
30 CALL PLOT (XXX,0.0,3)
   CALL PLOT (XXX,YLEN,2)
   CALL PLOT (0.0,YLEN,1)
   CALL PLOT (0.0,0.0,1)
   IF(ILOG)32,32,36
32 KUT=YLEN-.99
   CALL PLOT (0.0,1,0.3)
   DO 35 J=1,KUT
   TIC1=J
   CALL PLOT (0.1,TIC1,2)
   TIC2=TIC1+1.0
35 CALL PLOT (0.0,TIC2,3)
   GO TO 39
36 BASE=0.
   XDEC=YLEN/SCALEY
   NCYCLE=XDEC+.1
   DO 38 N=1,NCYCLE
   DO 37 I=1,10
   O=I
   TEMP=BASE+LOGF(Q)*SCALEY/2.30259
   CALL PLOT (0.0,TEMP,1)
   CALL PLOT (0.1,TEMP,1)
37 CALL PLOT (0.0,TEMP,1)
38 BASE=BASE+SCALEY
C   LABEL X SCALE
39 DO 40 J=1,11
   XX=(J-1)*TIC+.12
   SYM=1.2+.2*J
40 CALL NUMBER (XX,=.12,.07,SYM,0.0,4HF4.1)
C   NOTE ORDER OF EXPANSION
   IF(IPATH=2)405,407,405
405 CALL NUMBER (.12,.08,.14,LMAX,0.0,2HI2)
C   LABEL Y SCALE
407 IF(ILOG)41,41,46
41 NU=YLEN+1.01
   DO 43 J=1,NU
   YY=J+1
   SYM=YY+YY/SCALEY
   YY=YY-.25
45 CALL NUMBER (=.05,YY,.07,SYM,90.0,4HF6.0)
   GO TO 49
46 NU=XDEC+1.1
   AN=YY0/2.30259
   IF(AN)47,47,48
47 NN=AN+.1
   GO TO 480
48 NN=AN+.1
480 DO 485 J=1,NU
   YY=(J-1)*SCALEY+.06
   CALL NUMBER (=.05,YY,.07,NN,90.0,2HI3)
485 NN=NN+1
C   PRINT OUT AXIS LABELS AND MATERIAL IDENTIFICATION
49 CALL SYMBOL (.3,=.35,.14,MAT,0.0,3)
   CALL NUMBER (1.6,=.35,.14,NUM,0.0,2HI4)
   CALL SYMBOL (3.0,=.35,.14,XMESS,0.0,12)
   CALL SYMBOL (=-.25,2.0,.14,YMESS,90.0,10)

```

```

C   PLOT THE LINE
50 CALL LINE (X,Y,101,1)
   NX=15+5*K
   NY=15+5*K
   CALL PLOT (X(NX),Y(NY),3)
   XNEW=X(NX)+.3
   YNEW=Y(NY)+.3
   CALL PLOT (XNEW,YNEW,2)
   CALL NUMBER (XNEW,YNEW,.14,EN,0,0,4HF6,3)
   CALL PLOT (0,0,0,0,3)
55 RETURN
   END

```

```

SUBROUTINE POLYP (XLEN,Y0,SCALEY,YLEN,N,M,ILOG)
C
C   POLYP PLOTS THE POINTS USED IN FITTING FOR KPLOTS = 2 OR 3
C   POLYP PLOTS NEX OTHER SETS OF POINTS FOR KPLOTS = 3 OR 4
C   POLYP WRITES NEX*1 LEGENDS FOR KPLOTS = 3 OR NEX LEGENDS FOR
C   KPLOTS = 4
C
C   DIMENSION X(80),YY(80)
C   COMMON/POINTS/CSE(8,80),Y(8,80)/NAME/MESS(8,10),KPLOTS
C   COMPUTE THE X AND Y VALUES IN INCHES FOR PLOTTING
C   PRINT 50,XLEN,Y0,SCALEY,YLEN,N,M,ILOG
C   IF(ILOG)5,5,3
3  YY0=LOGF(Y0)
5  DO 10 I=1,N,1
   X(I)=XLEN+.5*(1.0-CSE(M,I))
   IF(ILOG)7,7,8
7  YY(I)=SCALEY*(Y(M,I)-Y0)
   GO TO 10
8  YY(I)=SCALEY*(LOGF(Y(M,I))-YY0)/2,30259
10 CONTINUE
C   PLOT THE POINTS
   NO=M+1
   DO 20 I=1,N
   IF (YY(I))11,15,12
11 YY(I)=0.
   GO TO 15
12 IF (YY(I)-YLEN)15,15,13
13 YY(I)=YLEN
15 CALL SYMBOL (X(I),YY(I),.14,NO,0,0,-1)
20 CONTINUE
   IF (KPLOTS=3)100,25,22
C   WRITE THE LEGEND
22 IF(M=1)100,100,25
25 S=M
   H=XLEN+.25*(1.0+S)
   DO 35 I=1,10
   T=I
   LEGEND=MESS(M,I)
   HUP=.25+.72*(T-1,0)
35 CALL SYMBOL (H,HUP,.14,LEGEND,90,0,6)
50 FORMAT (23H0POLYP HAS BEEN ENTERED/4F14.4,3I5)
100 CONTINUE
   RETURN
   END

```

```

SUBROUTINE POLYWOLY
C
C POLYWOLY USES POLYPLOT TO PLOT SEVERAL (NPLOTS) ANGULAR
C DISTRIBUTIONS ON ONE GRAPH
C
C PUNCHED OUTPUT FROM LEGENDRE ,OSCAR ,OR COAGOGO MAY BE USED
C AS INPUT
C
COMMON/COEFF/B(20)/PRINT/MAT,EN,K,NUM
COMMON/GRAPH/BLOCK(10000)
CALL PLOTS (BLOCK,10000,1)
PRINT 3
3 FORMAT(9H1POLYWOLY//)
5 READ 1000,NPLOTS
IF (EOF,60)100,10
10 READ 1003,XLEN,Y0,SCALEY,YLEN,ILOG
DO 50 K=1,NPLOTS
READ 1001,MAT,NUM,EN,L
READ 1002,(B(I),I=1,L)
CALL POLYPLOT (L,XLEN,Y0,SCALEY,YLEN,ILOG,2)
50 PRINT 1001,MAT,NUM,EN,L
ORG=XLEN*5.0
CALL PLOT (ORG,0,0,-3)
1000 FORMAT(20I3)
1001 FORMAT (A3,I5,F8,3,5X,I5)
1002 FORMAT (5E16,8)
1003 FORMAT (4F10,0,I3)
GO TO 5
100 CALL ENDPLOT
RETURN
END

```

```

SUBROUTINE OSCAR
C
C OSCAR READS AS INPUT LEGENDRE COEFFICIENTS OF FITS THAT HAVE
C ALREADY BEEN MADE IT WILL MAKE THE FOLLOWING CHANGES=
C 1 = NORMALIZE THE COEFFICIENTS AS IN LEGENDRE
C 2 = CHANGE FROM LAB TO C OF M SYSTEM
C 3 = CORRECT FIRST COEFFICIENT FOR INELASTIC SCATTERING AND FISSION
C ASSUMING ISOTROPY IN THE C OF M SYSTEM
C
COMMON/TRANS/AMASS,LAB,L,K,BLAB(20,100),BCM(20,100)
DIMENSION EN(100),SIGSCAT(100),SIGIN(100),SIGEL(100),SIGF(100)
1 READ 1000, NCOORD,NCOEFF,INEL,KSIG
IF (EOF,60)60,2
2 READ 1001,MAT,NO,AMASS,NLEVL,L,XSCALE,GAMF
READ 1009, NULL
READ 1009, NOTHING
READ 1002,(EN(I),SIGSCAT(I),I=1,NLEVL)
IF (KSIG-1)9,9,5
5 DO 8 K=1,NLEVL
8 SIGSCAT(K)=SIGSCAT(K)*12.5664
9 DO 10 K=2,L
READ 1009, NOTHING
10 READ 1002,(BLAB(K,I),I=1,NLEVL)
NORMALIZE AS IN LEGENDRE
15 DO 16 K=1,NLEVL
EN(K)=EN(K)/XSCALE
BLAB(1,K)=(SIGSCAT(K)*1000.)/12.5664
DO 16 I=2,L
IF (NCOEFF-1)16,155,16
155 BLAB(I,K)=SIGSCAT(K)*1000.*BLAB(I,K)/12.5664
16 CONTINUE
20 IF (NCOORD-1)28,25,28

```

```

C   CHANGE TO C OF M SYSTEM IF NECESSARY
25  LAB=1
    DO 27 K=1,NLEVL5
27  CALL MATRIX
    GO TO 30
28  DO 29 K=1,NLEVL5
    DO 29 I=1,L
29  BCM(I,K)=BLAB(I,K)
C   CORRECT FOR INELASTIC SCATTERING AND FISSION
30  IF (INEL=1)36,35,36
35  READ 1002,(SIGIN(K),SIGF(K),K=1,NLEVL5)
    GO TO 371
36  DO 37 K=1,NLEVL5
    SIGIN(K)=0.
37  SIGF(K)=0.
371 DO 39 K=1,NLEVL5
38  BCM(I,K)=BCM(I,K)*(SIGSCAT(K)=SIGIN(K)=GAMF*SIGF(K))/SIGSCAT(K)
39  SIGEL(K)=12.5664*BCM(I,K)/1000.
40  PRINT 1003
    PRINT 1004,MAT,AMASS,NLEVL5,L
    PRINT 1012,NCOORD,NCOEFF,INEL,KSIG,GAMF
    DO 50 K=1,NLEVL5
    PRINT 1010,EN(K)
    IF (NCOORD=1)48,45,48
45  PRINT 1005,(BLAB(I,K),BCM(I,K),I=1,L)
    GO TO 49
48  PRINT 1011,(BCM(I,K),I=1,L)
49  PUNCH 1006,MAT,NO,EN(K),L
50  PUNCH 1007,(BCM(I,K),I=1,L)
    PRINT 1008,(EN(K),SIGSCAT(K),SIGIN(K),SIGEL(K),SIGF(K),K=1,NLEVL5)
1000 FORMAT (20I3)
1001 FORMAT (A3,I3,F10.5,I3,I3,F5.0,F5.0)
1002 FORMAT (10F8.0)
1003 FORMAT(14H1PROGRAM OSCAR)
1004 FORMAT(6H0MAT =A3/7H MASS =F10.3/11H ENERGIES =I3/4H L =I3)
1005 FORMAT(34H0      B LAB                      B CM/(2E19.8))
1006 FORMAT (A3,I3,F8.3,5X,I5)
1007 FORMAT (5E16.8)
1008 FORMAT(73H0      MEV      SIGMA SCATTERING      INELASTIC      ELAST
XIC      FISSION/(F10.3,4E16.8))
1009 FORMAT (64X,I3)
1010 FORMAT(9H0ENERGY =F10.3,5H MEV)
1011 FORMAT(10H0      B CM/(E19.8))
1012 FORMAT(8H0NCOORD=I3,10H NCOEFF=I3.8H INEL=I3.8H KSIG=I3.8H
X GAMF=F8.4)
    GO TO 1
60  STOP
    END

```

SUBROUTINE MATRIX

