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GRIFE II
A COMPUTER PROGRAM FOR THE ANALYSIS OF
DATA FROM A PULSED - NEUTRON EXPERIMENT

MASTER

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ABSTRACT

GRIPE II, written in FORTRAN IV for use on the IBM-7040 computer, is a program for the analysis of experimental data taken in pulsed-neutron experiments. It may be used for experiments in either a critical or subcritical reactor and also for data with one or two exponential decays. The program features a complete error analysis including the significant but often neglected covariance terms, X-Y plots of the data with computed curves included, and routines to detect and reduce the influence of any bias in the experimental data. A value for the reactivity of a subcritical system is calculated using both the extrapolated-area-ratio method and the Garelis-Russell method. This program is operational, a typical processing time on the IBM-7040 being 1.1 minutes for each pulsed-neutron experiment.

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I. INTRODUCTION

The use of the pulsed-neutron technique to measure the reactivity and the kinetic parameters characterizing reactor systems has become widespread in recent years. Because of the large quantity of data taken in these measurements and the need for many calculations in the transformation of these data into the parameters of interest, it is highly desirable to perform the required analyses with a digital computer. The use of the computer offers the additional benefit of enabling a number of checks on the quality of the data which, if done by hand, would prove to be too laborious for routine use.

GRIPE II is a computer program for the determination of subcritical reactivity and the inverse reduced generation time β/Λ from experimental data taken in an externally pulsed reactor. The program is written in FORTRAN IV for an IBM-7040 with and X-Y plotter. The program features a simple input and output format, X-Y plots of the data on which computed best fits are shown, and a complete error analysis, including covariance terms, to determine the statistical uncertainties for each computed parameter. It also provides the experimenter with a number of checks on the statistical quality of the experimental data with respect to the models postulated.

The analysis technique used by GRIPE II presupposes that the time-dependent experimental data $N(t)$ will satisfy two conditions. First, it is assumed that the data may be described by the relationship $N(t) = N_p(t) + N_0 + B$, where N_0 and B are constants. Second, it is assumed that the function $N_p(t)$ may be described by the relation $N_p(t) = N_a \exp(-\alpha t)$ after some time interval τ . As discussed in Section VII, the time interval τ should be less than $0.7 \times (\Lambda/\beta)$ in order that the solution routines converge. These preconditions are generally satisfied in pulsed thermal reactors such as ATRC[1], ETRC[2], and ARMF-II[3]. (For convenience, a summary of the symbols and definitions used in this report is provided in Table I, pages 2 - 4.)

When the function $N(t)$ is descriptive of the neutron population at a point in a pulsed reactor as a function of the time-after-pulse injection, $N_p(t)$ is generally considered to be descriptive of the prompt neutron response to the pulse. If the reactor is pulsed at critical, the decay constant α of this prompt neutron response is equal to β/Λ and is the parameter of interest. Although in this case the quantity $[N(t) - N_p(t)]$ is not truly a constant, it may be treated as such in GRIPE II without significantly influencing the calculation of the decay constant. If the reactor is pulsed subcritically and if the pulse repetition rate R is sufficiently large (>8 cps), $[N(t) - N_p(t)]$ will be constant, the parameter B may be defined as the steady-state background, and N_0 may be defined as an equilibrium delayed neutron contribution. In such an experiment, both the quantity β/Λ and the subcritical reactivity are of interest.

Whether the reactor system is pulsed when critical or subcritical, GRIPE II orders the input data in time, resolution-corrects the data, calculates N_0 and B , calculates α , and calculates a statistical uncertainty for each computed quantity. If $N_p(t)$ is suspected to be of the form $N_1 \exp(-\alpha_1 t) + N_2 \exp(-\alpha_2 t)$ and if $\alpha_2 \geq 2\alpha_1$, GRIPE II will properly determine both α_1 and α_2 , but it will use α_1 in any subsequent reactivity calculations.

Table I

DEFINITIONS OF SYMBOLS USED IN THIS REPORT

<u>Symbol</u>	<u>Definition</u>
$N(t)$	Function of time describing the model to which the data are assumed to pertain
$N_p(t)$	Prompt neutron component of $N(t)$
N_o	A parameter descriptive of the delayed neutron component of $N(t)$
B	The reactor background with no pulsed source
α	The decay constant of the prompt neutron response to a pulse
N_a	The value of the exponential portion of $N_p(t)$ extrapolated to $t = 0$
Λ/β	The reduced neutron generation time
R	The pulse or sweep repetition rate
c	The root of the Garelis-Russell equation
$\sum_j^J N_{ij}$	The number of events recorded in channel i following the J^{th} sweep of a time-base analyzer
TB	Analyzer time base
GW	Analyzer gate width (subscripts: p for pulsed run, b for background run, e for effective)
RT	Counting system resolving time
PT	Equal to the number of pulses used when a pulsed source is used or to the total number of analyzer sweeps for background data
T_i	The time from the beginning of an analyzer sweep to the midpoint of the open gate for channel i
FC	The channel number corresponding to the time beyond which the data are statistical variations about a constant value

Table I (contd.)

DEFINITIONS OF SYMBOLS USED IN THIS REPORT

<u>Symbol</u>	<u>Definition</u>
LC	The channel number denoting the end of the data set to be included in the calculation of a constant value
S_1	The standard deviation of the data points from channels FC to LC when background (Type 1) data are considered
$\bar{B}$	The computed estimate for B
$\sigma_{\bar{B}}^2$	The computed variance of $\bar{B}$
S_2	The standard deviation of the data points from channels FC to LC when pulsed-reactor data are considered (data types 0, 2, and 3X)
$\overline{N_o + B}$	The computed estimate for $(N_o + B)$
$\sigma_{\overline{N_o + B}}^2$	The computed variance of $\overline{N_o + B}$
$\overline{N_o}$	The computed estimate for N_o
$\sigma_{\overline{N_o}}^2$	The computed variance of $\overline{N_o}$
τ	The time interval following a pulse beyond which $N_p(t) = N_a \exp(-\alpha t)$
$F(t)$	The functional form of $N(t)$ during the interval $0 \leq t \leq \tau$
$E(T_i)$	The difference in channel i between the statistical value of $(N_o + B)$ and the mean value $\overline{N_o + B}$
$N_q(T_i)$	Statistically varying estimates for $N_p(t)$
SM	A positive number used to establish the degree to which $E(T_i)$ influences the value of the $N_q(T_i)$
$W(T_i)$	The weighting factor of the square of the residual calculated in channel i during linear fitting process. It is defined as the reciprocal of the square of the expected error in the estimate $N_q(T_i)$

Table I (contd.)

DEFINITIONS OF SYMBOLS USED IN THIS REPORT

<u>Symbol</u>	<u>Definition</u>
FE	The channel number corresponding to the time τ
LE	The channel number of the last channel for which $N_q(T_i) > (SM \times S_2)$
FO	The number of channels by which FE is to be increased for each iteration to find a best value for α
LO	The number of channels by which LE is to be reduced for each iteration to find a best value for α
$\$E$	Subcritical reactivity calculated using the extrapolated-area-ratio method
$(\frac{\beta}{\Lambda})_E$	β/Λ as calculated from $\$E$
$\$G$	Subcritical reactivity calculated using the Garelis-Russell method

If the reactor system has been pulsed in a subcritical condition, GRIPE II will compute subcritical reactivity in dollar units $\$$ and β/Λ using two methods. In Method 1, reactivity is computed as

$$\$ = \frac{N_a R}{N_0 \alpha K}$$

and β/Λ is computed as

$$\frac{\beta}{\Lambda} = \frac{\alpha}{1 + \$}$$

This reactivity calculation is the extrapolated-area-ratio method suggested by Gozani^[4] for the case in which the pulse width is much less than $1/\alpha$. In Method 2, reactivity is calculated as

$$\$ = \frac{\alpha - c}{c}$$

where c is assumed equal to β/Λ and is the root of the Garelis-Russell equation^[5]:

$$\int_0^{\infty} N_p(t) e^{ct} dt - \int_0^{\infty} N_p(t) dt = \frac{N_0 K}{R}$$

In both methods, a constant K is included. This constant is to be supplied by the program user, and it permits (with $K = 1.0$) the use of the standard calculations or (with $K \neq 1.0$) the use of one of the modified calculations^[6, 7] which correct for kinetic distortions of the neutron distribution. GRIPE II will carry all statistical uncertainties through these calculations to provide an uncertainty for c , β , and β/Λ .

The general calculational procedure outlined above is diagrammed schematically in Figure 1. Each computational block shown in this figure will be subsequently discussed in detail in numbered sections corresponding to the numbered blocks. Contained in the Appendices to this report are instructions for the preparation of input data, a FORTRAN IV program listing, and some notes on the use of GRIPE II.

FIG. 1 A SCHEMATIC DIAGRAM OF THE CALCULATIONS PERFORMED BY GRIPE II.

II. EXPERIMENTAL DATA INPUT

For each pulsed-neutron experiment, one or two sets of data are collected. One is the reactor background as recorded in a multiply-swept time-base analyzer while the pulsed source is inoperative. The second set is the reactor response as recorded in a multiply-swept time-base analyzer while the reactor is pulsed a sufficient number of times to obtain a statistically significant data set. Usually, for an experiment in a subcritical reactor, this second data set will also contain data recorded in the analyzer during the return of the reactor distribution to equilibrium, following the cessation of pulsing. If the pulsed experiment is done subcritically, both sets are required; but if the experiment is done at critical, only the latter data set is required. If both sets are obtained, the analysis of the pertinent background data must precede the analysis of the companion pulsed-neutron data.

The data in each set are assumed to be the total number of events recorded in each channel of a time-base analyzer which has been swept many times. When the pulsed source is in operation, it is also assumed that the pulse is synchronized with the onset of a sweep, although a delay between the start of a sweep and the pulse is permissible. The events recorded in each channel during each sweep are added to the events recorded in that channel during preceding sweeps. Consequently, following the J^{th} sweep, the number of events stored in channel i of the analyzer may be symbolically represented as

$$\sum_j^J N_{ij} .$$

To perform the computer analysis, each of the data sets described above requires control cards. This control information generally falls into two categories: (a) information about the experimental apparatus and method, and (b) information useful in performing the analyses. Information of the former type will be described immediately below while that of the latter type will be described in subsequent sections pertinent to its use. The description of the input format and mechanics presented in Appendix A includes a cross reference to the location of the discussion for each of the parameters of this latter type.

One type of control information required for each data set pertains to the experimental apparatus and method. Such information is the sweep rate R , the counting system resolving time RT , and the total number of analyzer data channels I . Also necessary is a value for PT , which is equal either to the total number of pulses used (for data collected with the source operating) or to the total number of analyzer sweeps (for background data). Additionally, the analyzer time base TB , defined as the interval between the opening of successive gates for data accumulation, and the gate width GW are required. This gate width is equal to TB minus the read and write time for the analyzer memory; thus, $TB \geq GW$. Background data control cards require an additional specification of the effective[a] gate width GW_e used in the associated pulsed source measurement, in order that the computer can make the data sets compatible.

[a] The effective gate width is equal to the product of the gate width used in the associated pulsed experiment and the ratio of the number of analyzer sweeps used during the pulsed experiment to the number of analyzer sweeps used during the background measurement.

A necessary control variable is the type designation of the measurement technique to which the subsequent data pertain. Type 0 denotes data taken with the reactor pulsed at critical. Type 1 denotes data taken for the reactor background before or after a subcritical pulsed experiment. Type 2 denotes data taken during a pulsed subcritical experiment. Type 3X denotes data taken during a pulsed experiment, either when critical or subcritical, for which the prompt neutron response is suspected to result from the decay of two distributions, each of which has a different decay constant. That is, $N_p(t) = N_1 \exp(-\alpha_1 t) + N_2 \exp(-\alpha_2 t)$. When using a type 3X designation, X is either 0 or 2 for critical or subcritical experiments, respectively.

III. ORDERING OF COUNT DATA

The input count data are now associated with a time relative to a reference time, assumed in GRIPE II to be the beginning of an analyzer sweep. The particular association used assumes that the memory read and write times are equal. Thus, the time base TB is divided as shown graphically below

where the read and write times are equal to $(TB - GW)/2$. GRIPE II associates

a time T_i with the data point (accumulated counts) in channel i , $\sum_j^J N_{ij}$, as $T_i =$

$(i) \times (TB) - (TB/2)$. Consequently, T_i is the time (expressed in the same units as the time base) from the beginning of a sweep to the midpoint of the open gate for channel i .

