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AEC Research and Development Report

BNW PROGRAM NOISE

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July 1971

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BNW PROGRAM NOISE

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BNW PROGRAM NOISEABSTRACT

A computer code, NOISE, is presented which serves as an aid in determining reactor parameters from data obtained in zero-power reactor noise experiments. The code uses a nonlinear least-squares fitting package to provide the best estimate of these reactor parameters. Special options are available which allow for specification of the theoretical model, modifications of the experimental data in order to put them in units describable by the theory, and plotting features which illustrate the experimental measurements along with the best least-squares fit to the measurements.

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I. INTRODUCTION

A computer code, NOISE, is presented which serves as an aid in determining reactor parameters from zero-power reactor noise data. Zero-power reactor noise analysis is a method whereby random variables are used to describe physical phenomena of a reactor system.^(1,2) These random variables can be internally or externally induced. However, to be useful, they must be describable by probability theory. The analysis will determine what effect, as a function of frequency, the random variables have on the power spectrum of the reactor system. As a result, the transfer function (frequency response) is obtained.

Since the transfer function characterizes the frequency response of the reactor system, one can derive an analytic form for the transfer function by relating it to the kinetic equations⁽³⁾

$$\frac{dn}{dt} = \frac{\delta k - \beta}{\ell^*} n + \sum_{i=1}^j \lambda_i C_i \quad (1)$$

and

$$\frac{dC_i}{dt} = -\lambda_i C_i + \frac{\beta_i}{\ell^*} n \quad (2)$$

where,

C_i = delayed neutron precursor concentrations,

λ_i = decay constants,

n = neutron density,

ℓ^* = neutron generation time,

$\delta k = k_{eff} - 1$, to represent the reactivity,

β = effective delayed neutron fraction, and

j = total number of delayed neutron groups

Equations (1) and (2) can be combined such that

$$\frac{dn}{dt} = \frac{\delta k}{\ell^*} n - \sum \frac{dC_i}{dt} . \quad (3)$$

Now if we assume $n = n_0 + \delta n$ and $C_i = C_{0i} + \delta C_i$, then

$$\frac{dn}{dt} = \frac{d\delta n}{dt} = \frac{\delta k}{\ell^*} n_0 + \frac{\delta k \delta n}{\ell^*} - \sum_{i=1}^j \frac{d\delta C_i}{dt} = \frac{\delta k}{\ell^*} n_0 - \sum_{i=1}^j \frac{d\delta C_i}{dt} \quad (4)$$

and,

$$\begin{aligned} \frac{dC_i}{dt} &= \frac{d\delta C_i}{dt} = \frac{\beta_i}{\ell^*} (n_0 + \delta n) - \lambda_i (C_{0i} + \delta C_i) \\ &= \frac{\beta_i}{\ell^*} \delta n - \lambda_i \delta C_i \end{aligned} \quad (5)$$

since in the steady state equations,

$$\frac{dC_{0i}}{dt} = 0 = \frac{\beta_i}{\ell^*} n_0 - \lambda_i C_{0i} \quad (6)$$

We can reduce Equations (4) and (5) to the LaPlace-transform operational form of;

$$S\delta n(S) = \frac{n_0}{\ell^*} - \delta k(S) - S \sum_{i=1}^j \delta C_i(S) \quad (7)$$

and

$$S\delta C_i(S) = \frac{\beta_i}{\ell^*} \delta n(S) - \lambda_i \delta C_i(S) \quad (8)$$

By combining Equations (7) and (8) we obtain an equation for the transfer function,

$$TF = \frac{\delta n(S)}{\delta k(S)} = \frac{n_0}{\ell^*} \left\{ 1.0 / \left[S \left[1.0 + \sum_{i=1}^j \frac{\beta_i}{\ell^*(S + \lambda_i)} \right] \right] \right\}, \quad (9)$$

or

$$TF = \frac{\delta n(S)}{\delta k(S)} = \left(\frac{n_0}{\ell^*} \right) \frac{\prod_{i=1}^j (S + \lambda_i)}{S \prod_{i=1}^j (S + \alpha_i)} \quad (10)$$

where α_i represent the roots of the j-th degree equation which is formed by expanding the denominator of Equation (9) and equating it to zero.

For the case of the approximation of one delayed group of neutrons, the relationship from Equation (9) would yield;

$$\frac{\delta n(S)}{\delta k(S)} = \frac{n_0}{\ell^*} \left\{ \frac{1}{S \left[1 + \frac{\beta}{\ell^*(S + \bar{\lambda})} \right]} \right\} \approx \frac{n_0}{S \ell^*} \left\{ \frac{S + \bar{\lambda}}{S + \beta/\ell^*} \right\} \quad (11)$$

However, the quantity which is usually compared to the experimental measurement is the spectral power density. This quantity is represented by the square of the absolute value of the transfer function.

$$|TF|^2 = |n(\omega)|^2$$

$$|TF|^2 = \left(\frac{n_0}{\ell^* \omega} \right)^2 \frac{\prod_{i=1}^j (\omega^2 + \lambda_i^2)}{\prod_{i=1}^j (\omega^2 + \alpha_i^2)} + N$$

For one delayed group of neutrons this becomes,

$$|TF|^2 = \left(\frac{n_0}{\ell^* \omega} \right)^2 \frac{(\omega^2 + \lambda^2)}{(\omega^2 + \alpha^2)} + N \quad (12)$$

where,

$$S = j\omega = j(2\pi F)$$

and

$$\alpha = \bar{\beta}/\ell^* + \lambda \approx \bar{\beta}/\ell^* .$$

The term, N, has been added in Equation (12) and represents a quantity of "white noise" which is independent of the frequency response but which is caused by the statistical nature in which a detector (ion chamber) and the electronic equipment combine to collect information about the neutron fluctuations. The "white noise" is uncorrelated with the reactor noise and therefore adds to the square of the absolute value of the transfer function. The analytical form of the transfer function represented by Equation (12) is the basis of the theory assumed within the code. The measurement data represented in the form of the transfer function of Equation (12) are used as those data to be least-squares fitted within NOISE. The resultant best fit yields such information as the ratio of effective delayed neutrons to the neutron lifetime and the degree of subcriticality.

Reflector effects or equipment frequency attenuation are sometimes present when measurements are being collected. Because of this, NOISE contains several modifications of the basic form of the transfer

function represented by Equation (12). In addition, an analytical model is included which describes the transfer function when the reactor power is varied by inducement of a reactivity oscillator.

II. INSTRUMENT RESPONSE AND FUNCTIONAL FORM

Various techniques can be used for collecting spectral power variations. Some methods will have an inherent equipment attenuation which will affect the resultant power data. This added attenuation must either be accounted for within the theoretical function, or measured and removed from the resultant power data before attempting a least-squares fit to determine the break frequency.

A typical circuit for collecting spectral power variations is shown in Figure 1. However, the use of ion chambers, cables, and input resistors may vary according to experimental interest. Such an arrangement makes it necessary to observe the frequency response of the circuit and compare this response to the expected break frequency of the spectral power data.

FIGURE 1

(A Typical Data Collecting Circuit)

The equivalent circuit for determining the low frequency response of the circuit in Figure 1 is:

and a low frequency break is expected at $\rho = 2\pi f_b = 1/R_2 C$.

The equivalent circuit for determining the high frequency response is:

and a high frequency break is expected at $\xi = 2\pi f_b = 1/RC_{cc}$ in the spectrum where $R = R_1 R_2 / (R_1 + R_2)$.

The need for considering possible reflector and high or low frequency attenuation effects has brought about the necessity for six forms of the transfer function shown in Equation (12). In addition, a seventh form of the transfer function is included in order to account for reactivity induced oscillations of the spectral power data.