```

C   MATRIX CALCULATES THE TRANSFORMATION MATRIX FROM LAB TO C OF M
C   SYSTEM OR VICE VERSA
C   SUBROUTINE MATRIX AND FUNCTION CLEB WERE TAKEN FROM THE CHAD CODE
C   WHICH IS DESCRIBED IN NAA-SR-MEMO-11231
C
COMMON /TRANS/A,LAB,M,IE,BOLD(20,100),BNEW(20,100)
COMMON /B5/NFAC(101),FAC(101)
C
DIMENSION T(20,20)
C
DATA      ((FAC(I),I=1,101)=1.0,1.0,2.0,6.0,2.4,1.2,7.2,5.04,4.032
1,3.6288,3.6288,3.99168,4.790016,6.2270208,8.7178291,1.3076744,
22.0922790,3.5568743,6.4023737,1.2164510,2.4329020,5.1090942,
31.1240007,2.5852017,6.2044840,1.5511210,4.0329146,1.0888869,

```

```

43.0488834,8.8417620,2.6525286,8.2228387,2.6313084,8.6833176,
52.9523280,1.0333148,3.7199333,1.3763753,5.2302262,2.0397882,
68.1591528,3.3452527,1.4050061,6.0415263,2.6582716,1.1962222,
75.5026222,2.5862324,1.2413916,6.0828186,3.0414093,1.5511188,
88.0658175,4.2748833,2.3084370,1.2696403,7.1099859,4.0526920,
92.3505613,1.3868312,8.3209871,5.0758021,3.1469973,1.9826083,
X1.2688693,8.2476506,5.4434494,3.6471111,2.4800355,1.7112245,
X1.1978572,8.5047859,6.1234458,4.4701155,3.3078854,2.4809141,
X1.8854947,1.4518309,1.1324281,8.9461821,7.1569457,5.7971260,
X4.7536433,3.9455240,3.3142401,2.8171041,2.4227095,2.1077573,
X1.8548264,1.6507955,1.4857160,1.3520015,1.2438414,1.1567725,
X1.0873662,1.0329978,9.9167793,9.6192760,9.4268904,2(9.3326215))
DATA ((NFAC(I),I=1,101)=4(0),1,2,2,3,4,5,6,7,8,9,10,12,13,14,
115,17,18,19,21,22,23,25,26,28,29,30,32,33,35,36,38,40,41,43,44,46,
247,49,51,52,54,56,57,59,61,62,64,66,67,69,71,73,74,76,78,80,81,83,
385,87,89,90,92,94,96,98,100,101,103,105,107,109,111,113,115,116,
418,120,122,124,126,128,130,132,134,136,138,140,142,144,146,148,
5149,151,153,155,157)
G=1.0/A
15 IF(18.NE.1) GO TO 200
16 MM=MINOF(2*M,20)
DO 20 I=1,MM
DO 20 L=1,M
T(L,I)=0.0
20 CONTINUE
T(1,1)=1.0
IF(LAB.EQ.0) GO TO 100
T(2,1)=2.0*G/3.0
T(2,3)=2.0*G/3.0
M2=MINOF(M,10)
MUP=0
R=G*G/(1.0-G*G)
DO 50 I=1,M2
I1=I+1
RM=(R)**I1/SQRTF(1.0+R)
SUM=0.0
DO 30 K=1,20
K1=K+1
SN=K1+I1
DIV=(1.0-4.0*SN*SN)**4.0**K1
IA=K1+2*I1+2
IB=IA+K1
IC=K+I1
ID=2*K1+4*I1
ARG=FAC(IA)*FAC(IB)**2/(FAC(K)*FAC(ID)*FAC(IC)**2)
NEPT=NFAC(IA)+2*NFAC(IB)-NFAC(K)-NFAC(ID)-2*NFAC(IC)
TERM=(-R)**K1*(ARG+10.0**NEPT)/DIV
SUM=SUM+TERM
IF(ABSF(TERM).LT.1.0E-32) GO TO 40
IF(ABSF(RM*SUM).LT.1.0E-32) GO TO 40
30 CONTINUE
40 Z1=4*I1+3
IT=2*I1
X1=2.0*Z1*RM*SUM
T(2,IT)=X1
IF(MUP.NE.0) GO TO 48
IF(ABSF(X1).GE.1.0E-16) GO TO 50
MUP=IT-2
48 IF(ABSF(X1).LT.1.0E-32) GO TO 120
50 CONTINUE
IF(MUP.EQ.0) MUP=M
GO TO 120
100 T(2,1)=2.0*G/3.0
T(2,2)=1.0-.6*G**2
MUP=0
DO 110 I=3,MM
I1=I+1

```



```

Z1=I1
Z2=I1+2
Z3=2*I1+1
Z4=2*I1+3
I2=I1-1
X1=(Z1/Z3-Z2*G**2/Z4)*(-G)**I2
T(2,I)=X1
IF(MUP.NE.0) GO TO 105
IF(ABSF(X1),GE.1,0E=16) GO TO 110
MUP=I1
105 IF(ABSF(X1),LT.1,0E=32) GO TO 120
110 CONTINUE
IF(MUP.EQ.0) MUP=M
120 ILO=1
DO 160 L=3,M
L1=L-2
Z1=2*L1+1
Z2=L1+1
Z3=L1
DO 150 I=ILO,MM
I1=I-1
SUM=Z3*T(L1,I)/Z2
DO 140 N1=1,MUP
X2=T(2,N1)
IF(ABSF(X2),EQ.0.0) GO TO 140
N2=N1-1
MAX=N2+I1+1
IF(MAX.GT.MM) MAX=MM
MIN=XABSF(N2=I1)+1
SUM1=0.0
DO 130 M1=MIN,MAX,2
X1=T(L1+1,M1)
IF(ABSF(X1),LT.1,0E=16) GO TO 130
M2=M1-1
SUM1=SUM1+CLEB(N2,M2,I1)**2*X1
130 CONTINUE
SUM=SUM+Z1*X2+SUM1/Z2
140 CONTINUE
145 IF(I,GE.L) GO TO 147
IF(ABSF(SUM),GE.ABSF(T(L-1,I))) GO TO 148
147 T(L,I)=SUM
GO TO 150
148 ILO=I+1
150 CONTINUE
160 CONTINUE
200 DO 230 I=1,M
SUM=0.0
TOP=2*I-1
DO 220 J=1,M
BOTTOM=2*J-1
220 SUM=SUM+T(I,J)*BOLD(J,IE)*TOP/BOTTOM
230 BNEW(I,IE)=SUM
RETURN
END

```

```

C      FUNCTION CLEB(I1,I2,I3)
C
COMMON      /B5/NFAC(101),FAC(101)
C
CLEB=0.0
N1=I1+I2+I3+1
IF(N1.LE.0) GO TO 99
N2=I1-I2+I3+1
IF(N2.LE.0) GO TO 99
N3=I1+I2+I3+1
IF(N3.LE.0) GO TO 99
IT=I1+I2+I3
IF(XMODF(IT,2),NE.0) GO TO 99
N4=IT+2
NEPT=NFAC(N1)+NFAC(N2)+NFAC(N3)=NFAC(N4)
ARG=FAC(N1)*FAC(N2)*FAC(N3)/FAC(N4)
Z1=ARG*10.0**NEPT
D123=SQRTF(Z1)
IS=IT/2
SIGNX=1
IF(XMODF(IS+I3,2),EQ.1) SIGNX=-1
IA=IS+1
IB=IS-I1+1
IC=IS-I2+1
ID=IS-I3+1
NEPT=NFAC(IA)-NFAC(IB)-NFAC(IC)-NFAC(ID)
ARG=FAC(IA)/((FAC(IB)*FAC(IC)*FAC(ID)))
Z1=2*I3+1
CLEB=SIGNX*SQRTF(Z1)*D123*ARG*10.0**NEPT
99 RETURN
END

```

```

SUBROUTINE COAGOGO
C
C      COAGOGO READS SMITH COEFFICIENTS AND CHANGES TO LEGENDRE
C      NORMALIZATION ,OR READS LEGENDRE NORMALIZED COEFFICIENTS DIRECTLY
C      THE COEFFICIENTS ARE TRANSFERRED TO THE C OF M SYSTEM USING MATRIX.
C      IF NECESSARY
C      THE FIRST COEFFICIENT MAY BE CORRECTED FOR INELASTIC SCATTERING
C      THE DISTRIBUTION DEFINED BY THE LEGENDRE COEFFICIENTS MAY BE
C      PLOTTED USING POLYPL0T
C
DIMENSION A(10),XX(11),BP(20,11),SUM(11)
COMMON/GRAPH/BLOCK(10000)
COMMON/TRANS/AMASS,LAB,L,MM,B(20,100),BCM(20,100)
COMMON/COEFF/C(20)/PRINT/MAT,EN,JOKE,NO
LAB=1
JOKE=1
PRINT 1012
READ 1000,IFCAL
IF (IFCAL)3,1,3
C      INITIALIZE TAPE 1 FOR PLOTTING
3 CALL PLOTS(BLOCK,10000,1)
1 READ 1000,NCOORD,NCOEF,INEL,L
IF (EOF,60)60,2
2 READ 1001,MAT,NO,AMASS,NLEVL5
PRINT 1017,IFCAL,MAT,AMASS,NLEVL5,L
PRINT 1018,NCOORD,NCOEF,INEL
IF (NCOEF-1) 9,5,5

```