A second feature of the ordering stage, used only for data types 0, 2, and 3X, is a reconstruction of missing data points. It is occasionally desirable to delete a data point when it is highly probable that such a point contains excessive spurious counts due to electronic noise in addition to neutron counts. If such a deletion is made, the experimenter can either estimate a replacement value or put in a zero entry. If a zero entry is perceived, the computer will estimate a value by a linear interpolation of the two most nearly adjacent nonzero data entries.

IV. RESOLUTION CORRECTION

Strictly speaking, in a pulsed-neutron experiment using a repetitively-swept analyzer, it is not possible to provide a valid resolution correction to the accumulated data unless the number of neutrons output from the pulsed-neutron generator is absolutely invariant. Since such invariance is, in practice, unusual, it is highly desirable to use an electronic system which has a very small resolving time and also to position the neutron detector such that the maximum count rates permit little resolution loss. However, since resolution losses cannot be completely avoided, GRIPE II provides an approximate resolution correction to all data which would be nearly exact under the assumption of uniform pulse-generator output.

The resolution correction used in GRIPE II is that for a nonparalyzable counting system since such systems are widely used in pulsed-neutron experiments^[8]. If N_T is defined as the true number of events occurring per unit time in a detector and if N_R is defined as the number of events recorded per unit time by the counting system, these parameters may be related by

$$N_T = N_R / [1 - (RT)N_R] \quad (4-1)$$

for a nonparalyzable system^[9] when RT is the system resolving time. However, to apply this correction to the measured data, GRIPE II must assume that the neutron output of the pulse generator is constant.

To illustrate the necessity for the assumption of constant output, Equation (4-1) will be considered for the case in which $(RT)N_R \ll 1$. In this case, the relationship

$$N_{T_{ij}} = N_{R_{ij}} + N_{R_{ij}}^2 (RT)$$

is descriptive of the true number of events for channel i on sweep j . After the j th analyzer sweep, the true number of events for channel i may be expressed as

$$\sum_{j=1}^J N_{T_{ij}} = \sum_{j=1}^J N_{R_{ij}} + (RT) \sum_{j=1}^J N_{R_{ij}}^2$$

The quantity desired for use in subsequent analyses is $\sum_{j=1}^J N_{T_{ij}}$, and the quantity actually measured is $\sum_{j=1}^J N_{R_{ij}}$. Since $\sum_j N_{R_{ij}}^2 \neq \left(\sum_j N_{R_{ij}}\right)^2$, the desired quantity

cannot, in general, be accurately computed from the measured data. However, the

desired quantity can be computed when the assumption that $\sum_{j=1}^J N_{R_{ij}} = J(N_{R_{ij}})$ is

reasonably justified. This assumption can only be justified in a pulsed-neutron

experiment when the neutron output of the pulse generator is uniform, and the assumption will be required whether or not it is assumed that $(RT)N_R$ is small. Additionally, if measurements are made in a fast reactor using a time base on the same order or smaller than the pulse width, the validity of the assumption above requires invariance of the pulse shape as well as of the total output.

The analysis performed in GRIPE II requires the assumption of uniform pulse-generator output and uses Equation (4-1) to provide the basis for a resolution correction for each data entry. GRIPE II first converts the counts stored in each channel to an approximation of counts per unit time as

$$N_{Ri} = \sum_{j=1}^J N_{Rij} / (GW \times PT)$$

which requires the assumption of pulse uniformity. The resolution correction is then applied using the relationship $N_{Ti} = N_{Ri} / [1 - N_{Ri}(RT)]$. The resolution corrected data entry for channel i is then reconstructed as

$$\sum_{j=1}^J N_{Tij} = N_{Ti} \times GW \times PT$$

In all subsequent discussions, it will be assumed that stored count data have been resolution corrected; hence, the subscript T will be deleted.

As discussed in Section II, PT equals J only for background data and equals the number of pulses for all other data types. This was done on the assumption that the maximum count rates and, hence, those data most in need of resolution correction are obtained when the pulse generator is operational, and not in any subsequent accumulations with the pulsed source inoperative.

V. COMPUTATION OF ESTIMATES FOR N_0 AND B AND OF VARIANCES

As discussed in the Introduction, the input data $\sum_j^J N_{ij}$, now resolution corrected, are assumed in GRIPE II to be adequately described by the function $N(t) = N_p(t) + N_0 + B$ if the pulsed source is in operation and by a constant, equal to B, if a background is taken. In this section, GRIPE II calculates statistical estimates for the constants $(N_0 + B)$, B, and N_0 . In these calculations it is assumed that the data $\sum_j^J N_{ij}$, after some time corresponding to channel number FC[a], are statistical variations about a constant value, equal to $(N_0 + B)$ for types 0, 2, and 3X data and equal to B for type 1 data.

The program user is required to specify a conservative estimate for channel FC, conservative in the sense that FC is the smallest channel number for which the user is sure that the data in this and subsequent channels are statistical estimates of a constant value. The user must also supply a channel number LC[b], which is defined as the last data channel for which data are to be included in the calculation of the constant. For example, when used with data taken with a 512-channel analyzer, one might set FC = 250 and LC = 512 for types 0, 2, and 3X data, and FC = 2 and LC = 512 for type 1 data. The calculations of the desired constants using these channel numbers may now be performed, although they are performed in different fashions depending on the data type.

For type 1 data, an intermediate quantity B^* is calculated from the expression

$$B^* = \sum_{i=FC}^{LC} \left[\sum_{j=1}^J N_{ij} \right] / (LC - FC + 1)$$

and an intermediate standard deviation S_1^* of $\sum_{j=1}^J N_{ij}$ as sampled in channels FC to LC is calculated from the expression

$$(S_1^*)^2 = \sum_{i=FC}^{LC} \left[\sum_{j=1}^J N_{ij} - B^* \right]^2 / (LC - FC).$$

The variance of B^* may then be calculated by

$$\sigma_{B^*}^2 = (S_1^*)^2 / (LC - FC + 1).$$

[a] First point of the Constant portion of the data.

[b] Last point of the Constant portion of the data.

In order that the results of these calculations may be compatible with the results of calculations to be done on data taken with the pulsed source in operation, it becomes necessary to correct for any changes in the effective gate width between the taking of background data and pulse data. As stated in Section II, the value for the gate width used during this background measurement, GW_b , must be accompanied by a value for the effective gate width used in the companion pulsed-neutron measurement GW_e . GRIPE II may now compute an estimate $\bar{B}$ of desired parameter B as $\bar{B} = B \times (GW_e/GW_b)$, compute a standard deviation as $S_1 = S_1 \times (GW_e/GW_b)$, and compute the variance of mean value $\bar{B}$ as $\sigma_{\bar{B}}^2 = \sigma_B^2 \times (GW_e/GW_b)^2$.

It should be pointed out that it is highly desirable to have $GW_b = GW_e$, or to have extremely accurate values for both, since no provision has been made for the propagation of any uncertainties in these quantities.

For data types 0, 2, and 3X, GRIPE II obtains an estimate $\overline{N_0 + B}$ for the constant $(N_0 + B)$ using a slightly different procedure. Again sampling in data channels FC to LC, the quantity $N_0 + B$ is calculated from the expression

$$\overline{N_0 + B} = \sum_{i=FC}^{LC} \left[\sum_{j=1}^J N_{ij} \right] / (LC - FC + 1)$$

and again a standard deviation S_2 of $\sum_{j=1}^J N_{ij}$ is computed from the expression

$$(S_2)^2 = \sum_{i=FC}^{LC} \left[\sum_{j=1}^J N_{ij} - \overline{N_0 + B} \right]^2 / (LC - FC).$$

An estimate for N_0 , $\bar{N}_0$, will ultimately be used in some subcritical analyses, and it is highly desirable to reduce the variance of this estimate by as much as possible. Its variance, in turn, depends upon the variances of $N_0 + B$ and $\bar{B}$. The variance of $N_0 + B$ depends inversely upon $(LC - FC + 1)$, and it is thus desirable to increase $(LC - FC)$ to as large a value as possible. Rather than use the intentionally conservative initial value for FC in the variance calculation, GRIPE II seeks out the largest value for $(LC - FC)$ which still results in the use of data which are random variations about the constant value of $N_0 + B$.

Having computed $\overline{N_0 + B}$ once above, GRIPE II performs the search described by decreasing FC by 10 channels and recomputing $N_0 + B$ and S_2 . If the resulting standard deviation is greater than 1.005 times the previous value, the previous values are assumed to be best values. If, however, it is not greater than this, FC is again reduced by 10 channels, and the calculation and test are repeated. When this search is completed, one has values for $N_0 + B$ and S_2 , which are best in the sense that $(LC - FC)$ is the largest value possible for which the standard deviation of the intermediate data points increased by no more than 0.5 percent of the conservative value.

When the search described above has been completed, an estimate for the quantity $(N_0 + B)$ has been obtained, and its variance is calculated as

$$\sigma^2_{\frac{2}{N_0 + B}} = (S_2)^2 / (LC - FC + 1) .$$

It is now possible to calculate an estimate for N_0 as $\overline{N_0} = \overline{N_0 + B} - \overline{B}$, with a variance defined as $\sigma^2_{\overline{N_0}} = \sigma^2_{\overline{B}} + \sigma^2_{\overline{N_0 + B}}$.

VI. COMPUTATION OF DECAY CONSTANTS

The input count data may be considered as statistically varying estimates of

a continuous function $N(t)$, the data point $\sum_{j=1}^J N_{ij}$ being an estimate of $N(t)$ at time

T_i . As discussed in the Introduction, the function $N(t)$ is assumed to be of the form $N(t) = N_p(t) + N_0 + B$. For discussion, it will be further assumed that the function $N_p(t)$ is of an unknown form $F(t)$ until time τ , after which it assumes an exponential form. That is, $N_p(t) = F(t)$ for $0 \leq t \leq \tau$ and $N_p(t) = N_a \exp(-\alpha t)$ for $\tau \leq t < 1/R$. The objective of this section is to compute α and, in so doing, to obtain N_a and τ . In order to obtain α , the input data are manipulated to provide statistically varying estimates of the function $N_p(t)$. Following this, the time interval τ is determined, and α and N_a are calculated by an iterative process.

1. ISOLATION OF PROMPT DECAY

In this section the input data are converted to statistically varying estimates of $N_p(t)$. The estimate for channel i will be called $N_q(T_i)$. This estimate is calculated by subtracting the computed value of $\overline{N_0 + B}$ from each data point as

$$N_q(T_i) = \sum_{j=1}^J N_{ij} - \overline{N_0 + B} = N_p(T_i) + E(T_i)$$

where $E(T_i)$ is the difference between the statistically varying estimate of $(N_0 + B)$ at T_i and the mean value $\overline{N_0 + B}$. In order to isolate good estimates for $N_p(t)$, it will be necessary to use those values for $N_q(T_i)$ which are least influenced by $E(T_i)$.

In order to obtain values for $N_q(T_i)$ which are least influenced by $E(T_i)$, a technique is used which presupposes that the data in the latter channels of the analyzer were truly descriptive of a constant. GRIPE II can then assume that all values of $N_q(T_i)$ which are greater than some number $SM^{[a]}$ times standard deviation S_2 will be descriptive of $N_p(t)$. For example, if $SM = 10.0$, only values of $N_q(T_i)$ which are greater than $10.0 \times S_2$ will be considered as descriptive of $N_p(t)$; thus, 99.9 percent of the time (three-standard-deviation probability) no $E(T_i)$ constitutes more than 30 percent of any value of $N_q(T_i)$. The value of SM is specified by the user, and its choice should be considered with the knowledge that the larger SM is, the smaller the effect of $E(T_i)$; concurrently, the larger SM is, the smaller the number of data points which will be retained to describe $N_p(t)$. If SM is too large, the uncertainties in $N_p(t)$ arising from too few points in its description will be much more significant than the errors due to the influence of $E(T_i)$ that would be present with a smaller value of SM . For subcritical analyses in ATRC, ETRC, and ARMF-II, $SM = 10.0$ seems quite satisfactory.

[a] Standard deviation Multiplier.

As discussed previously, if a reactor is pulsed when critical, the data in the latter channels are not constant but are time varying. In this case GRIPE II computes a pseudo-constant $N_0 + B$, and following the subtraction of $N_0 + B$, the values of $E(T_i)$ will decrease with time. In such experiments the parameter of interest is α , and its determination again requires the isolation of $N_p(t)$. This isolation can still be effectively accomplished using the procedures described above by an appropriate choice of the number SM, but one has less assurance as to the extent to which the influence of $E(T_i)$ has been reduced.