The following forms of the transfer function, $Y = |TF|^2$, are coded in NOISE:

Version A:
$$Y = A_1 + \left(\frac{A_2^2}{\omega^2} \right) \frac{(\omega^2 + A_3)}{(\omega^2 + A_4)}$$

where $A_1 = N$, $A_2^2 = (n_0 \epsilon / \ell^*)^2$, $A_3 = \lambda_i^2$, $A_4 = \alpha_i^2$, and ϵ is a normalization constant. The λ_i is not really the decay constant since low frequency perturbation will cause a break frequency which overrides any break caused by λ_i .

Version B:
$$Y = A_1 + \left(\frac{A_2^2}{\omega^2} \right) \frac{\omega^2}{(\omega^2 + A_3')}$$

where $A_3' = \alpha_i^2$.

Version C:
$$Y = \left\{ A_1 + \left(\frac{A_2^2}{\omega^2} \right) \frac{(\omega^2 + A_3)}{(\omega^2 + A_4)} \right\} \frac{A_5}{(\omega^2 + A_5)}$$

where $A_5 = \xi^2$.

Version D:
$$Y = \left\{ A_1 + \left(\frac{A_2^2}{\omega^2} \right) \frac{\omega^2}{(\omega^2 + A_3')} \right\} \frac{A_4'}{(\omega^2 + A_4')}$$

where $A_4' = \xi^2$

Version E:

$$Y = \left\{ A_1 + \left(\frac{A_2^2}{\omega^2} \right) \frac{(\omega^2 + A_3)}{(\omega^2 + A_4)} \right\} \frac{\omega^2}{(\omega^2 + A_5)}$$

where $A_5' = \rho^2$.

Version F:

$$Y = \left\{ A_1 + \left(\frac{A_2^2}{\omega^2} \right) \frac{\omega^2}{(\omega^2 + A_3')} \right\} \frac{\omega^2}{(\omega^2 + A_4')}$$

where $A_4'' = \rho^2$.

The frequency response of the amplitudes of a sinusoidal reactivity driving function can be represented by the transfer functions (Versions A-F). In addition, an equation is obtained for the frequency dependent phase lag, θ , between the input and output oscillations. Thus,

Version G:

$$Y = \theta = \tan^{-1} \left[\frac{A_1'(A_1' + A_2') + \omega^2}{\omega A_2'} \right] + A_3''$$

where $A_1' = \lambda$, $A_2' = \alpha$, and $A_3'' = \theta_0 = \text{constant}$.

For illustrative purposes, each of the versions is shown in graphical form in Appendix A. The plots for Versions A through F are shown using the same values for identical parameters. The plot for Version G represents a least-squares fit to a typical set of phase angle data from an oscillator experiment in which the reactivity was varied sinusoidally.

III. METHOD OF LEAST-SQUARES

In the least-squares analysis of NOISE it is assumed that data points in the experimental domain can be represented by an explicit scalar theory $Y=Y(x,\underline{a})$, where x and $\underline{a}$ represent the independent variable and a single vector set of parameters, respectively.

The code minimizes the mean square misfit Q , which is formulated as

$$Q = \sum_m W_m \left[Y_m - Y(X_m, \underline{a}) \right]^2 \quad (13)$$

where

W_m represents the weighting property of each measurement,

Y_m represents the measured data,

X_m represents the independent variable (frequency) for each Y_m , and

Y represents the theoretical value of the analytic function at each X_m .

The parameters $\underline{a}$ are computed at each successive iteration using the basic iterative algorithm⁽⁴⁾

$$\underline{a}_{\text{new}} = \underline{a} - (\partial Q / \partial \underline{a}) \cdot (\partial^2 Q / \partial \underline{a} \partial \underline{a})^{-1} \quad (14)$$

where $\frac{\partial Q}{\partial \underline{a}}$ represents the misfit gradient, defined by,

$$\frac{\partial Q}{\partial \underline{a}} = \sum_m 2W_m \left[Y_m - Y(X_m, \underline{a}) \right] \left[-\partial Y(X_m, \underline{a}) / \partial \underline{a} \right] \quad (15)$$

and $\partial^2 Q / \partial \underline{a} \partial \underline{a}$ is the second misfit gradient (or matrix of second partial derivatives), defined by,

$$\begin{aligned} \frac{\partial^2 Q}{\partial \underline{a} \partial \underline{a}} = \sum_m 2W_m \left[\left\{ \partial Y(X_m, \underline{a}) / \partial \underline{a} \right\} \left\{ \partial (Y_m, \underline{a}) / \partial \underline{a} \right\} \right. \\ \left. - \left\{ Y_m - Y(X_m, \underline{a}) \right\} \left\{ \partial^2 Y(X_m, \underline{a}) / \partial \underline{a} \partial \underline{a} \right\} \right]. \end{aligned} \quad (16)$$

The measurement variance, σ^2 , can now be defined as

$$\sigma^2 = Q / (M - J), \quad (17)$$

where M and J denote the number of measurements and parameters, respectively.

Using the measurement variance σ^2 , one may compute the parameter variances $V(\underline{a})$ as $V(\underline{a}) \equiv \langle (\partial \underline{a})(\partial \underline{a}) \rangle = 2\sigma^2 (\partial^2 Q / \partial \underline{a} \partial \underline{a})^{-1}$ and the parameter standard deviation doubt as $\partial a_i = \pm [V_i(a_i)]^{1/2}$.

Within program NOISE a THEORY^(4,5) subroutine is provided which defines all the Versions A-G of the transfer functions. In addition, required first and second order partial derivatives of the transfer functions are contained within subroutine THEORY. The order of the fitting parameters which are coded is consistent with the order shown for the parameters A_i within Section II.

IV. COMPUTATION OF THE TRANSFER FUNCTION

The coded structure of the transfer function within subroutine THEORY^(4,5) and the form in which the data are usually collected make it necessary for some corrections to be made to the collected data before any least-squares fitting is attempted. In addition, decibel units are convenient to use to represent the units of the transfer function. In order to account for some of these necessary conversion factors, the following calculations are performed on the input data:

- $F_i = \overline{GT}_i \times \overline{FP}_i$ To obtain the true frequency F_i from the measured frequency $\overline{FP}_i$
- $\overline{DBGAIN}_i = 10 \log_{10} |TF|_i^2$ To obtain the gain in decibels from the amplitude information
- $\overline{PCERR}_i = 100 / \sqrt{\overline{DELT}_i \times C_1 \times F_i}$ Percent error of the frequency
- $\overline{DBERR}_i = 10 \text{Ln}_e(10) / \overline{PCERR}_i$ Decibel error.

In the above,

$\overline{FP}_i$ represents the uncorrected pseudo frequency of the measurement,

$\overline{GT}_i$ is a correction factor applied to each $\overline{FP}_i$ to correct them to the true frequency because of experimental flexibilities such as varying tape recorder speeds,

$\overline{DELT}_i$ represents the time span for each measurement,

C_1 represents an equipment correction factor relating the band width of the analysis equipment to the frequency F_i .

The experimental circuitry can be varied considerably, depending upon specific interest. However, for our purpose we found it convenient to allow several options for computation of the absolute gain. Therefore, the following data options are available to the user for internal calculations of the absolute gain, $|TF|^2$, by a proper choice of values for NWPS and NOSC. Note, however, that the data options must be consistent with the version of the transfer function selected for the least-squares fitting.