```

5. READ 1007, NULL
9 DO 50 MM=1, NLEVL
  IF (NCOEF=1) 7, 6, 6
C READ SMITH COEFFICIENTS
6 READ 1002, EN, SIGEL, (A(J), J=1, 6)
C REDEFINE COEFFICIENTS AS IN LEGENDREVILLE
  B(1, MM) = (SIGEL*1000.)/12, 5664
  DO 10 K=2, 7
10 B(K, MM) = SIGEL*1000.*A(K-1)/12, 5664
  GO TO 8
7 READ 1013, EN, L
  READ 1008, (B(K, MM), K=1, L)
8 IF (NCOORD=1) 14, 13, 14
C TRANSFER TO C OF M SYSTEM IF NECESSARY
13 CALL MATRIX
  GO TO 151
14 DO 15 K=1, L
15 BCM(K, MM)=B(K, MM)
151 SIGEL=12, 5664*BCM(1, MM)/1000.
16 IF (INEL=1) 19, 19, 17
C CORRECT FOR INELASTIC SCATTERING
17 READ 1009, SIGIN, SIGTOT
  BCM(1, MM) = BCM(1, MM)*(SIGTOT=SIGIN)/SIGTOT
  SIGEL = 12, 5664*BCM(1, MM)/1000.
  GO TO 20
19 SIGIN=0.
20 PUNCH 1006, MAT, NO, EN, L
  PRINT 1003, MAT, NO, EN, SIGEL
  PRINT 1019, SIGIN
  PUNCH 1004, (BCM(K, MM), K=1, L)
  IF (NCOEF=1) 22, 21, 21
21 L1=L+1
  PRINT 1014, (A(K), K=1, L1)
22 PRINT 1015, (B(K, MM), K=1, L)
  PRINT 1016, (BCM(K, MM), K=1, L)
C COMPUTE TYPICAL VALUES ALONG CURVE
  DO 25 K=1, 11
  XX(K)=-1.0+(K-1, 0)*0.2
  BP(1, K)=1.0
25 BP(2, K)=XX(K)
  DO 30 LL=3, L
  Q=LL-2
  DO 30 I=1, 11
30 BP(LL, I)=((2.0+Q*1.0)*XX(I)*BP(LL-1, I)-Q*BP(LL-2, I))/(Q+1.0)
  DO 35 I=1, 11
  SUM(I)=0.0
  DO 35 K=1, L
35 SUM(I)=SUM(I)+BP(K, I)*BCM(K, MM)
  PRINT 1005, (XX(I), SUM(I), I=1, 11)
  IF (IFCAL) 351, 50, 351
351 DO 355 I=1, L
355 C(I)=BCM(I, MM)
  IF (IFCAL) 36, 50, 37
36 READ 1011, XLEN, Y0, SCALEY, YLEN, ILOG
C PLOT THE CURVE
  CALL POLYPLOT (L, XLEN, Y0, SCALEY, YLEN, ILOG, 4)
  ORG=XLEN+5.0
  CALL PLOT (ORG, 0, 0, 3)
  GO TO 50
37 YMAX=0.0
  DO 39 I=1, 11
  IF (SUM(I)-YMAX) 39, 39, 38
38 YMAX=SUM(I)
39 CONTINUE
  IF (YMAX-2500.) 41, 40, 40
40 CALL POLYPLOT (L, 5.0, 0.0, .001, 10, 0, 0, 4)
  GO TO 45

```

```

41 IF (YMAX=500, )43,42,42
42 CALL POLYPLOT (L,5.0,0.0,0.004,10,0,0,4)
   GO TO 45
43 CALL POLYPLOT (L,5.0,0.0,0.01,5.0,0,4)
45 CALL PLOT (10,0,0.0,-3)
1000 FORMAT (20I3)
1001 FORMAT (A3,I3,F10,5,I3)
1002 FORMAT (6X,F4,3,F4,2,6(F5,3,4X))
1003 FORMAT (1H1,2X,A3,I5,12H ENERGY =E19.8,14H SIGMA EL =E19.8)
1004 FORMAT (5E16,8)
1005 FORMAT (32H0 COS OF THETA SIGMA/(2E19,8))
1006 FORMAT (A3,I5,F8,3,5X,I5)
1007 FORMAT (21X,I3)
1008 FORMAT (5E16,8)
1009 FORMAT (F10,5)
1011 FORMAT (4F10,0,I4)
1012 FORMAT (16H1PROGRAM COAGOGO)
1013 FORMAT (8X,F8,3,5X,I5)
1014 FORMAT (25H0INPUT SMITH COEFFICIENTS/(5E16,8))
1015 FORMAT (38H0LEGENDRE COEFFICIENTS IN INPUT SYSTEM/(5E16,8))
1016 FORMAT (39H0LEGENDRE COEFFICIENTS IN C OF M SYSTEM/(5E16,8))
1017 FORMAT(8H0IFCAL =I3/6H MAT =A3/7H MASS =F10,3/11H ENERGIES =I3/4H
   XL =I3)
1018 FORMAT(8H0NCOORD=I3,9H NCOEF=I3,8H INEL=I3)
1019 FORMAT (33H0 SIGMA INEL =E19,8)
   50 CONTINUE
   GO TO 1
60 IF (IFCAL)61,62,61
61 CALL ENDPLOT
62 END

```

SUBROUTINE RENORM

```

C
C CHANGE LEGENDRE COEFFICIENTS FROM MC**2 TO ENDF/B NORMALIZATION
C
   DIMENSION B(20),F(20)
   PRINT 5
   5 FORMAT (15H1PROGRAM RENORM)
   7 READ 10,MAT,NUM,ENERGY,L
   IF(EOF,60)70,8
   8 READ 15,(B(I),I=1,L)
10  FORMAT(A3,I5,F8,3,5X,I5)
15  FORMAT (5E16,8)
   SIGEL=12.5664*B(1)/1000.
   DO 25 I=2,L
   XI=I-1
25  F(I)=B(I)/((2.*XI+1.)*B(1))
   PRINT 30,MAT,NUM,ENERGY,SIGEL
   PRINT 35,(B(I),I=1,L)
   PRINT 40,(F(I),I=2,L)
   PUNCH 50,MAT,NUM,ENERGY,L,SIGEL
   PUNCH 60,(F(I),I=2,L)
30  FORMAT (///2X,A3,I5,12H ENERGY =E19.8,14H SIGMA EL =E19.8)
35  FORMAT (39H0INPUT COEFFICIENTS MC**2 NORMALIZATION/(5E16,8))
40  FORMAT (41H0OUTPUT COEFFICIENTS ENDF/B NORMALIZATION/(5E16,8))
50  FORMAT (A3,I5,F8,3,5X,I5,F10,5)
60  FORMAT (6E13,5)
   GO TO 7
70  STOP
   END

```

APPENDIX B
Listing of SAD Input Cards

1. LEGENDRE Input

```

1
1
LEGENDRE SAMPLE PROBLEM FOR ALUMINUM AT 3.01 MEV WITH LINEAR PLOTTING
1 1 2 2 2 0
AL 27 3.010 5 9 13 0 2 3 5.0 0.0 0.01 8.0 0
2
.846 419.00 .750 329.00 .616 228.00 .466 169.00 .290 122.00
.126 86.00 -.046 74.00 -.230 72.00 -.400 69.00 -.620 67.00
.766 82.00 1. 600. -1. 125.
0
BNL-400 VOL 1 PAGE 13-0-2 TOWLE AND GILBOY

```

2. POLYWOLY Input

```

2
6
10.0 0.0 0.01 8.0 0
NA 23 0.220 11 10
3.57540818+002 8.70372185+000 -1.32254214+000 8.11937118+001 1.50530812+001
-2.16243381+000 2.02389857+001 1.15080813+001 -3.67724405+001 -6.23500666+002
NA 23 0.240 11 10
4.76303388+002 1.65714057+002 1.03722249+002 -1.12797222+001 9.33528181+001
1.45309053+002 7.51770234+002 -7.03961506+002 -1.13908946+001 -5.78872071+002
NA 23 0.360 11 10
2.40108513+002 -5.33684290+001 2.26508409+001 -6.81605036+000 2.41189878+001
-1.56947408+000 -1.30638359+000 2.47631131+001 -5.29591736+002 3.32223399+000
NA 23 0.400 11 10
3.87119422+002 1.27331347+002 -2.18347498+001 1.01639532+001 -2.71795510+001
3.35294150+000 -5.70596509+001 9.71544115+001 -1.03857824+000 7.75918637+001
NA 23 0.430 11 10
2.54971330+002 -4.07054273+000 2.13298579+001 4.04103468+000 -1.83693623+001
2.84538622+000 -2.28593744+001 -2.32290747+001 9.30493563+002 -1.8 24.1 2+001
NA 23 0.450 11 10
3.99533856+002 1.09773965+002 1.20658110+001 -2.35736387+000 7.25319519+001
-4.05778908+001 -6.98665822+002 6.54497017+001 -6.47022123+001 6.42453420+001

```

3. OSCAR Input