2. THE DETERMINATION OF PARAMETERS FOR TYPE 0 AND 2 DATA

In Section VI-1 estimates $N_q(T_i)$ for $N_p(t)$ have been obtained, although some biasing due to the influence of $E(T_i)$ may yet exist. In order to obtain the desired parameters, it is necessary to determine the time τ beyond which $N_p(t)$ is equal to $N_a \exp(-\alpha t)$ and to determine α and N_a from the appropriate data. To perform these calculations, GRIPE II accepts an initial guess from the program user as to the channel number FE[a] corresponding to time τ at which $N_p(t)$ has assumed an exponential form. It then takes the natural logarithm of $N_q(T_i)$ for all values in channel FE to LE[b], where LE is defined as the last data channel for which $N_q(T_i) > SM \times S_2$.

2.1 Initial Calculation

If the selection above for τ was appropriate and if all biasing factors have been removed from the estimates for $N_p(t)$, the data, now in the form $\ln [N_q(T_i)]$, should fit a linear model. That is, $\ln [N_q(T_i)] = \ln (N_a) - \alpha T_i$. In this first iteration, GRIPE II assumes that the above conditions are satisfied and calculates the values of $\ln (N_a)$ and α which provide a best linear fit to the data $\ln [N_q(T_i)]$ in a weighted least-squares sense.

The calculations necessary to obtain such a data fit are described in many texts (one of which is given in Reference 10) and will not be described in this report. Each of the squares of the residuals in the least-squares fit is weighted by a number $W(T_i)$, which is calculated as shown below. In this fitting procedure, GRIPE II computes values for $\ln (N_a)$, α , the variance of each, and the covariance of the two.

The weighting factor $W(T_i)$ has been selected as equal to the reciprocal of the square of the expected error in $\ln [N_q(T_i)]$. Such a selection ensures that each residual is treated as a statistical variation about the model postulated rather than permitting the larger values of the data with larger absolute residuals to disproportionately influence the data fit. Additionally, such a weighting enables the weighted residuals to be indicative of the agreement between the data and the postulated model.

[a] First point defining Exponential decay.

[b] Last point defining Exponential decay.

The expected error in $\ln[N_q(T_i)]$, or $\delta(\ln N_q)$, is equal to $\frac{1}{N_q} \delta(N_q)$. Since

$$N_q = \sum_{j=1}^J N_{ij} - \overline{N_o} + B ,$$

then

$$\delta(N_q) = \sqrt{\left[\delta \left(\sum_{j=1}^J N_{ij} \right) \right]^2 + \left[\delta(\overline{N_o} + B) \right]^2} .$$

The expected error in the data taken in each channel on each sweep is $\sqrt{N_{ij}}$; thus, using the assumption of uniform pulse-generator output, the expected error in

$\sum_{j=1}^J N_{ij}$ is equal to $\sqrt{N_q + \overline{N_o} + B}$. The expected error in $\overline{N_o} + B$ at each point

is equal to one standard deviation S_2 . Consequently, values for $W(T_i)$, defined as the reciprocal of the square of the expected error in $\ln[N_q(T_i)]$, are calculated by GRIPE II as

$$W(T_i) = \left[N_q(T_i) \right]^2 / \left[N_q(T_i) + \overline{N_o} + B + (S_2)^2 \right] .$$

The programming, as shown in Appendix D, used to fit the data is different than that usually used for a linear least-squares analysis. This difference arises because the programming used is a linearized form of a nonlinear least-squares analysis written by D. H. Gipson of Phillips Petroleum Company. Its use was dictated solely by its availability as a result of unsuccessful preliminary attempts to find a satisfactory multi-variable nonlinear fit to pulsed-neutron data.

2.2 Iterations

Ideally, the values of $\ln[N_q(T_i)]$ selected for the first calculation would be only statistically varying estimates of $\ln[N_p(t)]$, and the fitting procedures described above would suffice for a determination of α . However, it is most probable that the data used are perturbed from the assumed linear model by at least three factors. First, if the estimate of τ were too small, the data in the first few channels considered would be descriptive of the general function $F(t)$ rather than the exponential decay. Second, as discussed in Section IV, the resolution correction applied requires the assumption of a uniform pulse-generator output; since this assumption is seldom exactly satisfied, those data entries in the first few channels considered (with their high counting rates) may not be entirely descriptive of $N_p(t)$. Third, if the value selected for SM were not appropriate, the data entries in the last few channels considered may contain significant contributions from the term $E(T_i)$. Since these factors can significantly influence the fit to the data, particularly in the first and last few channels used, an iterative calculation for the best values of the quantities in the fit has been included in GRIPE II.

In the first calculation, a value for α and its variance σ_α^2 were computed for values of $\ln [N_q(T_i)]$ from channels FE to LE. As discussed above, it is assumed that those factors causing the data to deviate from a linear model are most influential in the first and last few data points. Consequently, a better fit might be obtained if a few points were omitted at each end of the data sets considered. For this purpose the user must supply two integer numbers, FO[a] and LO[b]. These numbers are used to increase the channel number FE by FO and to decrease the channel number LE by LO. Since FE and LE are the channel numbers defining the data points included in the fit, this reduces the number of points in the fit, but it also causes the omission of those points most likely to be biased.

With the number of data points $\ln [N_q(T_i)]$ reduced by FO + LO, GRIPE II performs another best fit in a weighted least-squares sense to obtain a second set of values, $\ln (N_a)_I$, α_I , and $\sigma_{\alpha_I}^2$. If the first data fit was appropriate to the postulated model, it is most probable that $|\alpha_I - \alpha|$ will be less than σ_α , and it is most probable that $\sigma_{\alpha_I}^2$ will be larger than σ_α^2 , since fewer data points were used in the second fit. However, if the second data set better fit the linear model, it is most probable that $\sigma_{\alpha_I}^2$ will be less than σ_α^2 and that $|\alpha_I - \alpha|$ will be larger than σ_α . If $|\alpha_I - \alpha|$ is less than σ_α and if $\sigma_{\alpha_I}^2 > \sigma_\alpha^2$, the program assumes that the parameters obtained in the first calculation were descriptive of an exponential decay. However, if either test is not satisfied, the data set is again reduced by FO + LO data points, and the fit and tests are repeated until both tests provide a satisfactory result. As these iterations proceed, the computed values of $|\alpha_I - \alpha|$ and $\sigma_{\alpha_I}^2$ are printed out.

The selection of appropriate values for FO and LO should be governed by two factors. First, as the reactor is pulsed further and further subcritical for a given time-base, there are fewer and fewer data points defining the exponential decay. Thus, to preserve as many data points as possible, the sum FO + LO should be altered to suit each measurement. Second, the ratio FO/LO should be unity if it is equally probable that there is bias at both ends of the data set for the fit, or increased or decreased when more bias is probable in the first or last data points, respectively.

When these iterations have been completed, values will have been obtained for $\ln (N_a)$, α , σ_α^2 , $\sigma_{\ln(N_a)}^2$, and the covariance $\sigma_{\alpha, \ln(N_a)}$. Additionally, a value for τ has been established as time T_i corresponding to channel FE for which these parameter values were obtained.

2.3 X-Y Plots

Since the results of the least-squares analysis are so important in the reduction of pulsed-neutron data, it is desirable to have additional assurance that

[a] Parameter for removing points from the First portion of the decay by Omission.

[b] Parameter for removing points from the Last portion of the decay by Omission.

the values obtained and the numbers FO and LO used were appropriate for the input data. A visual presentation of the data with the best fit superimposed is, therefore, provided in the form of X-Y plots. Two plots are provided, one showing the data $\ln [N_q(T_i)]$ from channel FE + FO to LE - LO with the best straight line superimposed, and a second showing all data $\ln [N_q(T_i)]$ from channel 1 to the channel number corresponding to the initial value of LE with the best straight line again superimposed.

The plotting routine used is a modified version of a plot package written by L. J. Cutforth of Phillips Petroleum Company. These X-Y plots have proved to be a very useful portion of GRIPE II in that they provide both a visual observation of the quality of the data and a check on the applicability of the control parameters specified.

3. DETERMINATION OF PARAMETERS FOR TYPE 3X DATA

As discussed in Section II, the designation of data as type 3X implies that the prompt neutron response, $N_p(t)$, is composed of two exponentially decaying parts. That is, $N_p(t) = N_1 \exp(-\alpha_1 t) + N_2 \exp(-\alpha_2 t)$. Provided that $\alpha_2 \geq 2\alpha_1$, the computations in Section VI-2 will provide a good value for α_1 and $N_1 = \exp[\ln(N_a)]$. Thus, in this section, values for α_2 and N_2 will be computed.

To perform these computations, GRIPE II constructs a data set A_i , each member of which is defined by

$$A_i = \sum_{j=1}^J N_{ij} - \overline{N_o + B} - N_1 \exp[-\alpha_1 T_i] .$$

These data are obtained for the channel corresponding to the initially input value of FE to channel LE, where LE is redefined as the last data channel for which

$A_i > 0$. As before, only values for $\sum_{j=1}^J N_{ij} - \overline{N_o + B}$ are used which are greater than $SM \times S_2$.

When this second data set has been constructed, the program computes values of $\ln(A_i)$ for data channels FE to LE, and sets FO and LO equal to one. GRIPE II then computes best values for α_2 and $\ln(N_2)$ in the same fashion described in Section 2.2, except that new values are required for $W(T_i)$, the residual weighting factor. New values for $W(T_i)$ are equal to the reciprocal of the square of the expected error in A_i and are calculated from the expression

$$W(T_i) = (A_i)^2 / \left[N_q(T_i) + \overline{N_o + B} + (S_2)^2 + N_q(T_i) - A_i \sigma / (n-2) \right]$$

where σ is the sum of the squares of the weighted residuals for the determination of N_1 and α_1 using n data points. Again, as in Section 2.2, two X-Y plots are provided. For this calculation of α_2 , no summary of the iterations is output, only the final values.

VII. REACTIVITY CALCULATION

A calculation of reactivity is performed for data types 2 and 32. For these data types, the subcriticality in dollar units is calculated for the pulsed reactor using both the extrapolated-area-ratio method and the Garelis-Russell method. These calculations require that parameters N_0 , α , $\ln(N_a)$, and their variances have been computed, and that for times less than the computed τ there are appropriate estimates for $F(t)$ [ie, $N_q(T_i)$ for $T_i \leq \tau$].

1. EXTRAPOLATED-AREA-RATIO METHOD

In this section, the subcriticality is computed using the extrapolated-area-ratio method as developed by Gozani^[4]. The particular form used in GRIFE II is for the case in which the pulse width is much less than the reciprocal of the prompt decay constant α . This reactivity calculation is useful because the results should not be altered by prompt neutron harmonics. However, it will be inaccurate to the degree to which there is a finite rise and transmission time associated with the prompt neutron distribution at the point of detection.

The subcriticality of the reactor is computed in dollar units from the expression

$$\$_E = \frac{(R) \times (N_a)}{(\alpha) \times (N_0) \times (K)}$$

where $N_a = \exp[\ln(N_a)]$. An estimate for β/Λ is then computed from the expression

$$\left(\frac{\beta}{\Lambda}\right)_E = \frac{\alpha}{1 + \$_E}$$

The variance of the computed reactivity is then computed from the expression

$$\sigma_{\$_E}^2 = (\$_E)^2 \left[\frac{\sigma_{\alpha}^2}{(\alpha)^2} + \frac{\sigma_{N_0}^2}{(N_0)^2} + \frac{\sigma_{N_a}^2}{(N_a)^2} - 2 \frac{\sigma_{\alpha, N_a}}{(N_a) \times (\alpha)} \right]$$

where the variance $\sigma_{N_a}^2 = N_a^2 \sigma_{\ln(N_a)}^2$ and the covariance of α and N_a is $\sigma_{\alpha, N_a} = N_a \sigma_{\alpha, \ln(N_a)}$. A variance for $(\beta/\Lambda)_E$ is computed from the expression

$$\sigma_{(\beta/\Lambda)_E}^2 = \left(\frac{\beta}{\Lambda}\right)_E^2 \left[\frac{\sigma_{\$_E}^2}{(1 + \$_E)^2} + \frac{\sigma_{\alpha}^2}{(\alpha)^2} - \frac{2 \$_E}{\alpha(1 + \$_E)} \left(\frac{\sigma_{\alpha, N_a}}{N_a} - \frac{\sigma_{\alpha}^2}{\alpha} \right) \right]$$

If a delay Δt is used between the start of a sweep and the firing of a pulse, the computed value for $\$_E$ should be multiplied by $\exp(-\alpha \Delta t)$, and $(\beta/\Lambda)_E$ should be

adjusted accordingly. To a very good approximation, the fractional error ($\sigma_{\$}/\$_E$) will be unchanged.