<u>Input Option</u>	<u>Absolute Gain</u>
<ul style="list-style-type: none"> NWPS=1 NOSC=1 	$ TF _i^2 = \left[\frac{V_i * \overline{G2}_i}{\overline{DEL T}_i} \right]^2 * \frac{1}{F_i}$
<ul style="list-style-type: none"> NWPS=1 NOSC=0 	$ TF _i^2 = \left[\frac{V_i * \overline{G2}_i}{\overline{DEL T}_i} \right]^2$
<ul style="list-style-type: none"> NWPS=0 NOSC=1 	$ TF _i^2 = \left[\frac{V_i * \overline{G2}_i}{\overline{DEL T}_i} \right]^2 \left[\frac{1 + (2\pi F_i R_1')^2}{F_i} \right]$
<ul style="list-style-type: none"> NWPS=0 NOSC=0 	$ TF _i^2 = \left[\frac{V_i * \overline{G2}_i}{\overline{DEL T}_i} \right]^2 \left[1 + (2\pi F_i R_1')^2 \right]$

In the above,

V_i represents the uncorrected gain at each measurement i ,

$\overline{G2}_i$ is available as a correction factor for each V_i ,

$R_1' = \sqrt{RC}$, where RC is the time constant for the electronic circuitry containing resistance R and capacitance C .

V. COMMENTS:

The NOISE code represents a specialized adaptation of program LEARN.^{4,5)} The bulk of preliminary computation which precedes the least-squares analysis is done in subroutine PUTIN. There have been slight modifications elsewhere within the LEARN code such as;

- a) All rounding functions and sense switch uses have been deleted.
- b) Upon option, the code can make estimates of the least-squares parameters required by Version A through F.
- c) The input requirements have been simplified.
- d) Plotting options have been modified to generate logarithmic plots of the least-squares fits. Examples are shown in Appendix A.
- e) The output has been modified and is dependent upon the options exercised.
- f) The THEORY subroutine represents a choice of one of seven theoretical functions.
- g) Most of the normal input parameters which were required by LEARN have been preset or made non-functional.

The code makes use of the input utility package, NAMELIST.⁽⁶⁾ The use of NAMELIST will not be discussed here as most computer installations have their own similar utility packages. NOISE consists of approximately 4000 Fortran V statements which are mapped in overlay segments to reduce storage requirements. Program NOISE represents, in effect, the intended general use of Program LEARN. Except for the modifications mentioned above, the code has been written with the expressed use of all available dummy subroutines which reside in LEARN. The net result is a code which is especially adapted to zero-power reactor noise analysis.

VI. INPUT INSTRUCTIONS:

The input data are loaded via card input under the name \$LEARN, which identifies the NAMELIST⁽⁶⁾ data block. The following list is provided to help clarify the meaning and usage of the input variables.

<u>INPUT NAME</u>	<u>DESCRIPTION OF USE</u>
NO	<p>= Defines an execution option which can be used in one of three modes. (NO=0,-1, or +1)</p> <p>If NO=0, then estimates of the least-squares fitting parameters and their limits (A,AMIN, and AMAX) will be made for any of the theoretical functions defined by IGH=(1-6).</p> <p>If NO=-1, estimates of the fitting parameters and their limits are not attempted. Therefore, the values for A,AMIN, and AMAX are required input.</p> <p>If NO=1, corrected values for the frequencies and the transfer function are computed as a function of NOSC and NWPS and then punched on cards. This allows the user to obtain corrected data which could be used with another code for cross checking reasons.</p>
N	= Defines the initial number of input measurements.
NR10	<p>= An option to reduce multiple measurements, at the same corrected frequency, to a single valued measurement.</p> <p>If NR10=0, then pair reduction is performed.</p> <p>If NR10=1, pair reduction is not done.</p> <p>If NO=0, then NR10 is fixed at 0.</p>
FP(1)	= (FP(I),I=1,N) Uncorrected pseudo frequencies.
G1(1)	= (G1(I),I=1,N) Correction factors for each FP(I).

V(1) = (V(I), I=1, N) Uncorrected gain of each measurement.
 G2(1) = (G2(I), I=1, N) Correction factors for each V(I).
 DELT(1) = (DELT(I), I=1, N) Recording time span for each measurement.

ABNORM = Normalization constant for the transfer function.

$$\text{i.e. } |TF|_{i(\text{norm})}^2 = |TF|_i^2 / \text{ABNORM}$$

Preset to 1.0.

KYK = Used only if NO=0; KYK identifies a measurement on the plateau of the decibel curve which can be used as a means of helping the code to estimate the fitting parameters.

If KYK = 20, then the measurement Y_m at $[\beta/\ell^* - 20]$ is used as a means of identifying the amplitude of the transfer function for the initial least squares estimate.

II = Least-squares iteration limit. Not required if MAP≠0.

JJ = Defines the number of parameters, A, which are to be used in the least-squares fit.
 Not required if MAP≠0.

A(1) = (A(I), I=1, JJ) Represent estimates of the fitted values of the theoretical function.
 Not required if NO=0.

AMIN(1) = (AMIN(I), I=1, JJ) Identify the minimum value that each parameter, A, can have during the least-squares iteration process.
 Not required if NO=0.

INPUT NAME

DESCRIPTION OF USE

AMAX(1)

= (AMAX(I),I=1,JJ) Identify the maximum value that each parameter ,A, can have during the least squares iteration process.
Not required if NO=0.

BAD

= Identifies the percent deviation of the quantity

$$\left[|TF|_{\text{calc.}}^2 - |TF|_{\text{meas.}}^2 \right] / |TF|_{\text{calc.}}^2, \text{ or}$$

$(Y_{\text{calc}} - Y_{\text{Meas.}}) / Y_{\text{calc}}$ as it is in the THEORY routine

This simply means that any measurement value which when used in the above lies outside the limit $\pm |BAD|$, it will be flagged as "BAD" in the theory-measurement correlation output.

BAD is preset to 0.1 or $\pm 10\%$.

C(1)

= This quantity represents an equipment correction factor which is dependent upon the users measurement system.
Preset to C(1)=0.53.

W(1)

= (W(I),I=1,N) Stochastic weights for each measurement. Not required if NWGT = 0.

NWGT

= Dictates the use of a built-in weighting function:

$$W(I) = 1.0 / \left[\overline{PCERR(I)} * |TF|_{\text{measured.}}^2 \right]^2$$

If NWGT=0, the weighting function W(I) is used.
If NWGT = 1, the weighting function is not used and the values W(I) are required input depending upon the choice of the following available weighting properties.

NWGT is preset to zero.

UGEN = If UGEN $\neq$ -0., $W(I) = 1.0 / \left[|TF|_{\text{meas.}}^2 \right]$ UGEN
Preset UGEN = -0.

UEXP = If UEXP $\neq$ -0., $W(I) = W(I)^{\text{UEXP}}$
Preset UEXP = -0.

YEXP = If YEXP $\neq$ -0., $W(I) = W(I) / \left[|TF|_{\text{meas.}}^2 * |TF|_{\text{meas.}}^2 \right]$ YEXP
Preset YEXP = -0.

VABG = If VABG $\neq$ -0., $W(I) = V(I)^{\text{VABG}} * W(I)$
Preset VABG = -0.

WSUM = If WSUM $\neq$ -0., the sum of the weights is uniformly normalized to WSUM.
Preset WSUM = -0.

RC = Resistance*Capacitance of the electronic circuitry. If RC is known, it can be used to correct the input data before any least-square fitting is attempted. If RC is not known, it can be found by using one of the versions in THEORY which assume it to be a fitting parameter.
Required only if NWPS = 0.

NOSC }
NWPS } = These quantities identify the calculational form of the transfer function. They are described in detail in Section III.