```

3
1 0 0 2
0 16 15.9994 5 6 1.0 0.0
OXYGEN LAB LANGSDORF
B0
0.163 0.230 0.207 0.224 0.293 0.234 0.320 0.240 0.340 0.231
B1
-18.0 -66.0 -134.0 -128.0 -158.0
B2
-60.0 -37.0 -43.0 -42.0 -49.0
B3
-6.0 -33.0 -59.0 -11.0 -40.0
B4
+5.0 +38.0 +8.0 -8.0 +16.0
B5
+2.0 -44.0 -37.0 +4.0 -83.0

```

4. COAGOGO Input

4
1
1 1 0 5
CR 52 52,01 5

318	249	613	48	287	68	19	85	123	110	0	0	A50=CR
325	251	540	49	325	69	-38	86	136	109	0	0	A50=CR
353	289	542	43	339	61	-29	75	23	100	0	0	A50=CR
375	268	474	30	384	42	15	53	-1	69	0	0	A50=CR
381	262	547	28	381	40	21	50	-38	66	0	0	A50=CR

5. RENORM Input

5
FE 56 1.800 11 10
1.47556503+002 9.17572529+001 1.45646486+002 8.33339293+001 4.13325685+001
-2.52848718+000 8.33803009+002 -6.20039269+002 -4.88711564+002 -3.06504163+002
FE 56 2.010 21 10
1.88297854+002 1.75441580+002 3.08795506+002 2.38868612+002 1.25912084+002
7.07696606+001 4.21205180+001 2.65884669+001 1.24961383+001 4.03537850+000
FE 56 3.010 21 10
1.84681633+002 2.55840045+002 3.57808198+002 3.71114392+002 2.01959988+002
6.29261633+001 3.31620644+001 2.31704038+001 -5.68957825+001 -6.71035251+000
FE 56 3.990 21 10
1.64257617+002 3.03741405+002 3.93921738+002 4.29358595+002 2.93422543+002
1.39550689+002 8.18799337+001 5.66496494+001 1.88098790+001 -4.08612979+001
FE 56 4.192 11 10
1.58816456+002 3.42983749+002 4.27192474+002 4.16643729+002 2.85601971+002
1.23950277+002 4.32713581+001 1.34815317+001 2.67996663+000 6.03062832+001

APPENDIX C
Listing of SAD Printed Output

1. LEGENDRE Printed Output

LEGENDRE SAMPLE PROBLEM FOR ALUMINUM AT 3.01 MEV WITH LINEAR PLOTTING

MP= 1 MPE= 1 MPWGTS= 2 MRADEG= 2 MCRADG= 2 MERROR= 0

AL 27 3.010 MEV

LMIN= 5 LMAX= 9 LDELTA= .2 N= 13 NX= 0 NPLOTS= 2 KPLOTS= 3
 XLEN= 5.0000 Y0= 0.0000 SCALEY= 0.0100 YLEN= 8.0000 ILOG= 0

LEGENDRE COEFFICIENTS

1.54763544+002	1.71412512+002	1.75538339+002	6.71824495+001	3.29528632+001
COS THETA	Y EXPER	Y COMPUTED	DELTA Y	
8.46000000-001	4.19000000+002	4.14669293+002	-4.33070660+000	
7.50000000-001	3.29000000+002	3.27403745+002	-1.59625451+000	
6.16000000-001	2.28000000+002	2.35905525+002	7.90552511+000	
4.66000000-001	1.69000000+002	1.66408328+002	-2.59167162+000	
2.90000000-001	1.22000000+002	1.16704573+002	-5.29542672+000	
1.26000000-001	8.60000000+001	9.08429255+001	4.84292548+000	
-4.60000000-002	7.40000000+001	7.63822864+001	2.38228643+000	
-2.30000000-001	7.20000000+001	6.88566295+001	-3.14337054+000	
-4.00000000-001	6.90000000+001	6.63951752+001	-2.60482482+000	
-6.20000000-001	6.70000000+001	7.05436885+001	3.54368855+000	
-7.66000000-001	8.20000000+001	8.13783368+001	-6.21663155+001	
1.00000000+000	6.00000000+002	6.01849707+002	1.84970737+000	
-1.00000000+000	1.25000000+002	1.24659785+002	-3.40214882+001	

POLYP HAS BEEN ENTERED

5.0000 0.0000 0.0100 8.0000 13 1 0

STANDARD DEVIATIONS

1.36015709+000 2.21996148+000 2.81812509+000 2.88864319+000 3.06557869+000

SUM OF SQUARED DEVIATIONS,... 1.80835145+002

DETERMINANT,... 1.44289649+003

N... 13

L... 5

LEGENDRE COEFFICIENTS

1,54757221+002	1,71624606+002	1,75594841+002	6,79908273+001	3,34418669+001	-1,70497361+000
-7,93031033-001					

COS THETA	Y EXPER	Y COMPUTED	DELTA Y
8,46000000-001	4,19000000+002	4,15872501+002	-3,12749892+000
7,50000000-001	3,29000000+002	3,28280463+002	-7,19537377-001
6,16000000-001	2,28000000+002	2,35777300+002	7,77730002+000
4,66000000-001	1,69000000+002	1,65478088+002	-3,52191184+000
2,90000000-001	1,22000000+002	1,15803556+002	-6,19644449+000
1,26000000-001	8,60000000+001	9,06381879+001	4,63818794+000
-4,60000000-002	7,40000000+001	7,69557070+001	2,95570701+000
-2,30000000-001	7,20000000+001	6,97013266+001	-2,29867341+000
-4,00000000-001	6,90000000+001	6,68191172+001	-2,18088277+000
-6,20000000-001	6,70000000+001	7,00355057+001	3,03550572+000
-7,66000000-001	8,20000000+001	8,06364538+001	-1,36354619+000
1,00000000+000	6,00000000+002	6,00911357+002	9,11357269+001
-1,00000000+000	1,25000000+002	1,25090437+002	9,04371254+002

POLYP. HAS BEEN ENTERED

5,0000	0,0000	0,0100	8,0000	13	1	0
--------	--------	--------	--------	----	---	---

STANDARD DEVIATIONS

1,56529343+000	2,61186753+000	3,53253354+000	3,85689328+000	4,17840773+000	4,00303177+000
4,86901987+000					

SUM OF SQUARED DEVIATIONS,... 1,73786611+002

DETERMINANT,... 3,30728902+003

N.... 13

L.... 7

LEGENDRE COEFFICIENTS

COS THETA	Y EXPER	Y COMPUTED	DELTA Y			
1,56318442+002 7,48861843-001	1,70046695+002 1,27013059+000	1,81591823+002 -1,49816768+001	6,62093998+001	3,87325762+001	-1,06634862+001	
8,46000000-001	4,19000000+002	4,20927580+002	1,92757965+000			
7,50000000-001	3,29000000+002	3,24890321+002	-4,10967913+000			
6,16000000-001	2,28000000+002	2,31746138+002	3,74613841+000			
4,66000000-001	1,69000000+002	1,68181272+002	-8,18727907+001			
2,90000000-001	1,22000000+002	1,19597244+002	-2,40275558+000			
1,26000000-001	8,60000000+001	8,89129572+001	2,91295720+000			
-4,60000000-002	7,40000000+001	7,31659164+001	-8,30083597+001			
-2,30000000-001	7,20000000+001	7,09925883+001	-1,00741168+000			
-4,00000000-001	6,90000000+001	7,01078772+001	1,10787715+000			
-6,20000000-001	6,70000000+001	6,64814100+001	-5,18589990+001			
-7,66000000-001	8,20000000+001	8,21726432+001	1,72643179+001			
1,00000000+000	6,00000000+002	5,99829616+002	-1,70383528+001			
-1,00000000+000	1,25000000+002	1,24990436+002	-9,56413895+003			

POLYP HAS BEEN ENTERED

5,0000 0,0000 0,0100 8,0000 13 1 0

STANDARD DEVIATIONS

1,22258461+000	2,18701226+000	3,39642922+000	3,33505771+000	3,47113861+000	2,93403076+000
3,52021157+000	4,49048343+000	5,18277367+000			

SUM OF SQUARED DEVIATIONS,... 5,28266203+001

DETERMINANT,... 1,24928634+003

N,... 13

L,... 9

BEST FIT IS GIVEN BY 9 ORDER

SUM OF SQUARED DEVIATIONS= 5,28266203+001

2. POLYWOLY Printed Output

NA	23	0.220	10
NA	23	0.240	10
NA	23	0.360	10
NA	23	0.400	10
NA	23	0.430	10
NA	23	0.450	10

3. OSCAR Printed Output

MAT = 0

MASS = 15.999

ENERGIES = 5

L = 6

NCOORD = 1 NCOEFF = 0 INEL = 0 KSIG = 2 GAMF = 0.0000

ENERGY = 0.163 MEV

B LAB	B CM
2.30000000+002	2.30000000+002
=1.80000000+001	=4.82390740+001
=6.00000000+001	=5.50689508+001
=6.00000000+000	2.99930203+000
5.00000000+000	5.23161129+000
2.00000000+000	8.76599591+001

ENERGY = 0.207 MEV

B LAB	B CM
2.24000000+002	2.24000000+002
=6.60000000+001	=9.48855462+001
=3.70000000+001	=2.76570995+001
=3.30000000+001	=2.31599710+001
3.80000000+001	3.76491897+001
=4.40000000+001	=5.12422332+001

ENERGY = 0.293 MEV

B LAB	B CM
2.34000000+002	2.34000000+002
=1.34000000+002	=1.64241154+002
=4.30000000+001	=2.64539292+001
=5.90000000+001	=5.33022908+001
8.00000000+000	1.35802432+001
=3.70000000+001	=3.88458305+001

ENERGY = 0.320 MEV

B LAB	B CM
2.40000000+002	2.40000000+002
=1.28000000+002	=1.58954788+002
=4.20000000+001	=2.35937113+001
=1.10000000+001	=7.08882178+000
=8.00000000+000	=5.99083962+000
4.00000000+000	5.34231357+000

ENERGY = 0.340 MEV

B LAB	B CM
2.31000000+002	2.31000000+002
=1.58000000+002	=1.87991013+002
=4.90000000+001	=2.84351316+001

```

-4,00000000+001  -3,34098599+001
1,60000000+001   1,28091311+001
-8,30000000+001  -8,47563629+001

```

MEV	SIGMA SCATTERING	INELASTIC	ELASTIC	FISSION
0,163	2,89027200+000	0,00000000+000	2,89027200+000	0,00000000+000
0,207	2,81487360+000	0,00000000+000	2,81487360+000	0,00000000+000
0,293	2,94053760+000	0,00000000+000	2,94053760+000	0,00000000+000
0,320	3,01593600+000	0,00000000+000	3,01593600+000	0,00000000+000
0,340	2,90283840+000	0,00000000+000	2,90283840+000	0,00000000+000

4. COAGOGO Printed Output

```

IFCAL = 1
MAT = CR
MASS = 52,010
ENERGIES = 5
L = 5
NCOORD= 1 NCOEF= 1 INEL= 0

```

```

CR 52 ENERGY = 3,18000000+001 SIGMA EL = 2,49000000+000
SIGMA INEL = 0,00000000+000

```

INPUT SMITH COEFFICIENTS

```
6,13000000-001 2,87000000-001 1,90000000-002 1,23000000-001
```

LEGENDRE COEFFICIENTS IN INPUT SYSTEM

```
1,98147441+002 1,21464381+002 5,68583155+001 3,76480138+000 2,43721352+001
```

LEGENDRE COEFFICIENTS IN C OF M SYSTEM