2. GARELIS-RUSSELL METHOD

In this section the subcriticality of the reactor is computed using the Garelis-Russell method[5, 11], sometimes called the inverse generation method. With this method, reactivity in dollar units is calculated from the relationship

$$\$_G = (\alpha/c) - 1$$

where the parameter c is the root of the equation

$$\int_0^{\infty} N_p(t) \exp[ct] dt - \int_0^{\infty} N_p(t) dt = \frac{N_0}{R} K \quad (7-1)$$

The parameter c is generally considered to be equal to β/Λ . In order to calculate reactivity, c must be computed.

2.1 Computation of the Garelis-Russell Constant

The solution c of Equation (7-1) has been calculated by others [12] using an iterative scheme. However, in GRIPE II a direct solution approach has been used which permits a straightforward error analysis and which should be more accurate than the iterative approach. This accuracy is gained because, in the iterative approach, the term $\exp(ct)$ acts as a weighting factor which weights more heavily those data occurring at later times. However, it is those data which are statistically poor; thus, those values of $N_p(t) \exp(ct)$ which are most influential in the definition of c (using the iterative approach) are those with the greatest errors. The direct solution method as used by GRIPE II also has a disadvantage in that it requires τ to be less than $0.7/c$, and it requires some foreknowledge of the value for c . However, these disadvantages have proved to be insignificant in experiment analyses[13, 14] thus far performed in thermal reactors ATRC, ETRC, and ARMF-II.

It will be recalled that in Section VI, the function $N_p(t)$ was assumed to be of the form

$$N_p(t) = F(t) \text{ for } 0 \leq t \leq \tau$$

and

$$N_p(t) = N_a \exp(-\alpha t) \text{ for } \tau \leq t < \frac{1}{R} \quad [a]$$

As a result of the calculations in Section VI, a value for τ was obtained. Using that value and the above definition for $N_p(t)$, Equation (7-1) may be rewritten in the form

[a] The use of the Garelis-Russell method requires the assumption that $\frac{1}{R} \approx \infty$.

$$\int_0^{\tau} F(t) \exp(ct) dt + \int_{\tau}^{\infty} N_a \exp[(c-\alpha)t] dt - \int_0^{\tau} F(t) dt - \int_{\tau}^{\infty} N_a \exp(-\alpha t) dt = N_o \frac{K}{R}.$$

Provided that $c < \alpha$ (ie, the reactor is subcritical), some of the indicated integrations may be performed and terms rearranged to obtain

$$\left[\int_0^{\tau} F(t) \exp(ct) dt - \int_0^{\tau} F(t) dt \right] + \frac{N_a \exp[(c-\alpha)\tau]}{\alpha - c} - \frac{N_a}{\alpha} \exp(-\alpha\tau) = \frac{N_o K}{R}. \quad (7-2)$$

Restricting $c\tau$ to be less than 1.0, the term $\exp(c\tau)$ may be expanded in a Maclaurin series:

$$\exp(c\tau) = 1 + c\tau + \frac{c^2 \tau^2}{2} + \frac{c^3 \tau^3}{6} + \frac{c^4 \tau^4}{24} + \frac{c^5 \tau^5}{120} + \text{remainder}.$$

The product $c\tau$ will now be restricted to less than 0.7 in order that the remainder for the expansion contributes less than 0.1 percent of the total value. This expansion is then applied to Equation (7-2) to obtain

$$\begin{aligned} (\alpha - c) \left[\int_0^{\tau} F(t) \exp(ct) dt - \int_0^{\tau} F(t) dt \right] + N_a c \tau \exp(-\alpha\tau) + \frac{N_a c^2 \tau^2}{2} \exp(-\alpha\tau) \\ + \frac{N_a c^3 \tau^3}{6} \exp(-\alpha\tau) + \frac{N_a c^4 \tau^4}{24} \exp(-\alpha\tau) + \frac{N_a c^5 \tau^5}{120} \exp(-\alpha\tau) \\ + \frac{N_a c}{\alpha} \exp(-\alpha\tau) = \frac{N_o \alpha K}{R} - \frac{N_o c K}{R}. \end{aligned} \quad (7-3)$$

Focusing attention on the bracketed quantity in Equation (7-3), it can be seen that, provided ct is restricted as described (< 0.7), $\exp(ct)$ may also be expanded and the integrations performed term by term. If this expansion also is carried to fifth order and the terms for each order of c collected, an equation of sixth order is obtained. This equation is

$$\begin{aligned} -c^6 \left[\frac{1}{120} \int_0^{\tau} F(t) t^5 dt \right] + c^5 \left[\frac{\alpha}{120} \int_0^{\tau} F(t) t^5 dt \right. \\ \left. - \frac{1}{24} \int_0^{\tau} F(t) t^4 dt + \frac{N_a \tau^5 \exp(-\alpha\tau)}{120} \right] \end{aligned}$$

$$\begin{aligned}
& + c^4 \left[\frac{\alpha}{24} \int_0^\tau F(t) t^4 dt - \frac{1}{6} \int_0^\tau F(t) t^3 dt + \frac{N_a \tau^4 \exp(-\alpha\tau)}{24} \right] \\
& + c^3 \left[\frac{\alpha}{6} \int_0^\tau F(t) t^3 dt - \frac{1}{2} \int_0^\tau F(t) t^2 dt + \frac{N_a \tau^3 \exp(-\alpha\tau)}{6} \right] \\
& + c^2 \left[\frac{\alpha}{2} \int_0^\tau F(t) t^2 dt - \int_0^\tau F(t) t dt + \frac{N_a \tau^2 \exp(-\alpha\tau)}{2} \right] \\
& + c \left[\alpha \int_0^\tau F(t) t dt - N_a \tau \exp(-\alpha\tau) + \frac{N_a \exp(-\alpha\tau)}{\alpha} + \frac{N_o K}{R} \right] \\
& - \left[\frac{N_o K \alpha}{R} \right] = 0 \tag{7-4}
\end{aligned}$$

The desired value for c is one of the six roots of Equation (7-4). This equation is solved in GRIPE II, and the six roots are scanned to find the root appropriate to the calculation of reactivity.

In order to solve Equation (7-4), the coefficients of the powers of c must be computed. Values for all terms except the integrals are easily obtained from the estimates of the parameters computed in Section VI. The integrals are evaluated numerically in GRIPE II using the values of $N_q(T_i)$ for $T_i \leq \tau$ (obtained in Section VI-1) to provide estimates for $F(t)$ at each time T_i . With these estimates the integrals are evaluated using Simpson's Rule. Following these calculations all terms are combined to obtain the coefficients for the sixth order equation, Equation (7-4).

The six roots of Equation (7-4) are obtained using the Newton-Bairstow method (described in Appendix C) which determines the roots of an N^{th} order polynomial. This calculation is done in double-precision in GRIPE II, using a modified form of a calculational procedure written by G. A. Cazier of Phillips Petroleum Company. All roots are calculated, both real and complex, after which GRIPE II begins a search for the root or roots desired.

GRIPE II specifies that the value c which is appropriate to the calculation of reactivity will be real, greater than an input number MIN, and less than an input number MAX. If more than one value is found to satisfy these criteria, a reactivity will be calculated using each. The range MIN to MAX is specified by the user to suit his application. The range 70.0 to 250.0 has been used and found to be sufficiently broad for the thermal systems to which this program has been applied, since in those reactors β/Λ ($\approx c$) ranges from 100 to 210 sec^{-1} .

2.2 Computation of Reactivity

With a value for c calculated by the procedure described above, the sub-critical reactivity for the reactor is calculated in dollar units from the expression

$$\$_G = \frac{\alpha}{c} - 1.$$

In order to obtain an uncertainty for the computed value of reactivity, an uncertainty must be calculated for parameter c . The primary experimental errors contributing to an error in c can be seen in Equation (7-4) to be errors in α , N_a , and N_o . Other errors are introduced in the integrations by the estimates $N_q(T_i)$ for $T_i \leq \tau$; but since τ in this method is necessarily small, the error contribution from these estimates is not significant. Consequently, the variance of c , σ_c^2 , may be calculated from the relation

$$\sigma_c^2 = (\delta c)^2 = \left(\frac{\partial c}{\partial \alpha}\right)^2 \sigma_\alpha^2 + \left(\frac{\partial c}{\partial N_o}\right)^2 \sigma_{N_o}^2 + \left(\frac{\partial c}{\partial N_a}\right)^2 \sigma_{N_a}^2 + 2\left(\frac{\partial c}{\partial \alpha}\right)\left(\frac{\partial c}{\partial N_a}\right) \sigma_{\alpha, N_a}$$

where the variances σ_α^2 , $\sigma_{N_o}^2$, $\sigma_{N_a}^2$, and the covariance σ_{α, N_a} have been previously determined.

In order to compute σ_c^2 , values for the partial derivatives shown must be obtained. Estimates for these values are computed in GRIPE II by a calculation of the quantities $\Delta c/\Delta \alpha$, $\Delta c/\Delta N_o$, and $\Delta c/\Delta N_a$ for a one percent variation in each parameter. (One percent was selected since the error equations assume that the difference and differential are equal over the range of the error, and the error in each parameter is generally of this order.) The computing time for each of these estimates is on the order of a few seconds, and upon completion of these calculations, σ_c^2 may be evaluated as shown.

With σ_c^2 thus obtained, the variance of the reactivity value calculated is obtained from the equation

$$\sigma_{\$_G}^2 = \left(\frac{\alpha}{c}\right)^2 \left[\frac{\sigma_\alpha^2}{\alpha^2} + \frac{\sigma_c^2}{c^2} - \frac{2}{\alpha c} \left(\frac{\partial c}{\partial N_a} \sigma_{\alpha, N_a} + \frac{\partial c}{\partial \alpha} \sigma_c^2 \right) \right].$$

VIII. QUALITY TESTS ON EXPERIMENTAL DATA

When GRIPE II has completed the calculations described in the foregoing sections, values for the parameters of interest and the variance of each will have been obtained. However, there remains a question as to how well the experimental data were described by the models postulated in GRIPE II. Even though such agreement is implicit within the calculated variances, some additional tests are required to separate the degree of agreement and the precision of the measurement.

The Chi-square test^[15] has been included in GRIPE II to test the hypothesis that the observed data are random fluctuations about the proposed models. Thus, values for Chi-square are calculated (a) for those data which were expected to describe an exponential decay, (b) for those data obtained while pulsing which were expected to describe a constant, equilibrium condition, and (c) for those data which were expected to describe a constant reactor background. Chi-square is calculated as the square of the difference between the observed and the expected number of counts in a sample divided by the expected number of counts, summed over all samples. For tests on the data expected to describe a constant, the expected number of counts per sample is equal to the mean value of the sampled data. The expected number of counts for the data supposed to describe an exponential decay is equal to the value computed using the best values determined in the least-squares analysis. However, if the number of counts in a channel is less than five, the applicability of the Chi-square test is in doubt.

When the values for each Chi-square have been calculated as shown at the end of this section, they are output together with the associated number of degrees of freedom. These values may then be compared with the values shown in Table II to obtain an estimate for the probability of occurrence associated with the calculated value under the hypothesis of random variation about the assumed model. A low probability of occurrence indicates the presence of bias in the data relative to the hypothesized behavior. Whether or not a detected bias is important to the outcome of the experiment depends upon its source. Thus, if bias is indicated, it is necessary for the experimenter to attempt to determine its origin and, upon that determination, consider the acceptability of the experimental result.

When bias is indicated in the data describing the exponential decay, it may be due to a poor resolution correction, a nonuniform neutron output of the pulsed-source, a poor choice of SM, FO, or LO, or spurious electronic noise. In those data descriptive of a constant, one can always expect some bias due to the delayed neutrons in the reactor. F. deHoffman^[16] has shown that the magnitude of such bias depends upon the fuel material, the position-dependent chamber efficiency (counts/reactor fission), and the core composition. Other biasing factors are a time varying reactor background, a variation in neutron output of the pulsed source (when used), and spurious electronic noise.