IGH = Defines the theoretical function to be used in the least-squares fit. ($1 \leq \text{IGH} \leq 7$)
i.e. IGH = 1 uses version A
IGH = 2 uses version B
etc.

If IGH = 7, only the following input quantities are used:

[A, AMAX, AMIN, C(2), MAP, MARK, MM, VABG,
UEXP, UGEN, YEXP, WSUM, W, X, YM, ZDZSDS, TITLE.]

where, as defined earlier

$MM=N$

$X(1,1)=(X(I,1), I=1, MM)$ Frequency in cycles per sec.

$YM(1)=(YM(I), I=1, MM)$ Measurement in radians.

PLOTTING OPTIONS:

INPUT NAME

DESCRIPTION OF USE

MAP

= -1; Plots are to be generated.

Preset MAP=0. (No plots)

C(2)

= Defines the distance, in inches, of a single logarithmic cycle along the X-axis (frequency).

C(3)

= Defines the distance, in inches, of the total height of the Y-axis (decibels).

MARK

= +NN, where NN is a number which identifies the symbol to be used to represent measurements.

If MARK=+NN, separate plots are generated for each least-squares fit.

If MARK=-NN, the plots of the least-squares fits will be superimposed on the same graph.

TITLE(1)

= (TITLE(I), I=1,9) An alphanumeric title which appears at the top of each plot. It is limited to a 54 column field of information.

VII. ACKNOWLEDGEMENTS

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APPENDIX A

APPENDIX AIllustrative Plots for All Versions of the Transfer Function

The following plots are shown to typify the differences in graphical form of each of the versions of the transfer function. The phase angle plot illustrates a least-squares fit to a set of measured data.

THEORETICAL FUNCTION VERSION C. 5 PARAMETERS. IGH=3

A-5

BNWL-1609

APPENDIX B

APPENDIX BSample Input: (Version A)

```

C      SAMPLE INPUT DECK ASSEMBLY FOR PROGRAM NOISE (VERSION A)
C
C
C
C      'O RUN NOISE,CUBXXX,,120,2500          SEYBOLD (NOISE)
C      'X ASG,R A=UXXXX
C      '  ASG,W H=(,NH,AT)
C      ' MSG PLOT ON H. TYPE 400 AND BALL POINT PEN.
C      ' MSG SEND TO GD SEYBOLD, ROB-II, 3000 AREA.
C      ' XQT CUR
C      IN A
C      TRI A
C      'N XQT LEARN
C      $LEARN MAP=-1,N=38,NO=0,G1(1)=38*1.,DELT(1)=38*1.,IGH=1,C(2)=2.5,7.,
C      V(1)=
C      1137., 1171., 1308., 1377., 1592., 1983., 1893., 2274., 2763.,
C      2655., 2566., 2942., 3934., 3771., 4205., 5289., 5570., 5589.,
C      5559., 6042., 7117., 6861., 5950., 6686., 7036., 7424., 5651.,
C      5804., 6396., 6526., 6366., 4734., 4684., 5241., 5262., 3619.,
C      3631., 2669.,
C      FP(1)=
C      .1211, .1966, .2421, .3932, .4842, .6375, .7865, .9685, 1.275,
C      1.526, 1.573, 2.026, 2.550, 3.052, 4.052, 5.100, 6.968, 8.105,
C      8.926, 10.08, 13.935, 16.21, 17.78, 17.85, 20.16, 27.87, 32.18,
C      35.55, 35.70, 40.32, 55.74, 64.35, 71.10, 71.40, 80.64, 128.7,
C      142.2, 257.4,
C      G2(1)=
C      .889, 1.046, .889, 1.046, .889, .929, 1.046, .889, .929, 1.041,
C      1.046, 1.068, .929, 1.041, 1.068, .929, 1.078, 1.068, 1.130,
C      1.086, .999, 1.068, 1.255, 1.139, 1.078, 1.040, 1.337,
C      1.256, 1.149, 1.099, 1.012, 1.366, 1.309, 1.153, 1.093,
C      1.431, 1.321, 1.435,
C      TITLE(1)=54HNOISE TEST CASE, VERSION A, APR 22,1971. SEYBOLD*****
C      $
C      ' FIN

```

APPENDIX B

Sample Output: (Version A)