```
1,98147441+002 1,14273294+002 5,24561915+001 1,90036766+000 2,42084524+001
```

COS OF THETA

SIGMA

-1,00000000+000	1,58638423+002
-8,00000000+001	1,25066055+002
-6,00000000+001	1,22488796+002
-4,00000000+001	1,36900120+002
-2,00000000+001	1,58360522+002
0,00000000+000	1,80997515+002
2,00000000+001	2,03005633+002
4,00000000+001	2,26646432+002
6,00000000+001	2,58248484+002
8,00000000+001	3,08207384+002
1,00000000+000	3,90985746+002

CR 52 ENERGY = 3.25000000-001 SIGMA EL = 2.51000000+000

SIGMA INEL = 0.00000000+000

INPUT SMITH COEFFICIENTS

5.40000000-001 3.25000000-001 -3.80000000-002 1.36000000-001

LEGENDRE COEFFICIENTS IN INPUT SYSTEM

1.99738986+002 1.07859053+002 6.49151706+001 -7.59008149+000 2.71645022+001

LEGENDRE COEFFICIENTS IN C OF M SYSTEM

1.99738986+002 1.00669297+002 6.08374046+001 -9.75851654+000 2.76323319+001

COS OF THETA

SIGMA

-1.00000000+000	1.97297943+002
-8.00000000-001	1.41531103+002
-6.00000000-001	1.26983847+002
-4.00000000-001	1.36237342+002
-2.00000000-001	1.56514985+002
0.00000000+000	1.79682409+002
2.00000000-001	2.02247474+002
4.00000000-001	2.25360274+002
6.00000000-001	2.54813135+002
8.00000000-001	3.01040615+002
1.00000000+000	3.79119503+002

CR 52 ENERGY = 3.53000000-001 SIGMA EL = 2.89000000+000

SIGMA INEL = 0.00000000+000

INPUT SMITH COEFFICIENTS

5.42000000-001 3.39000000-001 -2.90000000-002 2.30000000-002

LEGENDRE COEFFICIENTS IN INPUT SYSTEM

2.29978355+002 1.24648268+002 7.79626623+001 -6.66937229+000 5.28950216+000

LEGENDRE COEFFICIENTS IN C OF M SYSTEM

2.29978355+002 1.16394817+002 7.32787752+001 -9.98213462+000 5.76577826+000

COS OF THETA

SIGMA

-1.00000000+000	2.02610226+002
-8.00000000-001	1.70025882+002
-6.00000000-001	1.57126610+002
-4.00000000-001	1.59324274+002
-2.00000000-001	1.72999393+002
0.00000000+000	1.95501134+002
2.00000000-001	2.25147316+002
4.00000000-001	2.61224407+002
6.00000000-001	3.03987527+002
8.00000000-001	3.54660448+002
1.00000000+000	4.15435591+002

CR 52 ENERGY = 3,75000000+001 SIGMA EL = 2,68000000+000

SIGMA INEL = 0,00000000+000

INPUT SMITH COEFFICIENTS

4,74000000+001 3,84000000+001 1,50000000+002 -1,00000000+003

LEGENDRE COEFFICIENTS IN INPUT SYSTEM

2,13267125+002 1,01088617+002 8,18945760+001 3,19900688+000 -2,13267125+001

LEGENDRE COEFFICIENTS IN C OF M SYSTEM

2,13267125+002 9,35100767+001 7,82579897+001 -4,73732332+001 -2,61926064+001

COS OF THETA

SIGMA

1,00000000+000	1,98226844+002
8,00000000+001	1,74556666+002
6,00000000+001	1,60227721+002
4,00000000+001	1,55337172+002
2,00000000+001	1,59938182+002
0,00000000+000	1,74039908+002
2,00000000+001	1,97607503+002
4,00000000+001	2,30562118+002
6,00000000+001	2,72780900+002
8,00000000+001	3,24096992+002
1,00000000+000	3,84299533+002

CR 52 ENERGY = 3,81000000+001 SIGMA EL = 2,62000000+000

SIGMA INEL = 0,00000000+000

INPUT SMITH COEFFICIENTS

5,47000000+001 3,81000000+001 2,10000000+002 -3,80000000+002

LEGENDRE COEFFICIENTS IN INPUT SYSTEM

2,08492488+002 1,14045391+002 7,94356379+001 4,37834225+000 -7,62271454+000

LEGENDRE COEFFICIENTS IN C OF M SYSTEM

2,08492488+002 1,06630623+002 7,53150830+001 6,35711128+001 -8,62673650+000

COS OF THETA

SIGMA

1,00000000+000	1,68514500+002
8,00000000+001	1,59652300+002
6,00000000+001	1,51030482+002
4,00000000+001	1,47445051+002
2,00000000+001	1,52343523+002
0,00000000+000	1,67824920+002
2,00000000+001	1,94639774+002
4,00000000+001	2,32190124+002
6,00000000+001	2,78529518+002
8,00000000+001	3,30363011+002
1,00000000+000	3,83047169+002

5. RENORM Printed Output

PROGRAM RENORM

```

FE 56 ENERGY = 1.80000000+000 SIGMA EL = 1.85425494+000
INPUT COEFFICIENTS MC**2 NORMALIZATION
1.47556503+002 9.17572529+001 1.45646486+002 8.33339293+001 4.13325685+001
-2.52848718+000 8.33803009+002 -6.20039269+002 -4.88711564+002 -3.06504163+002
OUTPUT COEFFICIENTS ENDF/B NORMALIZATION
2.07281620+001 1.97411138+001 8.06799213+002 3.11237222+002 -1.55779289+003
4.34672086+005 -2.80136425+005 -1.94825294+005 -1.09326243+005

```

```

FE 56 ENERGY = 2.01000000+000 SIGMA EL = 2.36622615+000
INPUT COEFFICIENTS MC**2 NORMALIZATION
1.88297854+002 1.75441580+002 3.08795506+002 2.38868612+002 1.25912084+002
7.07696606+001 4.21205180+001 2.65884669+001 1.24961383+001 4.03537850+000
OUTPUT COEFFICIENTS ENDF/B NORMALIZATION
3.10574579+001 3.27986219+001 1.81223985+001 7.42984121+002 3.41671738+002
1.72069929+002 9.41362008+003 3.90374581+003 1.12793820+003

```

```

FE 56 ENERGY = 3.01000000+000 SIGMA EL = 2.32078327+000
INPUT COEFFICIENTS MC**2 NORMALIZATION
1.84681633+002 2.55840045+002 3.57808198+002 3.71114392+002 2.61959988+002
6.29261633+001 3.31620644+001 2.31704038+001 -5.68957825+001 -6.71035251+000
OUTPUT COEFFICIENTS ENDF/B NORMALIZATION
4.61767711+001 3.87486500+001 2.87068838+001 1.21506391+001 3.09752530+002
1.38125703+002 8.36408885+003 -1.81220551+004 -1.91235285+003

```

```

FE 56 ENERGY = 3.99000000+000 SIGMA EL = 2.06412692+000
INPUT COEFFICIENTS MC**2 NORMALIZATION
1.64257617+002 3.03741405+002 3.93921738+002 4.29358595+002 2.93422543+002
1.39550689+002 8.18799337+001 5.66496494+001 1.88098790+001 -4.08612979+001
OUTPUT COEFFICIENTS ENDF/B NORMALIZATION
6.16392328+001 4.79638930+001 3.73419165+001 1.98483975+001 7.72349344+002
3.83449885+002 2.29921958+002 6.73614710+003 -1.30928152+004

```

```

FE 56 ENERGY = 4.19200000+000 SIGMA EL = 1.99575111+000
INPUT COEFFICIENTS MC**2 NORMALIZATION
1.58816456+002 3.42983749+002 4.27192474+002 4.16643729+002 2.85601971+002
1.23950277+002 4.32713581+001 1.34815317+001 2.67996663+000 6.03062832+001
OUTPUT COEFFICIENTS ENDF/B NORMALIZATION
7.19874497+001 5.37970038+001 3.74775601+001 1.99812747+001 7.09511299+002
2.09585712+002 5.65916656+003 9.92624441+004 1.99854284+004

```

APPENDIX D

Listing of SAD Punched Output1. LEGENDRE Punched Output

AL 27 3.010 13 5				
1,54763544+002	1,71412512+002	1,75538339+002	6,71824495+001	3,29528632+001
AL 27 3.010 13 7				
1,54757221+002	1,71624606+002	1,75594841+002	6,79908273+001	3,34418669+001
1,70497361+000	7,93031033-001			
AL 27 3.010 13 9				
1,56318442+002	1,70046695+002	1,81591823+002	6,62093998+001	3,87325762+001
1,06634862-001	7,48861843-001	1,27013059+000	1,49816768+001	

2. OSCAR Punched Output

0 16 0.163 6				
2,30000000+002	4,82390740+001	5,50689508+001	2,99930203+000	5,23161129+000
8,76599591-001				
0 16 0.207 6				
2,24000000+002	9,48855462+001	2,76570995+001	2,51599710+001	3,76491897+001
5,12422332+001				
0 16 0.293 6				
2,34000000+002	1,64241154+002	2,64539292+001	5,33022908+001	1,35802432+001
3,88458305+001				
0 16 0.320 6				
2,40000000+002	1,58954788+002	2,35937113+001	7,08882178+000	5,99083962+000
5,34231357+000				
0 16 0.340 6				
2,31000000+002	1,87991013+002	2,84351316+001	3,34098599+001	1,28091311+001
8,47563629+001				

3. COAGOGO Punched Output

CR 52 0.318 5				
1,98147441+002	1,14273294+002	5,24561915+001	1,90036766+000	2,42084524+001
CR 52 0.325 5				
1,99738986+002	1,00669297+002	6,08374046+001	9,75851654+000	2,76323319+001
CR 52 0.353 5				
2,29978355+002	1,16394817+002	7,32787752+001	9,98213462+000	5,76577826+000
CR 52 0.375 5				
2,13267125+002	9,35100767+001	7,82579897+001	4,73732332-001	2,61926064-001
CR 52 0.381 5				
2,08492488+002	1,06630623+002	7,53150830+001	6,35711128-001	8,02673650+000

4. RENORM Punched Output

FE	56	1.800	10	1.85425			
		2.07282=001	1.97411=001	8.06799=002	3.11237=002	=1.55779-003	4.34672-005
		=2.80136=005	=1.94825=005	=1.09326=005			
FE	56	2.010	10	2.36623			
		3.10575=001	3.27986=001	1.81224=001	7.42984=002	3.41672-002	1.72070-002
		9.41362=003	3.90375=003	1.12794=003			
FE	56	3.010	10	2.32078			
		4.61768=001	3.87487=001	2.87069=001	1.21506=001	3.09753-002	1.38126-002
		8.36409=003	=1.81221=004	=1.91235=003			
FE	56	3.990	10	2.06413			
		6.16392=001	4.79639=001	3.73419=001	1.98484=001	7.72349-002	3.83450-002
		2.29922=002	6.73615=003	=1.30928=004			
FE	56	4.192	10	1.99575			
		7.19874=001	5.37970=001	3.74776=001	1.99813=001	7.09511-002	2.09586-002
		5.65917=003	9.92624=004	1.99854=004			

APPENDIX E
Calcomp Plots from SAD

Fig. 1. Calcomp Plot from the
LEGENDRE Sample Problem
Using a Five-term Expansion

Fig. 2. Calcomp Plot from the
LEGENDRE Sample Problem
Using a Seven-term Expansion

Fig. 3. Calcomp Plot from the
LEGENDRE Sample Problem
Using a Nine-term Expansion

Fig. 4. Calcomp Plot from a LEGENDRE Problem illustrating Logarithmic Plotting

Fig. 6. A Typical Calcomp Plot from the COAGOGO Sample Problem

Fig. 5. Calcomp Plot from the POLYWOLY Sample Problem

APPENDIX F

Listing of Program DRIVER and Associated Subroutines