Chi-square is calculated for the data describing a single exponential decay as

$$\chi^2_{E_I} = \sum_{i=FE}^{LE} \frac{[N_g(T_i) - N_a \exp(-\alpha T_i)]^2}{N_a \exp(-\alpha T_i) + N_o + B}$$

Table II

CHI-SQUARE VALUES FOR SEVERAL PROBABILITIES OF
OCCURRENCE AND DEGREES OF FREEDOM

Probability of Occurrence	0.50	0.10	0.05	0.01
Degrees of Freedom[a]				
2	1.386	4.605	5.991	9.210
4	3.357	7.779	9.488	13.277
6	5.348	10.645	12.592	16.812
8	7.344	13.362	15.507	20.090
10	9.342	15.987	18.307	23.209
12	11.340	18.549	21.026	26.217
14	13.339	21.064	23.685	29.141
16	15.338	23.542	26.296	32.000
18	17.338	25.989	28.869	34.805
20	19.337	28.412	31.410	37.566
22	21.337	30.813	33.924	40.289
24	23.337	33.196	36.415	42.980
26	25.336	35.563	38.885	45.642
28	27.336	37.916	41.337	48.278
30	29.336	40.256	43.773	50.892

[a] For degrees of freedom greater than 30, the quantity

$2\chi^2 - \sqrt{2n^1} - 1$ is normally distributed with unit variance, where n^1 is the number of degrees of freedom.

where N_a and α are the best values obtained in the least-squares analysis of $N_q(T_i)$. The number of degrees of freedom is two less than the number of points in the sum. Chi-square for the second exponential of the two-exponential analysis is calculated from the expression

$$\chi_{E_2}^2 = \sum_{i=FE}^{LE} \frac{[A_i - N_2 \exp(-\alpha_2 T_i)]^2}{N_2 \exp(-\alpha_2 T_i) + N_1 \exp(-\alpha_1 T_i) + N_0 + B}$$

where N_2 , α_2 and N_1 , α_1 are the best values obtained in the least-squares analyses of A_i and $N_q(T_i)$, respectively.

Chi-square is calculated for the data descriptive of a constant as $S_1^2(n-1)/\bar{B}$ for background data and as $S_2^2(n-1)/\overline{N_o + B}$ for the data obtained with the operational pulsed source. The number of degrees of freedom associated with each value is equal to $(n-1)$ where, as above, n is equal to the number of data points defining the mean value.

IX. OUTPUT SUMMARY

There are four categories of output information for each pulsed-neutron experiment: (a) there is a complete listing of the input analyzer data, two data sets for data taken when subcritical and one set for data taken when critical; (b) there is a summary of the iterative calculations for α ; (c) there is an analysis summary sheet; and (d) there are the X-Y plots, two for a one-exponent analysis and four for a two-exponent analysis. Except for the analysis summary sheet [item (c)], the entries on the output sheets should be self-explanatory from the discussions in the preceding sections.

There are three categories of information on an analysis summary sheet. First, there is a summary of the input control information. Second, there is a summary of the results of all computations exclusive of the reactivity calculations. Third, there is a summary of the reactivity calculations as performed for each method used. In Table III, an analysis summary sheet has been reproduced with symbols described in this report replacing the numbers usually found opposite the alphanumeric titles. When used in conjunction with Table I (a complete listing of symbols and definitions), Table III should enable the program user to locate the parameters of interest to him.

Shown on pages 30 through 33 are the computer output sheets (exclusive of the data listings) for two pulsed-neutron experiments in ATRC. These were selected only to be illustrative of the calculations and outputs available.

Table III

LOCATION OF COMPUTED VALUES IN ANALYSIS SUMMARY SHEET

<u>GRIPE II Analysis Problem Title</u>			
Input Parameters			
Gate width	GW _p	Time base	TB
Pulse rate	R _p	Pulse number	PT
Resolving time	RT	Tau est.	FE (initial)
Front sub.	FO	Back sub.	LO
Data Analysis			
Decay constant	α	One standard deviation	σ_{α}
Delay background	N_o/GW_p	One standard deviation	σ_{N_o/GW_p}
Time to reach decay	τ	Chi-square for fit.	χ^2_{E1}
TZero intercept	N_a/GW_p	Deg. of freedom	(LE - FE - 1)
Mean value pulse back	$\frac{N_o}{N_o + B}$	Mean value reac back	$\bar{B}$
Chi-square	$S^2_2(LC-FC) / \overline{N_o + B}$	Chi-square	$S^2_1(LC-FC)/\bar{B}$
Deg. of freedom	(LC - FC)	Deg. of freedom	(LC - FC)
Final Values (only for type 2 and 32 data)			
Extrapolated-Area-Ratio			
Dollars subcritical	$\$E$	Inv. Gen. Time	$(\beta/\Lambda)_E$
One standard deviation	$\sigma_{\$}$	One standard deviation	$\sigma_{\beta/\Lambda}$
Garelis-Russell			
(There was --- root possible)			
Dollars subcritical	$\$G$	Inv. Gen. Time	c
One standard deviation	$\sigma_{\$}$	One standard deviation	σ_c
A ^{one} _{two} Exponential Analysis was Requested			
Second Exponential (only for type 3X data)			
Second decay constant	α_2	One standard deviation	σ_{α_2}
Second intercept	N_2/GW_p	One standard deviation	σ_{N_2/GW_p}
Chi-square for fit	χ^2_{E2}	Deg. of freedom	(LE - FE - 1)

DATA SET FOR SINGLE EXPONENTIAL WHICH WAS USED IN LAST ITERATION.

FULL DATA SET USED IN FITTING PROCESS WITH FINAL EXPONENTIAL FIT SHOWN.

SUMMARY OF ITERATIONS

TEST ON ALPHA	DIFF	0.2736786E 03 AND STD DEV	0.1109685E 01
TEST ON ALPHA	DIFF	0.3213619E 01 AND STD DEV	0.7461241E 00
TEST ON ALPHA	DIFF	0.1121952E 01 AND STD DEV	0.7435970E 00
TEST ON ALPHA	DIFF	0.3046494E 00 AND STD DEV	0.8024587E 00

ANALYSIS SUMMARY SHEET FOR A SINGLE EXPONENTIAL ANALYSIS

GRIPE II ANALYSIS

ATRC TAPE 41

INPUT PARAMETERS

GATE WIDTH	0.00007900	TIME BASE	0.00010000
PULSE RATE	9.75999999	PULSE NO.	3514.00000000
RESOLVING TIME	0.00000350	TAU EST	4
FRONT SUB	3	BACK SUB	3

DATA ANALYSIS

DECAY CONSTANT	278.01416779	ONE STD. DEV.	0.74359702
DELAY BACKGROUND	0.6979976E 07	ONE STD. DEV.	0.2361424E 05
TIME TO REACH DECAY	0.00095000	CHI SQ. FOR FIT	145.80149918
TZERO INTERCEPT	0.1971715E 09	DEG. OF FREEDOM	122.
MEAN VALUE PULSE BACK	804.73614502	MEAN VALUE REAC BACK	253.31806755
CHI SQUARE	316.90639496	CHI SQUARE	513.74968719
DEG. OF FREEDOM	292.	DEG. OF FREEDOM	510.

FINAL VALUES

EXTRAPOLATED-AREA-RATIO

DOLLARS SUBCRITICAL	0.99168371	INV. GEN. TIME	139.58750916
ONE STANDARD DEVIATION	0.00375676	ONE STANDARD DEVIATION	0.46150538

GARELIS-RUSSELL

(THERE WAS 1 ROOT POSSIBLE)

DOLLARS SUBCRITICAL	0.99052536	INV. GEN. TIME	139.66873932
ONE STANDARD DEVIATION	0.00378961	ONE STANDARD DEVIATION	0.42419147

A ONE EXPONENTIAL ANALYSIS WAS REQUESTED

ATRC TAPE 07 7-14-66

040467

DATA SET FOR FIRST EXPONENTIAL WHICH WAS USED IN LAST ITERATION.

ATRC TAPE 07 7-14-66

040467

FULL DATA SET USED IN FITTING PROCESS WITH FINAL EXPONENTIAL FIT SHOWN FOR FIRST EXPONENTIAL.

ATRC TAPE 07 7-14-66

040467

DATA SET FOR SECOND EXPONENTIAL WHICH WAS USED IN LAST ITERATION.

ATRC TAPE 07 7-14-66

040467

FULL DATA SET FOR SECOND EXPONENTIAL.

SUMMARY OF ITERATIONS

TEST ON ALPHA	DIFF	0.1975109E 04 AND STD DEV	0.1029794F 03
TEST ON ALPHA	DIFF	0.1536194E 03 AND STD DEV	0.5603153E 02
TEST ON ALPHA	DIFF	0.2445315E 03 AND STD DEV	0.3404757E 02
TEST ON ALPHA	DIFF	0.1369980E 03 AND STD DEV	0.2347927E 02
TEST ON ALPHA	DIFF	0.9040240E 02 AND STD DEV	0.1740063E 02
TEST ON ALPHA	DIFF	0.4805330E 02 AND STD DEV	0.1667906E 02
TEST ON ALPHA	DIFF	0.3904962E 02 AND STD DEV	0.2112367E 02
TEST ON ALPHA	DIFF	0.1890361E 02 AND STD DEV	0.2899120E 02

ANALYSIS SUMMARY SHEET FOR A DOUBLE EXPONENTIAL ANALYSIS

GRIFE II ANALYSIS

ATRC TAPE 07 7-14-66

INPUT PARAMETERS

GATE WIDTH	0.00007900	TIME BASE	0.00010000
PULSE RATE	9.79999999	PULSE NO.	3800.00000000
RESOLVING TIME	0.00000350	TAU EST	1
FRONT SUB	3	BACK SUB	1

DATA ANALYSIS

DECAY CONSTANT	1262.45455933	ONE STD. DEV.	21.12366986
DELAY BACKGROUND	0.1687478E 06	ONE STD. DEV.	0.3629063E 04
TIME TO REACH DECAY	0.00185000	CHI SQ. FOR FIT	8.54304922
TZERO INTERCEPT	0.1250445E 09	DEG. OF FREEDOM	15.
MEAN VALUE PULSE BACK	19.98295093	MEAN VALUE REAC BACK	6.65187252
CHI SQUARE	283.88750458	CHI SQUARE	622.47363281
DEG. OF FREEDOM	292.	DEG. OF FREEDOM	510.

FINAL VALUES

EXTRAPOLATED-AREA-RATIO

DOLLARS SUBCRITICAL	5.72875905	INV. GEN. TIME	187.62071037
ONE STANDARD DEVIATION	0.23061915	ONE STANDARD DEVIATION	4.27827185

GARELS-RUSSELL

(THERE WAS 1 ROOT POSSIBLE)

DOLLARS SUBCRITICAL	8.53105342	INV. GEN. TIME	132.45697975
ONE STANDARD DEVIATION	0.28247418	ONE STANDARD DEVIATION	2.71372169

A TWO EXPONENTIAL ANALYSIS WAS REQUESTED

SECOND EXPONENTIAL

SECOND DECAY CONSTANT	3851.92330933	ONE STD. DEV.	92.52905655
SECOND INTERCEPT	0.6016280E 09	ONE STD. DEV.	0.3379235E 08
CHI SQ. FOR FIT	19.05827951	DEG. OF FREEDOM	7.

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APPENDIX A -- PREPARATION OF INPUT FOR GRIPE II

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APPENDIX A -- PREPARATION OF INPUT FOR GRIPE II

As discussed in Section II of this report, two data sets are required for a pulsed experiment performed in a subcritical reactor, and one data set is required for a reactor pulsed when critical. The two sets of data for the subcritical reactor are (a) a set for the reactor background and (b) a set obtained with an operational pulsed-neutron source; the processing of the former must precede that for the latter.

The order of program assembly is as follows: (a) the object program deck, (b) a \$ENTRY card, (c) a card indicating the number of data sets to be processed, (d) a card indicating conservative estimates of the minimum and maximum values expected for β/Λ , and (e) the data sets to be processed, with four control cards preceding each data set. The card indicating the number of data sets [item (c)] contains only this entry, which is a right-adjusted integer value in columns one through five (Format I5). For the card containing a maximum expected range for β/Λ [item (d)], the minimum value is entered in columns 7 through 20 and the maximum value is entered in columns 27 through 40 [Format 2 (6X, E14.7)].

Each data set requires four control cards, two of which are title cards. The formats and entries for these four cards are described below. Also included in this description are page numbers [in brackets] which reference those portions of this report that describe the use of the parameter noted.

<u>Location</u>	<u>Symbol [a] Used in Report</u>	<u>Required Entry</u>	<u>Format</u>
Card One			
Col. 1-5	---	Data type designation (0, 1, 2, 30, 32) [8]	I5
Col. 6-10	---	Plot control -- enter 0 for no plot and 1 for X-Y plots	I5
Col. 11-15	FE	Number of channels corresponding to initial guess for τ , FE must be ≥ 1 [16]	I5
Col. 16-20	FC	Conservative estimate for the lowest channel number beyond which the data are estimates of a constant. For data types 0, 2, 30, 32, FC must be > 12 [12]	I5
Col. 21-25	LC	Last data channel for which the data are constant [12]	I5
Col. 26-30	FO	Number of channels which, in successive iterations, are to be omitted from the first of the data set defining α [18]	I5

[a] See Table I for a complete definition of these symbols.