TIME 2.5533333-03M

1

I NUM	FPRIME CPS	V VOLTS	DELTAT SEC	G1	G2	FREQUENCY CPS	GAIN		ERROR		
							ABSOLUTE	DECIBELS	PERCENT	DECIBELS	
1	1.211-01	1.1370+03	1.000+00	1.000+00	8.890-01	1.2110-01	8.4368+06	6.9262+01	3.9472+02	1.7143+01	1
2	1.966-01	1.1710+03	1.000+00	1.000+00	1.046+00	1.9660-01	7.6312+06	6.8826+01	3.0979+02	1.3454+01	2
3	2.421-01	1.3080+03	1.000+00	1.000+00	8.890-01	2.4210-01	5.5850+06	6.7470+01	2.7917+02	1.2124+01	3
4	3.932-01	1.3770+03	1.000+00	1.000+00	1.046+00	3.9320-01	5.2762+06	6.7223+01	2.1906+02	9.5135+00	4
5	4.842-01	1.5920+03	1.000+00	1.000+00	8.890-01	4.8420-01	4.1368+06	6.6167+01	1.9740+02	8.5730+00	5
6	6.375-01	1.9830+03	1.000+00	1.000+00	9.290-01	6.3750-01	5.3235+06	6.7262+01	1.7204+02	7.4715+00	6
7	7.865-01	1.8930+03	1.000+00	1.000+00	1.046+00	7.8650-01	4.9850+06	6.6977+01	1.5489+02	6.7266+00	7
8	9.685-01	2.2740+03	1.000+00	1.000+00	8.890-01	9.6850-01	4.2197+06	6.6253+01	1.3958+02	6.0617+00	8
9	1.275+00	2.7630+03	1.000+00	1.000+00	9.290-01	1.2750+00	5.1675+06	6.7133+01	1.2165+02	5.2831+00	9
10	1.526+00	2.6550+03	1.000+00	1.000+00	1.041+00	1.5260+00	5.0058+06	6.6995+01	1.1119+02	4.8291+00	10
11	1.573+00	2.5660+03	1.000+00	1.000+00	1.046+00	1.5730+00	4.5798+06	6.6608+01	1.0952+02	4.7564+00	11
12	2.026+00	2.9420+03	1.000+00	1.000+00	1.068+00	2.0260+00	4.8729+06	6.6878+01	9.6503+01	4.1911+00	12
13	2.550+00	3.9340+03	1.000+00	1.000+00	9.290-01	2.5500+00	5.2379+06	6.7192+01	8.6019+01	3.7357+00	13
14	3.052+00	3.7710+03	1.000+00	1.000+00	1.041+00	3.0520+00	5.0493+06	6.7032+01	7.8627+01	3.4147+00	14
15	4.052+00	4.2050+03	1.000+00	1.000+00	1.068+00	4.0520+00	4.9774+06	6.6970+01	6.8238+01	2.9635+00	15
16	5.100+00	5.2890+03	1.000+00	1.000+00	9.290-01	5.1000+00	4.7338+06	6.6752+01	6.0824+01	2.6416+00	16
17	6.968+00	5.5700+03	1.000+00	1.000+00	1.078+00	6.9680+00	5.1742+06	6.7138+01	5.2036+01	2.2599+00	17
18	8.105+00	5.5890+03	1.000+00	1.000+00	1.068+00	8.1050+00	4.3960+06	6.6431+01	4.8249+01	2.0954+00	18
19	8.926+00	5.5590+03	1.000+00	1.000+00	1.130+00	8.9260+00	4.4207+06	6.6455+01	4.5976+01	1.9967+00	19
20	1.008+01	6.0420+03	1.000+00	1.000+00	1.086+00	1.0080+01	4.2713+06	6.6306+01	4.3265+01	1.8790+00	20
21	1.394+01	7.1170+03	1.000+00	1.000+00	9.990-01	1.3935+01	3.6276+06	6.5596+01	3.6797+01	1.5981+00	21
22	1.621+01	6.8610+03	1.000+00	1.000+00	1.068+00	1.6210+01	3.3123+06	6.5201+01	3.4117+01	1.4817+00	22
23	1.778+01	5.9500+03	1.000+00	1.000+00	1.255+00	1.7780+01	3.1361+06	6.4964+01	3.2576+01	1.4148+00	23
24	1.785+01	6.6860+03	1.000+00	1.000+00	1.139+00	1.7850+01	3.2489+06	6.5117+01	3.2512+01	1.4120+00	24
25	2.016+01	7.0360+03	1.000+00	1.000+00	1.078+00	2.0160+01	2.8536+06	6.4554+01	3.0593+01	1.3286+00	25
26	2.787+01	7.4240+03	1.000+00	1.000+00	1.040+00	2.7870+01	2.1390+06	6.3302+01	2.6019+01	1.1300+00	26
27	3.218+01	5.6510+03	1.000+00	1.000+00	1.337+00	3.2180+01	1.7739+06	6.2489+01	2.4214+01	1.0516+00	27
28	3.555+01	5.8040+03	1.000+00	1.000+00	1.258+00	3.5550+01	1.4948+06	6.1746+01	2.3038+01	1.0005+00	28
29	3.570+01	6.3960+03	1.000+00	1.000+00	1.149+00	3.5700+01	1.5128+06	6.1798+01	2.2989+01	9.9842-01	29
30	4.032+01	6.5260+03	1.000+00	1.000+00	1.099+00	4.0320+01	1.2758+06	6.1058+01	2.1632+01	9.3948-01	30
31	5.574+01	6.3660+03	1.000+00	1.000+00	1.012+00	5.5740+01	7.4461+05	5.8719+01	1.8398+01	7.9903-01	31
32	6.435+01	4.7340+03	1.000+00	1.000+00	1.366+00	6.4350+01	6.4984+05	5.8128+01	1.7123+01	7.4366-01	32
33	7.110+01	4.6840+03	1.000+00	1.000+00	1.309+00	7.1100+01	5.2874+05	5.7232+01	1.6290+01	7.0748-01	33
34	7.140+01	5.2410+03	1.000+00	1.000+00	1.153+00	7.1400+01	5.1143+05	5.7088+01	1.6256+01	7.0599-01	34
35	8.064+01	5.2620+03	1.000+00	1.000+00	1.093+00	8.0640+01	4.1020+05	5.6130+01	1.5296+01	6.6431-01	35
36	1.287+02	3.6190+03	1.000+00	1.000+00	1.431+00	1.2870+02	2.0839+05	5.3189+01	1.2108+01	5.2584-01	36
37	1.422+02	3.6310+03	1.000+00	1.000+00	1.321+00	1.4220+02	1.6179+05	5.2090+01	1.1519+01	5.0026-01	37
38	2.574+02	2.6690+03	1.000+00	1.000+00	1.435+00	2.5740+02	5.6989+04	4.7558+01	8.5617+00	3.7183-01	38
0	0.000	NUMBER OF FREQ PAIRS, NORMALIZING FACTOR									

B-2

BNWL-1609

ALTERNATE POINT SLOPES IN REVERSE

1.8705+01	1.6401+01	1.5233+01	2.0163+01	2.3039+01	1.4066+01	1.4430+01	1.5910+01
1.2587+01	1.5336+01	1.4722+01	1.0186+01	9.3818+00	7.5132+00	2.0051+00	5.9748+00
3.3521+00	4.4392+00	1.3195+00	6.3549+00	1.5981+00	1.4274+00	1.2567+00	1.1015+00
-3.3887-01	5.5343-02	9.4955-01	5.7483+00	2.5020+00	4.0291+00	5.5562+00	2.6857+00
3.5081+00	4.3304+00	5.3242+00	5.9550+00				

AVERAGE SETS OF 3 ALTERNATE POINT SLOPES IN REVERSE

1.6731+01	1.7267+01	1.9480+01	1.9989+01	1.7178+01	1.4802+01	1.4309+01	1.4611+01
1.4215+01	1.3408+01	1.1423+01	9.0204+00	6.3000+00	5.1644+00	4.4440+00	5.2554+00
3.7036+00	4.0379+00	3.0909+00	3.1268+00	1.4274+00	1.2619+00	5.0644-01	1.0600-01
5.5343-02	2.2511+00	3.0666+00	4.0931+00	4.0291+00	4.0903+00	3.9167+00	3.5081+00
4.3876+00	5.2032+00						

THE REGION FOR DETERMINING THE BREAK FREQ IS BETWEEN K1 AND K2

STEEPEST SLOPE CENTER, K1= 34 STOPPING POINT, K2= 14

THE SLOPE AT K1 HAS BEEN FOUND TO BE 1.7178+01

THE CALC DB DIFFERENCE PROPORTIONAL TO 3DB IS 2.5767+00

B-3

BNWL-1609

THE FOLLOWING VALUES ARE CALCULATED IN THE RANGE OF K1 TO K2

CALC.	LOG OF	DB(CALC)	GAIN IN	ABSOLUTE	POINT
DECIBELS	FREQUENCY	-DB(MEAS)	DECIBELS	FREQUENCY	NUMBER
5.7088+01	1.8537+00	-0.0000	5.7088+01	7.1400+01	34
5.7119+01	1.8519+00	-1.1314-01	5.7232+01	7.1100+01	33
5.7863+01	1.8085+00	-2.6461-01	5.8128+01	6.4350+01	32
5.8935+01	1.7462+00	2.1582-01	5.8719+01	5.5740+01	31
6.1391+01	1.6055+00	2.9346-01	6.1058+01	4.9320+01	30
6.2259+01	1.5527+00	4.6118-01	6.1798+01	3.5700+01	29
6.2290+01	1.5508+00	5.4453-01	6.1746+01	3.5550+01	28
6.3033+01	1.5076+00	5.4422-01	6.2489+01	3.2180+01	27
6.4106+01	1.4451+00	8.0421-01	6.3302+01	2.7870+01	26
6.6522+01	1.3045+00	1.9683+00	6.4554+01	2.0160+01	25
6.7430+01	1.2516+00	2.3128+00	6.5117+01	1.7850+01	24
6.7460+01	1.2499+00	2.4957+00	6.4964+01	1.7780+01	23
6.8149+01	1.2098+00	2.9479+00	6.5201+01	1.6210+01	22

THE POINT AT WHICH THE BREAK FREQ WAS DETERMINED IS M1= 22

THE POINT ON THE PLATEAU AT WHICH THE DATA MIGHT BE NORMALIZED IS L1= 30

LOG(10) FREQ NORMALIZATION POINT IS AT 1.606+00
THIS SAME VALUE CORRESPONDS TO A FREQ 4.032+01

THE LOG OF THE FREQUENCY AT K1 IS 1.854+00
THE CORRESPONDING FREQUENCY IS AT 7.140+01
THE CORRESPONDING DECIBEL GAIN IS 5.709+01