```

PROGRAM DRIVER
EXTERNAL LINAXIS, LNAXIS
DIMENSION AAAAA(10000), Y(20,500), X(500), XX(500), YY(500), LMESS(8)
DIMENSION NXX(500), LDAYSQ(8), SOURCE (100,3), ENERGY(500), ORDER(100,
15)
C INITIALIZE TAPE (1) FOR PLOTTING
CALL PLOTS(AAAA,10000,1)
M=60 $ M2=61
NNX=0
TOPEGG=10.
7 READ (M,1111) INORM
1111 FORMAT (I3)
IF(EOF,60)8,1112
8 STOP
1112 READ (M,1401) LDAYSQ
1401 FORMAT (I2,7A8)
READ (M,1000) NNN,LMESS,NOENG
9 READ (M,1002) X0,SCALEXX,XEGG
1000 FORMAT(2I6,7A8,I2)
1002 FORMAT(6E12,0)
DO 1 I=1,NNN
IF(INORM)1003,1003,1004
1003 READ (M,1005) NAME,NATOM,X(I),NX,(Y(K,I),K=1,NX)
GO TO 1008
1004 READ (M,1006) NAME,NATOM,X(I),NX,Y(1,I),(Y(K,I),K=2,NX)
1005 FORMAT (A3,I5,F8,3,5X,I5/(5E16,8))
1006 FORMAT (A3,I5,F8,3,5X,I5,F10,5/(6E13,5))
1008 NXX(I)=NX
NNX=XMAXOF(NXX(I),NNX)
1 CONTINUE
NX=NNX
NNX = 0
XX0=LOGF(X0)
DO 780 KK= 1,NOENG
780 READ (M,600) ENERGY(KK),(SCURCE(KK,I),I=1,3),(ORDER(KK,I),I=1,5)
600 FORMAT(14X,F7,3,3A8,5A7)
DO 6 K=1,NX
K1=K-1
WRITE (M2,981) (LMESS(I),I=2,8), NAME,NATOM
981 FORMAT (1H120X,7A8,A3,I4,/)
IF(INORM) 1099,1099,1101
1099 WRITE(M2,1100) K1,K1
1100 FORMAT( 1X*8(L), L=12///17X*ENERGY*15X*8(*I2,*)*7X*ORDER*/)
GO TO 881
1101 IF(K1) 1102,1102,1104
1102 WRITE(M2,1103)
1103 FORMAT (1X*SIGMA S*///17X*ENERGY*15X*SIGMA S*5X*ORDER*/)
GO TO 881
1104 WRITE(M2,1106) K1,K1
1106 FORMAT( 1X*F(L), L=12///17X*ENERGY*15X*F(*I2,*)*7X*ORDER*/)
881 DO 781 KK=1,NOENG
781 WRITE(M2,600)ENERGY(KK),(SCURCE(KK,I),I=1,3),(ORDER(KK,I),I=1,5)
WRITE (M2,651)
651 FORMAT (1H0)
IF(INORM) 1040,1040,1041
1040 SCALE=1.
GO TO 1042
1041 SCALE=1000.
1042 IF (NNN=1) 15,25,35
15 STOP
25 IF (Y(K,1)) 26,27,27
26 YLIT = Y(K,1) $ YBIG = 50./SCALE $ GO TO 39.
27 YBIG = Y(K,1) $ GO TO 40
C*****
C THIS SECTION USED ONLY IF NNN(NO. OF ENERGIES) G.T. 1.

```

```

C SEARCH FOR LARGEST AND SMALLEST Y(K,I) OVER ALL ENERGIES
35 YBIG = 0.0 & YLIT = 0.0
C FIND YBIG
DO 77 I = 2,NNN
  IF (Y(K,I)-Y(K,I-1)) 16,16,17
17 YBIG = MAXIF(YBIG,Y(K,I))
  GO TO 77
16 YBIG = MAXIF(YBIG,Y(K,I-1))
77 CONTINUE
C NOW FIND SMALLEST Y
DO 78 I = 2,NNN
  IF (Y(K,I) - Y(K,I-1)) 19,18,18
19 YLIT = MINIF(YLIT,Y(K,I))
  GO TO 78
18 YLIT = MINIF(YLIT,Y(K,I-1))
78 CONTINUE
C SEARCH FOR YBIG AND LIT IS COMPLETED
  IF (YLIT) 39,40,40
C *****
C DO THIS SECTION ONLY IF ALL COEFFICIENTS ARE POSITIVE
C DETERMINE UPPER SCALING RANGE FOR Y
40 YYY0 = 0.0
  IF (50./SCALE=YBIG) 140,140,130
140 IF (100./SCALE=YBIG) 141,141,131
141 IF (200./SCALE=YBIG) 401,401,132
401 IF (500./SCALE=YBIG) 41,41,45
  41 IF (1000./SCALE=YBIG) 42,42,46
  42 IF (2000./SCALE=YBIG) 43,43,47
  43 IF (4000./SCALE=YBIG) 44,44,48
  44 IF (8000./SCALE=YBIG) 50,50,49
C *****
C DO THIS SECTION ONLY IF SOME COEFFICIENTS ARE NEGATIVE
39 DO 67 I = 1,100
  YYY0 = -1*500./SCALE
  IF (YYY0 - YLIT) 13,13,67
67 CONTINUE
C DETERMINE LOWER AND UPPER SCALING RANGE FOR Y-AXIS
13 RANGE = YBIG - MINIF(YLIT,YYY0)
  IF (50./SCALE=RANGE) 120,120,130
120 IF (100./SCALE=RANGE) 121,121,131
121 IF (200./SCALE=RANGE) 80,80,132
  80 IF (500./SCALE=RANGE) 81,81,45
  81 IF (1000./SCALE=RANGE) 82,82,46
  82 IF (2000./SCALE=RANGE) 83,83,47
  83 IF (4000./SCALE=RANGE) 84,84,48
  84 IF (8000./SCALE=RANGE) 50,50,49
C *****
C THIS SECTION USED IN BOTH CASES
130 SCALEYY = .2*SCALE
  GO TO 123
131 SCALEYY = .1*SCALE
  GO TO 123
132 SCALEYY = .05*SCALE
  GO TO 123
  45 SCALEYY = .02*SCALE
  GO TO 123
  46 SCALEYY = .01*SCALE
  GO TO 123
  47 SCALEYY = .005*SCALE
  GO TO 123
  48 SCALEYY = .0025*SCALE
  GO TO 123
  49 SCALEYY = .00125*SCALE
  GO TO 123
  50 SCALEYY = .0003125*SCALE
123 DO 30 I = 1,NNN
  IF (K=NXX(I)) 330,330,30
330 XX(I) = SCALEXX*(LOGF(X(I)) - XX0)/2.30259
  YY(I) = SCALEYY*(Y(K,I) - YYY0)

```

```

      WRITE(M2,1010) X(I),Y(K,I),NXX(I),XX(I),YY(I)
1010 FORMAT(10X2E20,8,1X,*(+I2,+)*2E20,8)
      30 CONTINUE
C     DRAW HORIZONTAL LOG AXES AND VERTICAL LINEAR AXES
      CALL LNGRID(1,0,XX(NNN),0,TOPEGG,1,,TOPEGG+1,,SCALEXX,XLAST,LNAXIS:
      *)
      CALL LNGRID(2,0,TOPEGG,0,XLAST,,SCALEXX,XEGG,1,,YLAST,LNAXIS)
      CALL SYMBOL(,50,1,,21,LMESS(2),90,,LMESS(1))
      CALL SYMBOL(,50,4,5,,21,LDAYSQ(2),90,,LDAYSQ(1))
      IF(INORM)900,900,910
900  CALL SYMBOL(,5,,39,,21,4HB(L),0,4)
      CALL SYMBOL(2,3,,39,,21,4H L=,0,4)
      CALL NUMBER(3,2,,39,,21,K1,0,2HI3)
      GO TO 930
910  IF(K1)915,915,920
915  CALL SYMBOL(,5,,39,,21,7HSIGMA(S,0,7)
      GO TO 930
920  CALL SYMBOL(,5,,39,,21,4HF(L),0,4)
      CALL SYMBOL(2,3,,39,,21,4H L=,0,4)
      CALL NUMBER(3,2,,39,,21,K1,0,2HI3)
930  CALL SYMBOL(4,5,,39,,21,NAME,0,3)
      CALLNUMBER(5,5,,39,,21,NATOM,0,2HI3)
      CALL LNLABEL(1,0,XX(NNN),,1,SCALEXX,X0,,10,,2HI3)
C     LABEL THE Y-AXIS
      CALL LNLABEL(2,0,TOPEGG,,03,2,,YYY0,2,/SCALEYY,5HE10,3)
C     *****
      DO 96 J = 1,NNN
      IF (K=NXX(J)) 200,200,96
200  IF (14=NXX(J)) 34,33,33
      34 CALL SYMBOL (XX(J),YY(J),,14,NXX(J)/2,0,,-1) $ GO TO 96
      33 CALL SYMBOL (XX(J),YY(J),,14,NXX(J),0,,-1)
      96 CONTINUE
C     READY FOR NEW PLOT
      29 ORGNEW=XLAST+.3.
      CALL PLOT(ORGNEW,0,0,.3)
      CALL PLOT(0,0,0,0,2)
      6 CONTINUE
      80707
      END

```

```

      SUBROUTINE LINAXIS(ITYPE,BEGIN,EEND,POS,CYCLEN,TA,TB,AXLAST)
      BASE=BEGIN TTA=TA+POSS TTB=TB+POS
      GO TO (10,15),ITYPE
10  CALL PLOT(BEGIN,POS,3)
      CALL PLOT(BEGIN,POS,2)
      GO TO 20
15  CALL PLOT(POS,BEGIN,3)
      CALL PLOT(POS,BEGIN,2)
20  N=(EEND-BEGIN+.001)/CYCLEN +1.
      AXLAST=N
      AXLAST=AXLAST*CYCLEN
      TEMP=BEGIN
      DO 35 I=1,N
      DO 35 J=1,10
      TEMP=TEMP+.1*CYCLEN
      PLOT MARKERS HERE
      GO TO (25,30),ITYPE
25  CALL PLOT(TEMP,POS,0)
      CALL PLOT(TEMP,TTA,0)$ CALL PLOT(TEMP,TTB,0)
      CALL PLOT (TEMP,POS,0)$ GO TO 35
30  CALL PLOT (POS,TEMP,0)$ CALL PLOT(TTA,TEMP,0)
      CALL PLOT (TTB,TEMP,0)$ CALL PLOT(POS,TEMP,0)
35  CONTINUE
      RETURN
      END

```