<u>Location</u>	<u>Symbol [a] Used in Report</u>	<u>Required Entry</u>	<u>Format</u>
Col. 31-35	LO	Number of channels, which in successive iterations, are to be omitted from the last of the data set defining α [18]	I5
Col. 36-45	SM	Multiplier of (S_2) to be used in defining those data descriptive of the prompt neutron response[15]	E10.5
Col. 46-55	GW _e	When entering background data, this entry must be the effective gate width for the associated pulsed run. Otherwise no entry is required[7]	E10.5
Card Two			
Col. 1-5	I	Number of data points in data set (generally, the number of channels in the analyzer). Must be ≤ 512 [7]	I5
Col. 6-15	PT	For background data, enter number of analyzer sweeps. For pulse data, enter number of pulses used[7, 11]	E10.5
Col. 16-25	RT	Resolving time of the counting system expressed in units of time[7, 10]	E10.5
Col. 26-35	TB	Analyzer time base in units of time [7, 9]	E10.5
Col. 36-45	R	Number of pulses per unit time[7]	E10.5
Col. 46-55	GW _b or GW _p	Analyzer gate width[7, 11, 13]	E10.5
Col. 56-65	K	Multiplier which permits the use of a modified pulsed-neutron analysis. For standard forms, $K = 1.0$ [4, 20, 23]	E10.5
Card Three			
Col. 3-80	---	Problem or data set title.	(2X, 13A6)
Card Four			
Col. 1-12	---	Lable desired on x-axis of the X-Y plots [generally "TIME IN () SEC"].	2A6
Col. 13-20	---	Blank	8X
Col. 21-32	---	Lable desired on y-axis of the X-Y plots (generally "LOG COUNTS").	2A6

[a] See Table I for a complete definition of these symbols.

Following these four control cards is the data set to which they pertain. The analyzer data must be entered in the order corresponding to increasing time, generally channel 1 to channel I. There are a maximum of 512 entries permitted for each data set. These are entered with eight six-digit integer values per card and one space between any two successive values. That is, the format for these cards is 8(I6, 1X). Should the first data channel of the analyzer be used to store information other than count data, this first value should be suppressed to zero (see Section II). Following this data set will be the four control cards for the next data set to be processed.

The format discussed immediately above for the data cards is well suited for use with an analyzer which outputs its memory through a Tally-punched paper tape unit. This tape may be easily processed in a tape-to-card unit to provide the required data cards.

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APPENDIX B -- COMMENTS ON THE USE OF GRIPE II

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APPENDIX B -- COMMENTS ON THE USE OF GRIPE II

GRIPE II has been quite successful in providing an analysis of pulsed-neutron data, particularly when experimental difficulties have been encountered. It has been used to process more than 100 pulsed-neutron data sets and has provided reasonable analyses in each case. The use of the X-Y plots has proved to be particularly desirable in these analyses, since errors in one or two channels are not obvious in the analyzer display and errors due to experimental bias (as indicated by χ^2 value) often do not become evident until the data are compared to the calculated best fit.

When using GRIPE II, the experimenter should obtain estimates for the following parameters from the analyzer memory display unit, following the completion of a pulsed experiment: (a) an estimate for τ , (b) an estimate for FC, and (c) an estimate for the average prompt response to the delay response, which will aid the selection of SM. Then, following the processing of the data, the output should be reviewed to determine if a change in some control parameter would provide an even better analysis.

Listed below are some of the parameters used in these analyses with comments applicable to their selection.

Parameter	Comment
LC	Generally, one should select $LC = I$, where I is the number of channels available for analysis. This permits the analysis for a constant to have a minimum variance.
SM	Good success has been obtained with $SM = 10.0$ for the analyses of subcritical systems. However, for critical systems analyses, $SM = 3.0$ is generally used because the difference between the average prompt response and the reactor background is usually much less than for subcritical data.
FE	If a two-exponential analysis is to be done, FE must be set to the channel number believed to correspond to the beginning of the most rapidly decaying exponential.
FO and LO	These two parameters should seldom be greater than 4. Following the first processing of the data, the X-Y plots should be examined to determine whether the selection of these parameters was correct.

Occasionally, it is desirable to simulate a reactor background $\bar{B}$ rather than use a value calculated from experimental data. For this purpose, it is desirable to have a single data card with each of the eight values set to 001000. In the associated background control cards, FC is set to 1, and LC is set to 8. With this set of cards it is possible to simulate any value for B by appropriate choices for GW_b and GW_e , since B will be equal to $1000 \times GW_e/GW_b$.

If the pulsed-neutron source-time base analyzer combination is synchronized so that there is a delay time Δt between the onset of an analyzer sweep and the firing of the pulsed-neutron source, the analysis routines of GRIPE II

remain valid. However, in this case, the calculated reactivity for the extrapolated-area-ratio method must be multiplied by $\exp(-\alpha\Delta t)$ to be correct and an appropriate change made in $(\beta/\Lambda)_E$.

Two of the error flags included in GRIPE II should be discussed. The first gives the message INSUFFICIENT DATA DEFINING EXPONENTIAL. Although the meaning is clear, the position in the output listing has significance. If it immediately follows the data listing, it implies that the search described in Section V indicates no exponential to be present or that FE is too large. If it follows some results of iteration calculations, it implies that all of the data points were omitted during iterations without ever satisfying the criteria for selecting α . This can result from choosing FO + LO or FE or both too large. If this error flag follows the reactivity calculations, it indicates that in determining parameters for the second exponential, the second exponential did not exist, there were too few channels to define it, or the parameter FE was too large.

The second important error flag states WARNING ---- C x τ IS () CONVERGENCE IN DOUBT. This message appears whenever $c\tau$ is greater than 0.7, and it indicates that the remainder for the series shown on page 22 of the text has become larger than intended. Consequently, there is a doubt as to whether the expanded form of the integral in Equation (7-3) has converged to the proper value.

APPENDIX C -- NEWTON-BAIRSTOW ITERATIVE METHOD

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APPENDIX C -- NEWTON-BAIRSTOW ITERATIVE METHOD

(G. A. Cazier)[a]

The technique adopted in this report for the solution of the Garelis-Russell Equation (7-1) requires the numerical determination of the six roots of a sixth order polynomial equation. The methods used for this determination are the Newton and the Bairstow iterative schemes. Since the class of polynomial for which the Bairstow iteration fails to converge is not the same as that for which the Newton iteration fails, the Bairstow and Newton iterations are performed simultaneously. If the given polynomial is properly scaled and the sequence of polynomial coefficients is reversed when required, the simultaneous Newton and Bairstow methods will almost always converge. A brief description of the calculative procedure for each method is given below:

Newton Iteration

Given polynomial $f(x)$ of degree n , it may be written as

$$f(x) = a_0 x^n + a_1 x^{n-1} + a_2 x^{n-2} + \dots + a_{n-1} x + a_n \quad (c-1)$$

If the linear term $(x-z)$ is factored out of (c-1), the result

$$f(x) = (x-z) (x^{n-1} + b_1 x^{n-2} + \dots + b_{n-2} x + b_{n-1}) + R \quad (c-2)$$

is obtained. Factoring $(x-z)$ out of (c-2), the result

$$f(x) = (x-z)^2 (x^{n-2} + c_1 x^{n-3} + \dots + c_{n-3} x + c_{n-2}) + R' \quad (c-3)$$

is obtained.

By equating the coefficients of x^{n-1} , x^{n-2} , x^{n-3} , ..., in Equations (c-1) and (c-2), one obtains

$$a_1 = b_1 - z, \quad a_2 = b_2 - z b_1$$

or, in general,

$$a_{n-1} = b_{n-1} - z b_{n-2}, \quad a_n = R - z b_{n-1}$$

Thus,

$$b_k = a_k + z b_{k-1}$$

so that

$$f(z) = b_n = a_n + z b_{n-1}$$

Similarly, for Equations (c-2) and (c-3)

$$f'(z) = c_{n-1} = b_{n-1} + z c_{n-2}$$

[a] With the Machine Computations Branch, Atomic Energy Division, Phillips Petroleum Company.

Newton's iteration then becomes

$$z^* = z - \frac{R}{R'} = z - \frac{b_n}{c_{n-1}}$$

where z is an estimate of the root r , and z^* is a new estimate. The iteration is continued until $\left| \frac{a_n}{b_n} \right| > 10^F$, where F is the number of significant figures carried (14).

Bairstow Iteration

Equation (c-1) is divided by $x^2 + p_i x + q_i$ to obtain

$$\begin{aligned} \frac{f(x)}{x^2 + p_i x + q_i} &= g(x) + R = b_0 x^{n-2} + b_1 x^{n-3} + \dots + b_{n-3} x + b_{n-2} \\ &\quad + \frac{b_{n-1} x + b_n}{x^2 + p_i x + q_i} \end{aligned} \quad (c-4)$$

where p_i and q_i are guesses and R is the remainder term. The function $g(x)$ is then divided by $x^2 + p_i x + q_i$ and the results

$$\begin{aligned} \frac{g(x)}{x^2 + p_i x + q_i} &= h(x) + S = c_0 x^{n-4} + c_1 x^{n-5} + \dots + c_{n-5} x + c_{n-4} \\ &\quad + \frac{c_{n-3} x + c_{n-2}}{x^2 + p_i x + q_i} \end{aligned} \quad (c-5)$$

are obtained, where S is the remainder term. The conditions for $x^2 + p_i x + q_i$ to be a factor are

$$R(p, q) = 0 \quad \text{and} \quad S(p, q) = 0.$$

Using Taylor's expansion for functions of two variables about the points (α, β) ,

$$\begin{aligned} R(p, q) &= R(\alpha, \beta) + \frac{\partial R(\alpha, \beta)}{\partial p} (p - \alpha) + \frac{\partial R(\alpha, \beta)}{\partial q} (q - \beta) + \text{terms in } (p - \alpha)^2 \text{ and} \\ &\quad (q - \beta)^2, \text{ and } S(p, q) = S(\alpha, \beta) + \frac{\partial S(\alpha, \beta)}{\partial p} (p - \alpha) + \frac{\partial S(\alpha, \beta)}{\partial q} (q - \beta) + \text{terms in} \\ &\quad (p - \alpha)^2 \text{ and } (q - \beta)^2. \end{aligned}$$

Let $p_{k+1} = p$, $q_{k+1} = q$, $p_k = \alpha$, and $q_k = \beta$ so that

$$\frac{\partial R(p_k, q_k)}{\partial p} (p_{k+1} - p_k) + \frac{\partial R(p_k, q_k)}{\partial q} (q_{k+1} - q_k) = -R(p_k, q_k)$$

$$\frac{\partial S(p_k, q_k)}{\partial p} (p_{k+1} - p_k) + \frac{\partial S(p_k, q_k)}{\partial q} (q_{k+1} - q_k) = -S(p_k, q_k) .$$

The partial derivatives are evaluated and the results

$$c_{n-2} \Delta p + c_{n-3} \Delta q = b_{n-1}$$

$$\bar{c}_{n-1} \Delta p + c_{n-2} \Delta q = b_n$$

are obtained, where

$$\bar{c}_{n-1} = -(p_i c_{n-2} + q_i c_{n-3})$$

and

$$\Delta p = \frac{b_{n-1} c_{n-2} - b_n c_{n-3}}{c_{n-2}^2 - \bar{c}_{n-1} c_{n-3}}$$

$$\Delta q = \frac{-b_{n-1} \bar{c}_{n-1} + b_n c_{n-2}}{c_{n-2}^2 - \bar{c}_{n-1} c_{n-3}}$$

from which the recurrence relations

$$p_{i+1} = p_i + \frac{b_{n-1} c_{n-2} - b_n c_{n-3}}{c_{n-2}^2 - \bar{c}_{n-1} c_{n-3}}$$

$$q_{i+1} = q_i + \frac{-b_{n-1} \bar{c}_{n-1} + b_n c_{n-2}}{c_{n-2}^2 - \bar{c}_{n-1} c_{n-3}}$$

are obtained.

A method for guarding against loss of significance in the synthetic division process has been devised which consists of reversing the sequence of coefficients in the original polynomial (see the article by Kenneth W. Ellenberger in Communications of the ACM, Volume 3, Number 12, December 1960). In addition, the original coefficients of the polynomial are scaled by their geometric mean. This not only helps prevent numbers calculated from becoming too large for the capacity of the machine used, but also improves the rate of convergence.