THE GUESSTIMATES ARE THE FOLLOWING

A(1)= 5.69892+04 HIGH FREQUENCY BKG
A(2)= 2.32885+05 N(0)/L
A(3)= 5.56345-02 DECAY CONSTANT (SQUARED)
A(4)= 1.03735+04 BETA/L (SQUARED)

B-4

BNWL-1609

NON-LINEAR MAXIMUM-LIKELIHOOD MINIMUM-MISFIT LOGIC															
BATTELLE NORTHWEST LABORATORY PROGRAM LEARN (15MAR65) BNWL-390 (16JUL68)											INPUT				
ITERATIONS		PARAMETERS		COORDINATES		LOGIC LIST		MEASUREMENTS		SETS(SUBSETS)		FAILURE LIMIT			
II	100	JJ	4	KK	1	LL	0	MM	38	LOTS	0	LOSS	5		
UGEN(ERATOR)		UEXP(ONENT)		YEXP(ONENT)		WSUM (WEI/UT)		LOG(DET(W))		HALF (HUNT)		RATE(CONVERGE)		BAD (REFIT)	
-0.0000000		-0.0000000		-0.0000000		-0.0000000		-0.0000000		5.0000000-01		1.0000000+00		9.9999999-02	
HYPER PLOTS		RMS PLOT FIT		PLOT-FIT TRYS		ERR(OR CURVE)		POINT SYMBOL		CURVE SEGMENT		PLOTTER GRID		PLOTTER GRID	
MAP -1		9.9999999-05		MOST 0		-1.0000000+00		MARK 1		LINE 2		MESHX 10		MESHY 10	
PARAMETER MINIMA AMIN(J),J=1,				4		0.0000000		3.6772976+02							
0.0000000				2.3288537+04											
PARAMETER ESTIMATES A(J),J=1,				4		5.5634471-02		1.0373510+04							
5.6989179+04				2.3288537+05											
PARAMETER MAXIMA AMAX(J),J=1,				4		4.0000000+00		2.0125939+05							
5.6989178+05				2.3288537+06											
MEASUREMENTS YM(M),M=1,				38											
8.4368495+06		7.6312140+06		5.5850133+06		5.2761572+06		4.1368032+06		5.3234926+06		4.9850079+06		4.2197314+06	
5.1675299+06		5.0058284+06		4.5798150+06		4.8729099+06		5.2379331+06		5.0492862+06		4.9774288+06		4.7337833+06	
5.1741588+06		4.3960000+06		4.4207234+06		4.2713047+06		3.6275877+06		3.3123355+06		3.1360979+06		3.2489420+06	
2.8536364+06		2.1389746+06		1.7738929+06		1.4948392+06		1.5128252+06		1.2757600+06		7.4460734+05		6.4984436+05	
5.2874157+05		5.1143296+05		4.1019607+05		2.0839048+05		1.6179255+05		5.6989179+04					
STOCHASTIC WEIGHT W(M),M=1,				38		INVERSE MEAN		SQUARE DOUBT (SPUR(W)=		4.7166646-12,		LOG(ABS(DET(W)))=		-1.4111210+03)	
9.0169443-20		1.7892545-19		4.1136016-19		7.4860706-19		1.4995845-18		1.1922374-18		1.6774241-18		2.8827427-18	
2.5305798-18		3.2275908-18		3.9747401-18		4.5220830-18		4.9260196-18		6.3445441-18		8.6683249-18		1.2062277-17	
1.3794453-17		2.2228672-17		2.4207284-17		2.9282981-17		5.6123789-17		7.8305133-17		9.5813873-17		8.9625204-17	
1.3121065-16		3.2285059-16		5.4200979-16		8.4319206-16		8.2673556-16		1.3129809-15		5.3282942-15		8.0761749-15	
1.3479028-14		1.4467605-14		2.5400567-14		1.5707196-13		2.8791109-13		4.2004866-12					
COORDINATES (X(M,K),M=1,				38),K=1,		1									
1.2110000-01		1.9660000-01		2.4210000-01		3.9320000-01		4.8420000-01		6.3750000-01		7.8650000-01		9.6850000-01	
1.2750000+00		1.5260000+00		1.5730000+00		2.0260000+00		2.5500000+00		3.0520000+00		4.0520000+00		5.1000000+00	
6.9680000+00		8.1049999+00		8.9260000+00		1.0080000+01		1.3935000+01		1.6209999+01		1.7780000+01		1.7850000+01	
2.0160000+01		2.7870000+01		3.2180000+01		3.5550000+01		3.5700000+01		4.0320000+01		5.5740000+01		6.4349999+01	
7.1099999+01		7.1399999+01		8.0639999+01		1.2870000+02		1.4220000+02		2.5740000+02					
THEORY-MEASUREMENT HYPER-MAPS (Y-SCALE (Y1,DY,Y2)=(S1,DS,S2)MILS, X-SCALE ((X1,DX,X2)=(S1,DS,S2)MILS),K=1, 1),M=1, 1															
DATA		RESOLUTION DZ		DATA		PLOT		RESOLUTION DS		PLOT					
END POINT Z1		(0=IMPLICIT)		END POINT Z2		END POINT S1		(0=IMPLICIT)		END POINT S2					

B-5

BNWL-1609

TIME 1.3830000-02M

2

1.0000000+04	0.0000000	3.1622776+07	1.0000000+00	0.0000000	8.0000000+00
9.9999999-02	7.4999999-02	1.0000000+03	0.0000000	0.0000000	1.0000000+01

OUTPUT

OUTPUT

PARTITION P	ENTROPY S=LOG(DP/DV)	ITERATIVE LOGIC	PARTITION P	ENTROPY S=LOG(DP/DV)
NORMAL	SN=-(YM-Y)**2	Q(M)=-W(M)*S(YM(M),Y(X(M),A))	SYMMETRIC	SS=-LOG(EXP((YM-Y)**2)-1)
EXPONENTIAL	SE=-Y+LOG(Y**YM/FACT(YM))	Q=SUM(Q(M))	SKEW	SK=-LOG(EXP((YM-Y)**2)+1)
BINOMIAL	SB=SE(Y,YM)+SE(1-Y,N-YM)	DA=-(DQ/DA)/(DDQ/DA/DA)		