```

SUBROUTINE LNAXIS(ITYPE,BEGIN,END,POS,CYCLEN,TA,TB,AXLAST)
BASE=BEGIN$ TTA=TA+POS$ TTB=TB+POS
GO TO (10,15),ITYPE
10 CALL PLOT(BEGIN,POS,3)
CALL PLOT(BEGIN,POS,2)
GO TO 20
15 CALL PLOT(POS,BEGIN,3)
CALL PLOT(POS,BEGIN,2)
20 NCYCLES=(END-BEGIN*.001)/CYCLEN *1.
DO 40 N=1,NCYCLES
C PLOT MARKERS HERE
DO 35 I=1,10
Q=I
TEMP=BASE+LOGF(Q)*CYCLEN/2,30259
GO TO (25,30),ITYPE
25 CALL PLOT(TEMP,POS,0)
CALL PLOT(TEMP,TTA,0)$ CALL PLOT(TEMP,TTB,0)
CALL PLOT(TEMP,POS,0)$ GO TO 35
30 CALL PLOT(POS,TEMP,0)$ CALL PLOT(TTA,TEMP,0)
CALL PLOT(TTB,TEMP,0)$ CALL PLOT(POS,TEMP,0)
35 CONTINUE
40 BASE=BASE+CYCLEN
AXLAST=BASE
55 RETURN
END

```

```

SUBROUTINE LINLABEL(IDIR,BEGIN,END,POS,DELTAL,ORGVAL,DELTAV,NFORM)
NTOT=(END-BEGIN*.001)/DELTAL *1,
XPT=BEGIN
AN=ORGVAL
DO 20 I=1,NTOT
GO TO (10,15),IDIR
10 CALL NUMBER(XPT,POS,.07,AN,0,,NFORM)
GO TO 17
15 CALL NUMBER(POS,XPT,.07,AN,90,0,NFORM)
17 XPT=XPT+DELTAL
20 AN=AN+DELTAV
RETURN
END

```

```

SUBROUTINE LNLABEL(IDIR,BEGIN,END,POS,DELTAL,ORGVAL,DELTAV,NFORM)
NTOT=(END-BEGIN*.001)/DELTAL *1,
ND=LOGF(DELTAV)/2,30259 *1,
XPT=BEGIN
AN=LOGF(ORGVAL)/2,30259
IF(AN) 1,2,2
1 NN=AN+.1
GO TO 5
2 NN=AN+.1
5 DO 20 I=1,NTOT
GO TO (10,15),IDIR
10 CALL NUMBER(XPT,POS,.07,NN,0,,NFORM)
GO TO 17
15 CALL NUMBER(POS,XPT,.07,NN,90,0,NFORM)
17 XPT=XPT+DELTAL
20 NN=NN+ND
RETURN
END

```

```

SUBROUTINE LNGRID(ITYPE,BEGIN,FEND,POSBEG,POSEND,DELTAL,DELTAX,
1CYCLEL,AXLAST,AAXIS)
  EEND=FEND
  PBASE=POSBEG
  NTOT=(POSEND-POSBEG+.001)/DELTAL
  AXISTM=POSBEG+DELTAX
  CALL AAXIS(ITYPE,BEGIN,FEND,POSBEG,CYCLEL,0,,125,EEND)
  IDIR=2
  DO 55 L=1,NTOT
15 PBASE=PBASE+DELTAL
  C CHECK FOR IN-BETWEEN AXIS TIME
    IF(PBASE-AXISTM+.001) 20,60,60
20 GO TO (25,40),ITYPE
25 GO TO (30,35),IDIR
30 CALL PLOT (BEGIN,PBASE,3)
  CALL PLOT (EEND,PBASE,2)
  GO TO 55
35 CALL PLOT (EEND,PBASE,3)
  CALL PLOT (BEGIN,PBASE,2)
  GO TO 55
40 GO TO (45,50),IDIR
45 CALL PLOT (PBASE,BEGIN,3)
  CALL PLOT(PBASE,EEND,2)
  GO TO 55
50 CALL PLOT(PBASE,EEND,3)
  CALL PLOT (PBASE,BEGIN,2)
55 IDIR=2/IDIR
  C DRAW FINAL AXIS
  CALL AAXIS(ITYPE,BEGIN,FEND,POSEND,CYCLEL,.,125,0.,XXXXX)
  AXLAST=EEND
  RETURN
60 CALL AAXIS(ITYPE,BEGIN,FEND,PBASE,CYCLEL,.,125,.,125,XXXXX)
  AXISTM=AXISTM+DELTAX
  IDIR=2
  GO TO 55
  END

```


APPENDIX G Listing of DRIVER Input Cards