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APPENDIX D -- PROGRAM LISTING FOR GRIPE II

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APPENDIX D -- PROGRAM LISTING FOR GRIPE II

On the following pages is a FORTRAN IV listing of the main program deck for GRIPE II. Not included, for brevity, are listings of the required subroutines. However, the listing presented should aid the reader in answering any specific questions with regard to calculations performed for which answers were not found in the text of this report.

GR1PE II ISN	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/J4/67	PAGE 1
U	SIBFTC	LIST		
C			0001	
C	GR1PE II	A PROGRAM TO ANALYZE PULSED NEUTRON DATA	0002	
C	FOR REACTIVITY AND INVERSE GENERATION TIME		0003	
C	N,C.KAUFMAN	IDAHO NUCLEAR CORPORATION JULY 1966	0004	
C			0005	
1	COMMON X(400,2),Y(400),W(400)		0006	
C			0007	
C			0008	
2	DIMENSION NSUR(5),IPAR(40),INDEX(40),JPAR(40),B(50),A(50,25),		0009	
1	PAR1(40),PVECT(40),B1(50),A1(50,25),SCAL(40),A2(25,25),C(40,40),		0010	
2	PAR2(40),PU(40),PL(40),EPS(40),S(3),AL(3),PARW(40),ALPNUM(2,40),		0011	
3	ALPW(2,40),SUMYP(40),SUMFP(40),TITLE(13)		0012	
3	DIMENSION COUNT(512),TMRX(50),AXL(8),TOT(8),ROT(8),SLTX(6)		0013	
4	INTEGER CONTW,CONTH		0014	
5	DIMENSION KXT(512),TMRX(512),XKT(512),ROLL(7)		0015	
6	DIMENSION XX(400),LABELX(2),LABELY(2)		0016	
7	CALL MOLCCT(SYM,12H750000000000)		0017	
10	CALL DATSUB(DATE)		0018	
11	CH=20		0019	
12	OL=14		0020	
13	NPLT=0		0021	
C			0022	
14	READ(5,822) MPP		0023	
16	READ(5,1226)ZFUS,ZEUSA		0024	
17	DN=0,0		0025	
20	DU 656 JKK=1,MPP		0026	
21	WRITE(6,701)		0027	
22	WZZK=0,0		0028	
23	READ(5,783)(KXXA,IPL0T,LFM,MPOC,KPO,LZLZ,KZKZ,VSLCT,WAPP)		0029	
37	IF(KXXA,GT,5)WZZK=1,0		0030	
42	IF(KXXA,GT,5)KXXA=KXXA-30		0031	
45	IF(KXXA,LE,1) DN=0,0		0032	
50	IF(KXXA,LE,1) GRXT=0,0		0033	
53	READ(5,706) NDP,PON,RSTX,TTB,PR,DLTA,WZAP		0034	
55	READ(5,520)NOCARD,(TITLE(I),I=1,13)		0035	
63	READ(5,1224)(LABELX,LABELY)		0036	
72	READ(5,707)(KXT(I),I=1,NDP)		0037	
77	IDENT=0,0		0038	
100	WRITE(6,528)(TITLE(I),I=1,13)		0039	
105	TIME=0,0		0040	
106	WRITE(6,704)		0041	
107	GW=DLTA		0042	
110	SST=TTB/2,0		0043	
111	DO 708 IR=1,NDP		0044	
112	IDENT=IDENT+1		0045	
113	XKT(IDENT)=KXT(IDENT)		0046	
114	TIME=TIME+TTB		0047	
115	TMRX(IDENT)=TIME-SST		0048	
116	CONTINUE		0049	
120	WRITE(6,709)((IDENT,TMRX(IDENT),XKT(IDENT)),IDENT=1,NDP)		0050	
131	DO 98 IB=1,NDP		0051	
132	COUNT(IB)=XKT(IB)		0052	
133	98 CONTINUE		0053	
C			0054	

ISN	SOURCE STATEMENT	
C	TEST COUNT FOR MISSING DATA AND LINEAR INTERPOLATION	0055
C		0056
135	IF(KXXA.EQ.1)GO TO 99	0057
140	DO 603 IB=1,NDP	0058
141	IF(COUNT(IB).EQ.0,0) GO TO 604	0059
144	GO TO 754	0060
145	604 KNS=1	0061
146	J=IB	0062
147	608 JA=J *KNS	0063
150	IF(COUNT(JA).EQ.0,0) GO TO 606	0064
153	GO TO 607	0065
154	606 KNS=KNS+1	0066
155	GO TO 608	0067
156	607 KA=J*KNS	0068
157	LA=J-1	0069
160	IF(LA.EQ.0) GO TO 609	0070
163	GO TO 753	0071
164	609 REAM=0.0	0072
165	GO TO 611	0073
166	753 REAM= COUNT(LA)	0074
167	611 CONTINUE	0075
170	BAG= COUNT(KA)+REAM	0076
171	RUT=KNS+1	0077
172	SAK = BAG/RUT	0078
173	DO 612 IG=1,KNS	0079
174	IX=J-1+IG	0080
175	IT=J-2+IG	0081
176	SIT=IG	0082
177	IF(IT.EQ.0) GO TO 613	0083
202	COUNT(IX)=COUNT(IT) + (SIT*SAK)	0084
203	GO TO 614	0085
204	613 COUNT(IX) = SIT*SAK	0086
205	614 CONTINUE	0087
206	612 CONTINUE	0088
210	754 CONTINUE	0089
211	603 CONTINUE	0090
213	DO 601 IB=1,NDP	0091
214	XKT(IB)=COUNT(IB)	0092
215	601 CONTINUE	0093
217	99 CONTINUE	0094
C		0095
C	RESOLUTION CORRECTION	0096
C		0097
220	IF(KXXA.LE.1) GO TO 781	0098
223	LSOB=MPOC	0099
224	GO TO 782	0100
225	781 LSOB=NDP	0101
226	782 CONTINUE	0102
227	DO 722 LXX=1,LSOB	0103
230	ART=XKT(LXX)/(DLTA+PON)	0104
231	IF(ART.GT.0.0)GO TO 726	0105
234	ART=0.0	0106
235	726 ARTXX=(ART/(1.0-ART*RSTX))	0107
236	XKT(LXX)=(ARTXX*DLTA+PON)	0108
237	722 CONTINUE	0109

ISN	SOURCE STATEMENT	
C		0110
C	CALCULATE MEAN MPOC TO KPO	0111
C		0112
241	TUZA=1.0	0113
242	SHAM=10000.0	0114
243	TAXY=10000.0	0115
244	CKAR=10000.0	0116
245	712 IF(MPOC,GE,KPO) GO TO 788	0117
250	EANY=TAXY	0118
251	RACK=CKAR	0119
252	IF(KXXA,EO.1) GO TO 536	0120
255	IF(TUZA,GT.1.0)MPOC=MPOC*10	0121
260	IF(MPOC,LE.0) GO TO 527	0122
263	536 CONTINUE	0123
264	CON=0.0	0124
265	NUR=0	0125
266	DO 714 NOK=MPOC,KPO	0126
267	IF(NOK,GT,NDP)GO TO 714	0127
272	NUR=NUR+1	0128
273	CON=CON+XKT(NOK)	0129
274	714 CONTINUE	0130
276	RUPX=NUR	0131
277	TAXY=CON/RUPX	0132
C		0133
C	VARIANCE CALCULATION MPOC TO KPO	0134
C		0135
300	RAIN=0.0	0136
301	DO 719 ITH=MPOC,KPO	0137
302	IF(ITH,GT,NDP)GO TO 719	0138
305	RAIN=((ABS(XKT(ITH)-TAXY))*2.0) * RAIN	0139
306	719 CONTINUE	0140
310	CKAR=SQRT(RAIN/(RUPX-1.0))	0141
311	IF(KXXA,EO.1) GO TO 717	0142
314	IF(TUZA,EO.2.0)SHAM=1.005*RACK	0143
317	TUZA=TUZA+1.0	0144
320	IF(CKAR,LT,SHAM) GO TO 712	0145
323	527 CONTINUE	0146
324	HXLXT=EANY	0147
325	HSLST=RACK	0148
326	MPOC=MPOC*10	0149
327	GO TO 721	0150
330	717 RACK=CKAR*WAPP/GW	0151
331	EANY=TAXY*WAPP/GW	0152
332	VXLXT=EANY	0153
333	VSLST=RACK	0154
334	721 CONTINUE	0155
C		0156
335	KPPA=KPO-MPOC	0157
336	SUSXT=KPPA	0158
337	IF(KXXA,EO.1) SKKPA=SUSXT	0159
342	SUSXX=SQRT(SUSXT*1.0)	0160
343	SXRT=RACK/SUSXX	0161
344	GRXX=SQRT((SXRT**2.0)*(GRXT**2.0))	0162
345	GRXT=GRXX	0163
346	GO TO 789	0164

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ISN		SOURCE STATEMENT		
347	788	EANY=0,0	0165	
350	789	DO 793 LKXX=1,NDP	0166	
351		XKT(LKXX)=XKT(LKXX)-EANY	0167	
352	793	CONTINUE	0168	
354	713	CONTINUE	0169	
355		DN=EANY-DN	0170	
356		IF(KXXA,EO,1) GO TO 656	0171	
	C		0172	
	C	TAKE LOG OF APPROPRIATE DATA	0173	
	C		0174	
361		NFL=NDP-LFM	0175	
362		IF(NFL,GT,400)GO TO 688	0176	
365		GO TO 687	0177	
366	688	NDP=400+LFM	0178	
367	687	CONTINUE	0179	
370		RACK=VSLCT+RACK	0180	
371	736	DO 739 JXN=LFM,NDP	0181	
372		LPS=JXN-LFM+1	0182	
373		X(LPS,1)=TMRX(JXN)	0183	
374		Y(LPS)=XKT(JXN)	0184	
375		IF(Y(LPS),LE,RACK) GO TO 901	0185	
400		W(LPS)=(XKT(JXN)**2,0)/(XKT(JXN) +W(LST*(HSLST**2,0))	0186	
401		Y(LPS)=ALOG(Y/LPS))	0187	
402	739	CONTINUE	0188	
	C		0189	
	C	SET PARAMETERS FOR FIT	0190	
	C		0191	
404	901	NDP=JXN-1	0192	
405		NFL=NDP-LFM	0193	
406		WRITE(6,500)	0194	
407		VARX=0,0	0195	
410		SUIT=0,0	0196	
411		NODATA=NFL	0197	
412		GO TO 814	0198	
413	811	SUIT=PAR1(2)	0199	
414		VARX=SWEET	0200	
415		SXM=SIG**2,0	0201	
416		RA3=RA2	0202	
417		ATYLE=PAR1(1)	0203	
420		NODATA=NODATA-KZKZ-LZLZ	0204	
421		IF(NODATA,LE,1)WRITE(6,501)	0205	
424		IF(NODATA,LE,1)GO TO 656	0206	
427		DO 813 LKXX=1,NODATA	0207	
430		LJXX=LKXX+LZLZ	0208	
431		X(LKXX,1)=X(LJXX,1)	0209	
432		Y(LKXX)=Y(LJXX)	0210	
433		W(LKXX)=W(LJXX)	0211	
434	813	CONTINUE	0212	
436		AUFK=VARX/SUIT	0213	
437		AUFK=ABS(AUFK)	0214	
440	814	CONTINUE	0215	
441		PAR1(1)=0,0	0216	
442		PAR1(2)=0,0	0217	
443		N=2	0218	
444		NOXI=1	0219	