SEQUENTIAL REFINEMENT TRAJECTORY SEEKING SOLID 36-BIT CONVERGENCE ON LOCAL SECOND-ORDER ENTROPY-MAXIMUM MISFIT-MINIMUM

GOOD OR BAD	TRY I	TAG J	PARAMETER A(J)	* PIN	MISFIT Q=SUM(Q(M))	ENTROPY-GRADIENT -DQM/DA(J)	EQUIPARTITION = +DQT/DA(J)	DETERMINANT DDQ/DA/DA BLADE	NEXT MOVE DA(J)	NEXT TREND DQ=(DQ/DA)DA/2
	0	1	5.6989179+04			7.2159003-07	8.1979758-07	2.5768673-05	-4.8188037+04	
	0	2	2.3288537+05			5.4427876-07	4.3704946-07	4.2478079-11	1.5122663+05	
	0	3	5.5634471-02			7.0842037-05	6.6805385-05	9.4237175-12	6.8060943-01	
GOOD	0	4	1.0373510+04		7.2771219-03	-1.1141142-06	-9.2515228-07	7.0174379-13	1.5803708+04	-8.9824026-03
	1	1	8.8011426+03			7.2159003-07	8.2920605-07	2.9956117-05	3.5558061+03	
	1	2	3.8411201+05			7.5248293-07	9.0700170-07	3.4389517-11	-3.6817721+04	
	1	3	7.3624390-01			7.7437601-05	9.9431086-05	9.3959693-12	-2.1367697-01	
GOOD	1	4	2.6177219+04		2.8486850-03	-1.1244874-06	-1.3713498-06	1.5526045-12	-1.6637489+03	-2.4501748-03
	2	1	1.2356949+04			7.2159003-07	7.2812268-07	2.2828442-05	1.4996456+03	
	2	2	3.4729429+05			6.8938347-07	7.0678584-07	2.1664730-11	-5.8745457+03	
	2	3	5.2256693-01			6.7536122-05	7.0821670-05	9.3914078-12	-3.6591806-02	
GOOD	2	4	2.4513470+04		2.1006295-04	-9.8336115-07	-1.0169405-06	1.1083906-12	-1.0805496+01	-4.6095872-05
	3	1	1.3856594+04			7.2159003-07	7.2176470-07	2.1341412-05	3.7733811+00	
	3	2	3.4141974+05			6.7776860-07	6.7824168-07	1.8974401-11	-4.5293508+01	
	3	3	4.8597512-01			6.5299038-05	6.5450436-05	9.3885982-12	8.6107997-04	
GOOD	3	4	2.4502665+04		1.6312953-04	-9.5071388-07	-9.5207565-07	1.0251272-12	5.7927372+01	-4.9761009-08
	4	1	1.3860368+04			7.2159003-07	7.2159009-07	2.1229602-05	-2.5454055-01	
	4	2	3.4137445+05			6.7735685-07	6.7735786-07	1.8768085-11	8.3300955-01	
	4	3	4.8683620-01			6.5129982-05	6.5130726-05	9.3882208-12	2.2050150-05	
GOOD	4	4	2.4560592+04		1.6307959-04	-9.4813831-07	-9.4814510-07	1.0202588-12	5.8536451-01	-1.5648401-12
	5	1	1.3860113+04			7.2159003-07	7.2159003-07	2.1228798-05	-6.2657271-04	
	5	2	3.4137528+05			6.7735526-07	6.7735526-07	1.8766588-11	1.9563642-03	
	5	3	4.8685826-01			6.5128771-05	6.5128768-05	9.3882177-12	2.5185359-07	
BAD	5	4	2.4561177+04		1.6307960-04	-9.4811955-07	-9.4811956-07	1.0202286-12	9.3809675-04	-3.7909082-18
	5	1	1.3860368+04						-5.7038498-02	
	5	2	3.4137445+05						1.8646254-01	
	5	3	4.8683620-01						4.9415185-06	

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TIME	2.2936667-02M										3
CUBIC	5	4	2.4560592+04						1.3114751-01	-4.9378217-13	
	6	1	1.3860310+04		7.2159003-07	7.2159006-07	2.1229421-05	-2.0040324-01			
	6	2	3.4137464+05		6.7735649-07	6.7735725-07	1.8767747-11	6.5957318-01			
	6	3	4.8684114-01		6.5129709-05	6.5130281-05	9.3882200-12	1.7525589-05			
BAD	6	4	2.4560723+04	1.6307961-04	-9.4813409-07	-9.4813934-07	1.0202519-12	4.5717036-01	-9.4739292-13		
	6	1	1.3860368+04					-5.5339386-03			
	6	2	3.4137445+05					1.7822364-02			
	6	3	4.8683620-01					4.7952478-07			
CUBIC	6	4	2.4560592+04					1.2726874-02	-4.5637695-14		
	7	1	1.3860362+04		7.2159003-07	7.2159007-07	2.1229585-05	-2.4818472-01			
	7	2	3.4137446+05		6.7735681-07	6.7735779-07	1.8768051-11	8.1652445-01			
	7	3	4.8683668-01		6.5129955-05	6.5130679-05	9.3882207-12	2.1732979-05			
BAD	7	4	2.4560604+04	1.6307960-04	-9.4813789-07	-9.4814453-07	1.0202581-12	5.7307906-01	-1.4987033-12		
	7	1	1.3860368+04					-2.1634296-04			
	7	2	3.4137445+05					6.1537553-04			
	7	3	4.8683620-01					1.8779771-08			
CUBIC	7	4	2.4560592+04					4.9999262-04	-1.7880567-15		
	8	1	1.3860367+04		7.2159003-07	7.2159009-07	2.1229602-05	-2.5516706-01			
	8	2	3.4137445+05		6.7735685-07	6.7735786-07	1.8768083-11	8.3496574-01			
	8	3	4.8683622-01		6.5129981-05	6.5130722-05	9.3882208-12	2.2301991-05			
BAD	8	4	2.4560592+04	1.6307959-04	-9.4813828-07	-9.4814508-07	1.0202588-12	5.8630254-01	-1.5690835-12		
	8	1	1.3860368+04					-2.7039599-06			
	8	2	3.4137445+05					-0.0000000			
	8	3	4.8683620-01					4.1259155-10			
CUBIC	8	4	2.4560592+04					1.0815840-05	-3.9598665-17		
	9	1	1.3860368+04		7.2159003-07	7.2159009-07	2.1229602-05	-2.5454055-01			
	9	2	3.4137445+05		6.7735685-07	6.7735786-07	1.8768085-11	8.3300955-01			
	9	3	4.8683620-01		6.5129982-05	6.5130726-05	9.3882208-12	2.2050150-05			
GOOD	9	4	2.4560592+04	1.6307959-04	-9.4813831-07	-9.4814510-07	1.0202588-12	5.8536451-01	-1.5648401-12		

NON-LINEAR MAXIMUM-LIKELIHOOD STATISTICAL ANALYSIS

TAG	BEST FIT	ROOT MEAN	MEASUREMENT	MISFIT	GRADIENT	NORMAL BLADES OF	CURVATURE TENSOR	NEXT MOVE	DA(J)
J	PARAMETER	* SQUARE DOUBT	VARIANCE	DDQ/DA(J)	DDQ/DA(J1)/DA(J1)	DDQ/DA(J1)/DA(J2)	BY SADDLE-LEG	J2 MATRIX INVERSE	
J	A(J)	PIN	DA(J)	I*I=-1	Q/(MM-JJ)	SHOULD BE 0	J1 MINUS=SADDLE	NONZERO=SADDLE	J2
1	1.3860368+04	1.4528424+03		5.2180482-14	3	2.1229602-05	0.0000000	4	-2.5553848-01
2	3.4137445+05	3.0663390+03		1.0074719-12	4	1.8768085-11	0.0000000	1	8.3767594-01
3	4.8683620-01	6.7966242-01		7.4165754-10	1	9.3882208-12	0.0000000	2	2.2352995-05
4	2.4560592+04	1.1015427+03	4.7964586-06	-6.8033235-12	2	1.0202588-12			5.8762154-01

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TIME 3.8373333-02M

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MEAN SQUARE CORRELATED PARAMETER DOUBT (DADA(J1,J2),J1=1, 4),J2=1, 4

	J2= 1	J2= 2	J2= 3	J2= 4
J1= 1	2.1107508+06	-3.1998058+06	-4.4916165+01	-8.2286932+05
J1= 2	-3.1998058+06	9.4024351+06	1.4829825+02	2.5651380+06
J1= 3	-4.4916165+01	1.4829825+02	4.6194102-01	1.0349281+02
J1= 4	-8.2286932+05	2.5651380+06	1.0349281+02	1.2133963+06

MEAN SQUARE CORRELATED DOUBT PROPAGATES TO FUNCTION F HAVING PARAMETER GRADIENT DF/DA AS DFUF=(DF/DA).(DADA).(DF/DA)