```

0
15SEQ,8085 3-5=66
  46      18BNL=400 DATA,VOL 1
  ,1      5,0      11,0
AL  27  0,220      7  5
2,95680685+002  5,57412912+001  2,32002650+001  =1,45203784+000  6,09696097+000
AL  27  0,220      7  6
2,95836096+002  5,53465684+001  2,28652567+001  =2,55090555+000  6,28274653+000
2,20392024+000
AL  27  0,600      15  5
3,57736682+002  2,52486785+002  4,29998051+001  =3,25237059+001  =2,60288273+001
AL  27  0,600      15  7
3,56344685+002  2,52736407+002  4,20950428+001  =3,37046830+001  =4,10555324+001
1,12456848+001  3,38866907+001
AL  27  0,600      15  9
3,56049914+002  2,52031678+002  4,37608598+001  =3,43052897+001  =4,19872260+001
5,33686064+000  3,54906850+001  1,21909046+001  9,77881466+001
AL  27  0,900      7  5
2,32355190+002  1,54803357+002  5,63022918+001  9,70038445+000  =4,06374401+000
AL  27  0,900      7  6
2,32352698+002  1,54617793+002  5,63118743+001  8,64013975+000  =4,07482938+000
1,76372607+000
AL  27  0,980      10  5
2,34338596+002  1,95214253+002  5,83676350+001  1,57670967+001  1,48879767+001
AL  27  0,980      10  7
2,34289903+002  1,94297109+002  6,09703042+001  1,16545207+001  1,50478012+001
6,40683099+000  =2,85533899+000
AL  27  2,010      10  5
2,24025382+002  2,28854545+002  1,23273154+002  5,60926558+001  =1,15415402+001
AL  27  2,010      10  7
2,24661582+002  2,28230837+002  1,26123274+002  5,60357394+001  =6,32831038+000
=3,67363068+001  =1,03143633+001
AL  27  2,500      15  5
2,39461314+002  3,08308443+002  2,96165467+002  5,13855219+001  1,22306877+001
AL  27  2,500      15  7
2,39040468+002  3,08053014+002  2,59908013+002  5,84983129+001  1,83382029+001
=1,28334188+001  =8,19329228+000
AL  27  2,500      15  9
2,39100967+002  3,08285941+002  2,56002265+002  5,83447554+001  1,86117615+001
=1,41446484+001  =5,48253316+000  1,65571482+000  =4,12187825+000
AL  27  2,700      13  5
2,22381860+002  2,07167859+002  1,46209861+002  6,36569018+001  2,71760181+001
AL  27  2,700      13  7
2,23361562+002  2,04458687+002  1,46495636+002  5,55181728+001  2,59202894+001
1,52672725+001  =1,07568142+000
AL  27  2,700      13  9
2,21571031+002  2,02536769+002  1,39622171+002  5,65758506+001  1,98996934+001
1,83950488+001  =1,18922047+000  =2,58444932+000  1,50888869+001
AL  27  3,010      13  5
1,54763544+002  1,71412512+002  1,75538339+002  6,71824495+001  3,29528632+001
AL  27  3,010      13  7
1,54757221+002  1,71624606+002  1,75594841+002  6,79908273+001  3,34418669+001
=1,70497361+000  =7,93031033+001
AL  27  3,010      13  9
1,56318442+002  1,70046695+002  1,81591823+002  6,62093998+001  3,87325762+001
=1,06634862+001  7,48861843+001  1,27013059+000  =1,49816768+001
AL  27  3,500      9  5
1,11832827+002  1,49176123+002  1,18299563+002  6,16464693+001  2,29886260+001
AL  27  3,500      9  7
1,11793083+002  1,47435379+002  1,18439385+002  5,32605093+001  2,07861217+001
1,39391531+001  3,73867902+000
AL  27  3,700      27  5
1,45413396+002  1,29669457+002  9,54454643+001  5,64132788+001  5,18750635+001
AL  27  3,700      27  7
1,42109317+002  1,29203707+002  9,65906482+001  5,70054168+001  3,90312269+001
1,78808998+001  2,85264108+001
AL  27  3,700      27  9
1,44473601+002  1,26665874+002  9,80014094+001  5,41554557+001  4,38005669+001
1,03665319+001  1,07022048+001  2,22631316+001  1,65979689+001

```

AL 27 3,700	27 11				
1,51419465+002	1,06957609+002	1,26394751+002	2,61209914+001	6,41185004+001	
3,94075879+000	6,49064285+000	3,72310758+001	7,96798730+000	3,70638235+001	
2,91583007+001					
AL 27 3,850	11 5				
1,22355959+002	1,76143900+002	1,46034092+002	8,50302400+001	6,17190057+001	
AL 27 3,850	11 7				
1,22013180+002	1,74028381+002	1,44975460+002	7,00931611+001	5,72980956+001	
2,62780247+001	8,41815293+000				
AL 27 3,990	13 5				
1,32801544+002	2,08444712+002	1,95089026+002	1,15591746+002	7,38793944+001	
AL 27 3,990	13 7				
1,32903999+002	2,04185266+002	1,94272599+002	1,01167600+002	6,52752969+001	
3,11717615+001	1,40687880+001				
AL 27 4,100	13 5				
1,31367329+002	1,70009136+002	1,93984907+002	2,92733593+001	3,94773859+001	
AL 27 4,100	13 7				
1,31396328+002	1,69743326+002	1,94126455+002	2,91754565+001	4,25048325+001	
1,86782467+002	5,34528548+000				
AL 27 4,100	13 9				
1,31785682+002	1,68395788+002	1,95804672+002	2,63803327+001	4,60067118+001	
4,44693707+000	5,37829824+000	8,39553863+000	1,92704365+001		
AL 27 4,200	11 5				
1,02817709+002	1,41307814+002	1,23120486+002	7,38824670+001	3,76386613+001	
AL 27 4,200	11 7				
1,03461046+002	1,39870058+002	1,25057122+002	7,22850737+001	4,64348830+001	
4,42210320+000	1,66399424+001				
AL 27 4,500	11 5				
9,75573897+001	1,39763942+002	1,23953444+002	8,08167149+001	4,40172199+001	
AL 27 4,500	11 7				
9,76126535+001	1,38442273+002	1,24014839+002	7,18650589+001	4,36356970+001	
1,60019151+001	4,50581055+001				
AL 27 4,800	10 5				
8,91857467+001	1,44063859+002	1,34607058+002	1,02241630+002	4,59734688+001	
AL 27 4,800	10 7				
8,97775014+001	1,41203493+002	1,36733322+002	9,10590596+001	4,65853825+001	
1,87927464+001	1,95176819+000				
AL 27 5,000	21 5				
9,73611414+001	1,78354946+002	1,91505337+002	1,61250876+002	9,19152621+001	
AL 27 5,000	21 7				
9,79517623+001	1,78134369+002	1,93414863+002	1,48487533+002	9,10751873+001	
2,57983947+001	4,23920341+000				
AL 27 5,000	21 9				
9,78077913+001	1,77795984+002	1,93029881+002	1,48577773+002	9,15006746+001	
3,06175146+001	1,10171848+000	8,18566568+000	7,72480908+000		
AL 27 5,000	21 11				
9,76826993+001	1,78011972+002	1,92535831+002	1,49069381+002	9,10406112+001	
3,12060698+001	7,73182743+001	7,89677720+000	8,83839510+000	1,30253732+000	
2,94472746+000					
AL 27 7,000	14 5				
8,07208410+001	1,40889355+002	1,73904896+002	1,90264723+002	1,65093534+002	
AL 27 7,000	14 7				
7,73407964+001	1,33683717+002	1,81492692+002	1,53905395+002	1,33942513+002	
8,08785853+001	3,58224541+001				
AL 27 7,000	14 9				
7,79379041+001	1,33882860+002	1,80716282+002	1,50080795+002	1,31662071+002	
7,22393481+001	3,12637731+001	1,63279626+001	9,09454846+000		
AL 27 ENERGY=	220 BNL=400,VOL,1,01		5 6		
AL 27 ENERGY=	600 BNL=400,VOL,1,02		5 7 9		
AL 27 ENERGY=	900 BNL=400,VOL,1,01		5 6		
AL 27 ENERGY=	980 BNL=400,VOL,1,03		5 7		
AL 27 ENERGY=	2,010 BNL=400,VOL,1,03		5 7		
AL 27 ENERGY=	2,500 BNL=400,VOL,1,04		5 7 9		
AL 27 ENERGY=	2,700 BNL=400,VOL,1,06		5 7 9		
AL 27 ENERGY=	3,010 BNL=400,VOL,1,03		5 7 9		
AL 27 ENERGY=	3,500 BNL=400,VOL,1,07		5 7		
AL 27 ENERGY=	3,700 BNL=400,VOL,1,08		5 7 9 11		
AL 27 ENERGY=	3,850 BNL=400,VOL,1,07		5 7		
AL 27 ENERGY=	3,990 BNL=400,VOL,1,03		5 7		
AL 27 ENERGY=	4,100 BNL=400,VOL,1,09		5 7 9		
AL 27 ENERGY=	4,200 BNL=400,VOL,1,07		5 7		
AL 27 ENERGY=	4,500 BNL=400,VOL,1,07		5 7		
AL 27 ENERGY=	4,800 BNL=400,VOL,1,07		5 7		
AL 27 ENERGY=	5,000 BNL=400,VOL,1,10		5 7 9 11		
AL 27 ENERGY=	7,000 BNL=400,VOL,1,11		5 7 9		

APPENDIX H
Listing of DRIVER Printed Output

BNL-400 DATA, VOL 1

AL 27

B(L), L = 0

ENERGY	B(0)	ORDER
0.220 BNL-400, VOL, 1, 01	5 6	
0.600 BNL-400, VOL, 1, 02	5 7 9	
0.900 BNL-400, VOL, 1, 01	5 6	
0.980 BNL-400, VOL, 1, 03	5 7	
2.010 BNL-400, VOL, 1, 03	5 7	
2.500 BNL-400, VOL, 1, 04	5 7 9	
2.700 BNL-400, VOL, 1, 06	5 7 9	
3.010 BNL-400, VOL, 1, 03	5 7 9	
3.500 BNL-400, VOL, 1, 07	5 7	
3.700 BNL-400, VOL, 1, 08	5 7 9 11	
3.850 BNL-400, VOL, 1, 07	5 7	
3.990 BNL-400, VOL, 1, 03	5 7	
4.100 BNL-400, VOL, 1, 09	5 7 9	
4.200 BNL-400, VOL, 1, 07	5 7	
4.500 BNL-400, VOL, 1, 07	5 7	
4.800 BNL-400, VOL, 1, 07	5 7	
5.000 BNL-400, VOL, 1, 10	5 7 9 11	
7.000 BNL-400, VOL, 1, 11	5 7 9	

2.20000000+001	2.95680685+002 (5)	1.71210976+000	5.91361370+000
2.20000000+001	2.95836096+002 (6)	1.71210976+000	5.91672192+000
6.00000000+001	3.57736682+002 (5)	3.89074796+000	7.15473364+000
6.00000000+001	3.56344685+002 (7)	3.89074796+000	7.12689370+000
6.00000000+001	3.56049914+002 (9)	3.89074796+000	7.12099828+000
9.00000000+001	2.32355190+002 (5)	4.77120238+000	4.64710380+000
9.00000000+001	2.32352696+002 (6)	4.77120238+000	4.64705396+000
9.80000000+001	2.34338596+002 (5)	4.95611982+000	4.68677192+000
9.80000000+001	2.34289903+002 (7)	4.95611982+000	4.68579806+000
2.01000000+000	2.24025382+002 (5)	6.51596640+000	4.48050764+000
2.01000000+000	2.24661582+002 (7)	6.51596640+000	4.49323164+000
2.50000000+000	2.39461314+002 (5)	6.98968515+000	4.78922628+000
2.50000000+000	2.39040468+002 (7)	6.98968515+000	4.78080936+000
2.50000000+000	2.39100967+002 (9)	6.98968515+000	4.78201934+000
2.70000000+000	2.22381860+002 (5)	7.15680357+000	4.44763720+000
2.70000000+000	2.23361562+002 (7)	7.15680357+000	4.46723124+000
2.70000000+000	2.21571031+002 (9)	7.15680357+000	4.43142062+000
3.01000000+000	1.54763544+002 (5)	7.39281672+000	3.09527088+000
3.01000000+000	1.54757221+002 (7)	7.39281672+000	3.09514442+000
3.01000000+000	1.56318442+002 (9)	7.39281672+000	3.12636884+000
3.50000000+000	1.11832827+002 (5)	7.72032377+000	2.23665654+000
3.50000000+000	1.11793083+002 (7)	7.72032377+000	2.23586166+000
3.70000000+000	1.45413396+002 (5)	7.84099191+000	2.90826792+000
3.70000000+000	1.42109317+002 (7)	7.84099191+000	2.84218634+000
3.70000000+000	1.44473601+002 (9)	7.84099191+000	2.88947202+000
3.70000000+000	1.51419465+002 (11)	7.84099191+000	3.02838930+000
3.85000000+000	1.22355959+002 (5)	7.92728675+000	2.44711918+000
3.85000000+000	1.22013180+002 (7)	7.92728675+000	2.44026360+000
3.99000000+000	1.32801544+002 (5)	8.00484742+000	2.65603088+000
3.99000000+000	1.32903999+002 (7)	8.00484742+000	2.65807998+000
4.10000000+000	1.31367329+002 (5)	8.06390210+000	2.62734658+000
4.10000000+000	1.31396328+002 (7)	8.06390210+000	2.62792656+000
4.10000000+000	1.31785682+002 (9)	8.06390210+000	2.63571364+000
4.20000000+000	1.02817709+002 (5)	8.11622916+000	2.05635418+000
4.20000000+000	1.03461046+002 (7)	8.11622916+000	2.06922092+000

4.50000000+000	9.75573897+001 (5)	8.26604495+000	1.95114779+000
4.50000000+000	9.76126535+001 (7)	8.26604495+000	1.95225307+000
4.80000000+000	8.91857467+001 (5)	8.40618827+000	1.78371493+000
4.80000000+000	8.97775014+001 (7)	8.40618827+000	1.79555003+000
5.00000000+000	9.73611414+001 (5)	8.49483192+000	1.94722283+000
5.00000000+000	9.79517623+001 (7)	8.49483192+000	1.95903525+000
5.00000000+000	9.78077913+001 (9)	8.49483192+000	1.95615583+000
5.00000000+000	9.76826993+001 (11)	8.49483192+000	1.95365399+000
7.00000000+000	8.07208410+001 (5)	9.22547054+000	1.61441682+000
7.00000000+000	7.73407964+001 (7)	9.22547054+000	1.54681593+000
7.00000000+000	7.79379041+001 (9)	9.22547054+000	1.55875808+000

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AL 27

B(L), L=10

ENERGY	B(10)	ORDER
0.220 BNL-400, VOL, 1, 01	5 6	
0.600 BNL-400, VOL, 1, 02	5 7 9	
0.900 BNL-400, VOL, 1, 01	5 6	
0.980 BNL-400, VOL, 1, 03	5 7	
2.010 BNL-400, VOL, 1, 03	5 7	
2.500 BNL-400, VOL, 1, 04	5 7 9	
2.700 BNL-400, VOL, 1, 06	5 7 9	
3.010 BNL-400, VOL, 1, 03	5 7 9	
3.500 BNL-400, VOL, 1, 07	5 7	
3.700 BNL-400, VOL, 1, 08	5 7 9 11	
3.850 BNL-400, VOL, 1, 07	5 7	
3.990 BNL-400, VOL, 1, 03	5 7	
4.100 BNL-400, VOL, 1, 09	5 7 9	
4.200 BNL-400, VOL, 1, 07	5 7	
4.500 BNL-400, VOL, 1, 07	5 7	
4.800 BNL-400, VOL, 1, 07	5 7	
5.000 BNL-400, VOL, 1, 10	5 7 9 11	
7.000 BNL-400, VOL, 1, 11	5 7 9	

3.70000000+000	-2.91583007+001 (11)	7.84099191+000	4.70841699+000
5.00000000+000	2.94472746+000 (11)	8.49483192+000	5.02944727+000

APPENDIX I

Calcomp Plots from DRIVER Fig. 7. Calcomp Plot for $l = 0$ from the DRIVER Sample Problem

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Fig. 8. Calcomp Plot for $l = 10$ from the DRIVER Sample Problem

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