THEORY-MEASUREMENT HYPER-SPACE PLOTS

DO PLOT 1 TIME 4.3853333-02M

PROGRAM EQUATIONS HAVE BEEN CHANGED SUCH THAT THE REAL VALUES ARE

PARAMETERS	ERRORS
1.38603675+04	1.45284240+03
3.41374450+05	3.06633900+03
6.97736490-01	4.87048070-01
1.56718190+02	3.51440590+00

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NON-LINEAR MAXIMUM-LIKELIHOOD THEORY-MEASUREMENT CORRELATION ANALYSIS (I*I=-1)										
TAG	COORDINATE	MEASUREMENT	BEST THEORY	RANDOM RMS	RESOLUTION	THEORY	DOUBT(ERROR)	PROBABILITY	FIT	
M K	X(M,K)	YM(M)	Y(X(M,K),A)	DOUBT DY	ERROR DY	ERR(Y-YM)/Y	RMS D(Y-YM)	OF LESS ERROR	IS	
1 1	1.21100-01	8.4368495+06	8.7483755+06	5.53450+06	-1.44828+04	3.56096-02	4.75007+06	2.16997-02	GOOD	
2 1	1.96600-01	7.6312140+06	6.2721667+06	2.09268+06	-1.13682+03	-2.16679-01	4.73579+06	1.85675-01	BAD	
3 1	2.42100-01	5.5850133+06	5.7556467+06	1.37835+06	1.64147+03	2.97845-02	3.12412+06	3.58266-02	GOOD	
4 1	3.93200-01	5.2761572+06	5.1359044+06	5.30661+05	4.97907+03	-2.73083-02	2.47499+06	4.22464-02	GOOD	
5 1	4.84200-01	4.1368032+06	5.064090+06	3.63258+05	5.67085+03	1.73699-01	1.75116+06	3.58991-01	BAD	
6 1	6.37500-01	5.3234926+06	4.8995010+06	2.39331+05	6.23367+03	-8.65377-02	1.99143+06	1.62642-01	GOOD	
7 1	7.86500-01	4.9850079+06	4.8485017+06	1.92749+05	6.49198+03	-2.81543-02	1.67996+06	6.25054-02	GOOD	
8 1	9.68500-01	4.2197314+06	4.138611+06	1.70532+05	6.65376+03	1.23421-01	1.27858+06	3.45188-01	BAD	
9 1	1.27500+00	5.1675299+06	4.7822517+06	1.59332+05	6.77056+03	-8.05642-02	1.36748+06	2.14331-01	GOOD	
10 1	1.52600+00	5.0058234+06	4.7660568+06	1.56761+05	6.80326+03	-5.03082-02	1.20893+06	1.51293-01	GOOD	
11 1	1.57300+00	4.5798150+06	4.7634754+06	1.56493+05	6.80589+03	3.85860-02	1.08731+06	1.28564-01	GOOD	
12 1	2.02600+00	4.8729099+06	4.7417790+06	1.55016+05	6.79703+03	-2.76544-02	1.01816+06	9.79628-02	GOOD	
13 1	2.55000+00	5.2379331+06	4.7185428+06	1.53836+05	6.73905+03	-1.10074-01	9.74696+05	3.89508-01	BAD	
14 1	3.05200+00	5.0492862+06	4.6949133+06	1.52500+05	6.65422+03	-7.54802-02	8.56003+05	3.05525-01	GOOD	
15 1	4.05200+00	4.9774288+06	4.6401872+06	1.48981+05	6.42573+03	-7.26785-02	7.28791+05	3.36387-01	GOOD	
16 1	5.10000+00	4.7337833+06	4.5704643+06	1.44208+05	6.12214+03	-3.57336-02	6.13877+05	1.94811-01	GOOD	
17 1	6.96300+00	5.1741588+06	4.8163380+06	1.33608+05	5.46933+03	-1.71595-01	5.74333+05	7.84428-01	BAD	
18 1	8.10500+00	4.3960000+06	4.3063594+06	1.26229+05	5.02971+03	-2.08159-02	4.47039+05	1.44125-01	GOOD	
19 1	8.92600+00	4.4207234+06	4.2206984+06	1.20624+05	4.70355+03	-4.73914-02	4.28475+05	3.28077-01	GOOD	
20 1	1.00300+01	4.2713047+06	4.0930729+06	1.12518+05	4.24393+03	-4.35448-02	3.38763+05	3.21242-01	GOOD	
21 1	1.39350+01	3.6275877+06	3.6302403+06	8.57107+04	2.82943+03	7.30702-04	2.79492+05	6.76756-03	GOOD	
22 1	1.62100+01	3.3123355+06	3.3499123+06	7.14949+04	2.15028+03	1.12173-02	2.36943+05	1.13034-01	GOOD	
23 1	1.77800+01	3.1360979+06	3.1601458+06	6.27508+04	1.75937+03	7.60974-03	2.14762+05	8.03540-02	GOOD	
24 1	1.78500+01	3.2489420+06	3.1518035+06	6.23828+04	1.74339+03	-3.08200-02	2.22767+05	3.07767-01	GOOD	
25 1	2.01600+01	2.8536364+06	2.8839068+06	5.13045+04	1.28117+03	1.04963-02	1.84183+05	1.18563-01	GOOD	
26 1	2.78700+01	2.1389746+06	2.1241093+06	2.77637+04	4.35519+02	-6.99836-03	1.18683+05	9.24449-02	GOOD	
27 1	3.21300+01	1.7738929+06	1.7946266+06	2.11055+04	2.39241+02	1.15532-02	9.16731+04	1.66393-01	GOOD	
28 1	3.55500+01	1.4948392+06	1.5791008+06	1.77732+04	1.52951+02	5.33605-02	7.32978+04	7.15824-01	GOOD	

TIME 8.2086665-02M										5
29	1	3.57000+01	1.5128252+06	1.5702805+06	1.76517+04	1.50031+02	3.65892-02	7.40952+04	5.28676-01	GOOD
30	1	4.03200+01	1.2757600+06	1.3270947+06	1.46764+04	8.58996+01	3.86820-02	5.86320+04	5.81865-01	GOOD
31	1	5.57400+01	7.4460734+05	8.0545516+05	9.52153+03	2.73796+01	7.55446-02	2.84522+04	9.47005-01	GOOD
32	1	6.43500+01	6.4984436+05	6.3361316+05	7.74881+03	2.17408+01	-2.56169-02	2.31054+04	4.64242-01	GOOD
33	1	7.11000+01	5.2874157+05	5.3380688+05	6.63018+03	1.96475+01	9.48904-03	1.76603+04	1.94247-01	GOOD
34	1	7.14000+01	5.1143296+05	5.2992097+05	6.58503+03	1.95737+01	3.48882-02	1.69755+04	6.48555-01	GOOD
35	1	8.06400+01	4.1019607+05	4.2816722+05	5.35619+03	1.76464+01	4.19723-02	1.26548+04	7.66129-01	GOOD
36	1	1.28700+02	2.0839048+05	1.8562449+05	2.09277+03	1.05067+01	-1.22645-01	5.11439+03	9.99980-01	BAD
37	1	1.42200+02	1.6179255+05	1.5548638+05	1.69132+03	9.09403+00	-4.05578-02	3.71469+03	8.37149-01	GOOD
38	1	2.57400+02	5.6989179+04	5.7999758+04	1.04416+03	3.31772+00	1.74238-02	2.27192+02	1.55901-01	GOOD

GOOD RUN SOLID CONVERGENCE TRUE MINIMUM NO SADDLE NO SPILL NO DIVISION BY ZERO CAVEAT EMPTOR MULTIPLE SOLUTIONS

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W. L. Purcell
L. C. Schmid (5)
G. D. Seybold (20)
R. I. Smith
K. B. Stewart
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Technical Information Files (2)