GR1PE II	SOURCE STATEMENT		FORTRAN SOURCE LIST	04/04/67	PAGE 5
ISN					
445		ROPY= ROPEX		0220	
446		POLKY= POLKX		0221	
447		LOGX=0		0222	
450		LOGY=0		0223	
451		XL=7.0		0224	
452		XMIN=0.0		0225	
453		XMAX=0.0		0226	
454		YL=5.0		0227	
455		YMIN=0.0		0228	
456		YMAX=0.0		0229	
457		NSUB(1)=0		0230	
460		NSUB(2)=0		0231	
461		NSUB(3)=0		0232	
462		NSUB(4)=0		0233	
463		NSUB(5)=0		0234	
464		JPAR(1)=1		0235	
465		JPAR(2)=1		0236	
466		PL(1)=0.0		0237	
467		PL(2)=-1000000.0		0238	
470		PU(1)=1000.0		0239	
471		PU(2)=0.0		0240	
	C			0241	
	C	BEGIN FIT FOR ALPHA		0242	
	C			0243	
472	405	IP=0		0244	
473		DO 410 I=1,N		0245	
474		IF (IPAR(I).NE.1) GO TO 410		0246	
477		IP=IP+1		0247	
500		INDEX(IP)=I		0248	
501	410	JPAR(I)=IPAR(I)		0249	
503		JP=IP		0250	
504		DEFER=NODATA-IP		0251	
505		ITERAT=1		0252	
506	415	ISWICH=0		0253	
507		LAST=1		0254	
510	420	ITST1=0		0255	
511		ITST2=0		0256	
	C			0257	
	C	ZERO OUT MATRIX AREAS		0258	
	C			0259	
512		DO 425 J=1,JP		0260	
513		B(J)=0.0		0261	
514		DO 425 I=1,JP		0262	
515	425	A(I,J)=0.0		0263	
	C			0264	
	C	COMPUTE THE NORMAL EQUATIONS		0265	
	C			0266	
520		DO 445 I=1,NODATA		0267	
521		CALL FCN(N,NSUB,ITST1,ITST2,NOXI,I,JPAR,PAR1,F,PVECT)		0268	
522		IF (ITST1.EQ.0) ITST1=1		0269	
525		RES=Y(I)		0270	
526		DO 445 M1=1,JP		0271	
527		B(M1)=B(M1)+W(I)*RES+PVECT(M1)		0272	
530	435	DO 445 N1=M1,JP		0273	
531		A(M1,N1)=A(M1,N1)+W(I)*PVECT(M1)*PVECT(N1)		0274	

ISN	SOURCE STATEMENT	
532	445 CONTINUE	0275
	C	0276
536	K=JP-1	0277
537	DO 450 N1=1,K	0278
540	J=N1+1	0279
541	DO 450 M1=J,JP	0280
542	450 A(M1,N1)=A(N1,M1)	0281
	C	0282
	C	0283
	C	0284
	SCALE THE NORMAL EQUATIONS AND SAVE MATRICES FOR LAST ITER,	
545	DO 455 N1=1,JP	0285
546	B1(N1)=B(N1)	0286
547	DO 455 M1=1,JP	0287
550	455 A1(M1,N1)=A(M1,N1)	0288
553	600 DO 605 I=1,JP	0289
554	605 SCAL (I)=SQRT(A(I,I))	0290
556	DO 610 J=1,JP	0291
557	B(J)=B(J)/SCAL (J)	0292
560	DO 610 I=1,JP	0293
561	610 A(I,J)=A(I,J)/(SCAL (I)*SCAL (J))	0294
564	DO 615 J=1,JP	0295
565	DO 615 I=1,JP	0296
566	615 A2(I,J)=A(I,J)	0297
	C	0298
	C	0299
	C	0300
	COMPUTE INVERSE MATRIX AND CORRECTIONS TO PARAMETERS	
571	650 CALL MAINS(A,JP,B,1,DET,IFS)	0301
572	IF(IFS,NE,0)GO TO 655	0302
575	WRITE(6,501)	0303
576	GO TO 811	0304
577	655 IF(LAST,EO,0)GO TO 660	0305
602	CALL MAMPY(A,JP,JP,A2,JP,C)	0306
603	DO 657 J=1,JP	0307
604	DO 657 I=1,JP	0308
605	657 A(I,J)=A(I,J)/(SCAL (I)*SCAL (J))	0309
610	660 DO 665 J=1,JP	0310
611	665 B(J)=B(J)/SCAL (J)	0311
613	1019 DO 1030 J=1,JP	0312
614	I=INDEX(J)	0313
615	PAR1(I)=PAR1(I)+B(J)	0314
616	IF(PAR1(I)+PU(I))1025,1030,1020	0315
617	1020 PAR1(I)=PU(I)	0316
620	GO TO 1030	0317
621	1025 IF(PAR1(I).GE.PL(I))GO TO 1030	0318
624	PAR1(I)=PL(I)	0319
625	1030 CONTINUE	0320
627	ITST1=0	0321
630	ITST2=1	0322
631	SUM=0.0	0323
632	RA2 =0.0	0324
633	ITST2=0	0325
634	DO 1040 J=1,JP	0326
635	SUMYP(J)=0.0	0327
636	1040 SUMFP(J)=0.0	0328
640	1045 DO 1070 I=1,NODATA	0329

GRUPE II	ISN	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/04/67	PAGE 7
	641	CALL FCN(N,NSUB,ITST1,ITST2,NOXI,I,JPAR,PAR1,F,PVECT)		0331	
	642	IF(ITST1,EQ,0) ITST1=1		0331	
	645	RES=Y(I)-F		0332	
	646	SUM=SUM+W(I)*RES*RES		0333	
	647	RA5=(ABS(EXP(Y(I))-EXP(F)))*2,0		0334	
	650	IF(WZZK,NE,2,)RA2=RA2+(RA5)/(HXLXT*EXP(F))		0335	
	653	RA4=PASIT*EXP(-DCYT*X(I,1))		0336	
	654	IF(WZZK,EQ,2,)RA2=RA2+(RA5)/(HXLXT*EXP(F)+RA4)		0337	
	657	DO 1065 J=1,JP		0338	
	660	SUMYP(J)=SUMYP(J)+W(I)*Y(I)*PVECT(J)		0339	
	661	SUMFP(J)=SUMFP(J)+W(I)*F*PVECT(J)		0340	
	662 1065	CONTINUE		0341	
	664 1070	CONTINUE		0342	
	666	SIG=SQRT(SUM/DFR)		0343	
	667	TOY=SIG		0344	
	C			0345	
	C	OUTPUT FINAL VALUES AFTER ALPHA TEST		0346	
	C			0347	
	670 1100	SWEET=TOY*SORT(A(2,2))		0348	
	671	POLKX= A(1,1)*TOY*TOY		0349	
	672	ROPEX= A(2,1)*TOY*TOY		0350	
	673	XAP=ABS(PAR1(2)-SUIT)		0351	
	674	IF(WZZK,EQ,2,0)GO TO 4771		0352	
	677	WRITE(6,812)XAP,SWEET		0353	
	700 4771	CONTINUE		0354	
	701	IF(XAP,GT,SWEET) GO TO 811		0355	
	704	IF(SWEET,LT,VARX)GO TO 811		0356	
	707	ZLLZ=LZLZ		0357	
	710	SKKPP=NODATA+LZLZ+KZKZ		0358	
	711	LZZL=X(1,1)/TTB		0359	
	712	LZZL=IABS(LZZL-LFM)		0360	
	713	TAU=X(1,1)-(LZZL+TTB)		0361	
	714	LBXR=0		0362	
	C			0363	
	C	BEGIN PLOT PACKAGE		0364	
	C			0365	
	715 2135	LBXR=LBXR+1		0366	
	716	IF(LBXR,EQ,1) GO TO 2132		0367	
	721	IF(LBXR,EQ,2) GO TO 2133		0368	
	724	IF(LBXR,EQ,3) GO TO 10		0369	
	727 2133	NODATA=NODATA +LFM +(LZZL/LZLZ)*(LZLZ+KZKZ)		0370	
	730	IF(WZZK,EQ,2,0)GO TO 4772		0371	
	733	DO 2136 JX=1,NODATA		0372	
	734	X(JX,1)=TMRX(JX)		0373	
	735	IF(XKT(JX),LE,0,0) Y(JX)=0,0		0374	
	740	IF(XKT(JX),LE,0,0) GO TO 2136		0375	
	743	Y(JX)=ALOG(XKT(JX))		0376	
	744 2136	CONTINUE		0377	
	746	PAR1(2)=SUIT		0378	
	747	PAR1(1)=ATTLE		0379	
	750	GO TO 2132		0380	
	751 4772	CONTINUE		0381	
	752	DO 4773 JX=1,NODATA		0382	
	753	X(JX,1)=TMRX(JX)		0383	
	754	Y(JX)=XKT(JX)-PASIT*EXP(-DCYT*TMRX(JX))		0384	

GRIDE II	ISN	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/04/67	PAGE 8
	755	IF(Y(JX),LE.0.0)GO TO 3334		0385	
	760	GO TO 3337		0386	
	761	3334 Y(JX)=0.0		0387	
	762	GO TO 4773		0388	
	763	3337 CONTINUE		0389	
	764	Y(JX)=ALOG(Y(JX))		0390	
	765	4773 CONTINUE		0391	
	C			0392	
	767	PAR1(2)=SUIT		0393	
	770	PAR1(1)=ATTLE		0394	
	771	2132 CONTINUE		0395	
	772	IF(IPL0T,EO.0)GO TO 10		0396	
	775	NPL0T=0		0397	
	776	MAXX=0		0398	
	777	MAXY=0		0399	
	1000	IF(XMIN,EO.0,0.AND,XMAX,EO.0,0)MAXX=1		0400	
	1003	IF(YMIN,EO.0,0.AND,YMIN,EO.0,0)MAXY=1		0401	
	1006	CALL PLOTS(0,,,-11,,,-3)		0402	
	1007	310 XFCN=X(1,1)		0403	
	1010	XEND=X(1,1)		0404	
	1011	DO 315 J=2,NODATA		0405	
	1012	IF(XFCN,GT,X(J,1))XFCN=X(J,1)		0406	
	1015	315 IF(XEND,LT,X(J,1))XEND=X(J,1)		0407	
	1021	IF(MAXX,EO.0)GO TO 316		0408	
	1024	XMIN=XFCN		0409	
	1025	XMAX=XEND		0410	
	1026	GO TO 317		0411	
	1027	316 IF(XFCN,LT,XMIN)XMIN=XFCN		0412	
	1032	IF(XEND,GT,XMAX)XMAX=XEND		0413	
	1035	317 YYMIN=Y(1)		0414	
	1036	YYMAX=Y(1)		0415	
	1037	DO 320 J=2,NODATA		0416	
	1040	IF(YYMIN,GT,Y(J))YYMIN=Y(J)		0417	
	1043	320 IF(YYMAX,LT,Y(J))YYMAX=Y(J)		0418	
	1047	IF(MAXY,EO.0)GO TO 321		0419	
	1052	YMIN=YYMIN		0420	
	1053	YMAX=YYMAX		0421	
	1054	GO TO 322		0422	
	1055	321 IF(YYMIN,LT,YMIN)YMIN=YYMIN		0423	
	1060	IF(YYMAX,GT,YMAX)YMAX=YYMAX		0424	
	1063	322 IF(LOGX,EO.0)DX=(XMAX-XMIN)/XL		0425	
	1066	IF(LOGY,EO.0)DY=(YMAX-YMIN)/YL		0426	
	1071	YLL=YL+1		0427	
	1072	IF(NPLT,GT,0)GO TO 325		0428	
	1075	CALL PLTJOB(0,,1,)		0429	
	1076	NPLT=1		0430	
	1077	325 CALL SYMBL4(,5,1,,CL,TITLE,90,,78)		0431	
	1100	CALL SYMBL4(,1,,1,,CL,DATE ,90,,6)		0432	
	1101	IF(LOGY,EO.0)CALL PLOT(2,,1,5,-3)		0433	
	1104	335 IF(LOGY,EO.0)CALL AXIS(0,,,-1,,LABELX,12,XL,0,,XMIN,DX,-2)		0434	
	1107	345 CALL AXIS(0,,,-1,,LABELY,12,YL+2,,90,,YMIN,DY,-2)		0435	
	1110	350 DO 355 J=1,NODATA		0436	
	1111	IF(LOGX,EO.0)XX(J)=(X(J,1)-XMIN)/DX		0437	
	1114	IF(LOGY,EO.0)Y(J)=(Y(J)-YMIN)/DY		0438	
	1117	355 CALL SYMBL4(XX(J),Y(J),CH,SYM,0,,1)		0439	

GRIPE II		FORTRAN SOURCE LIST	04/04/67	PAGE 9
ISN	SOURCE STATEMENT			
1121	ITST1=0		0440	
1122	ITST2=1		0441	
1123	I=1		0442	
1124	DELTA X=DX/20,		0443	
1125	360 X(1,1)=XFCN		0444	
1126	CALL FCN(N,NSUB,ITST1,ITST2,NOXI,I,JPAR,PAR1,F,PVECT)		0445	
1127	IF(ITST1.EQ.0)ITST1=1		0446	
1132	XP=(X(1,1)-XMIN)/DX		0447	
1133	YP=(F-YMIN)/DY		0448	
1134	IF(YP.LT.(-1.0))YP=-1.0		0449	
1137	IF(YP.GT.YLL)YP=YLL		0450	
1142	IF(NPLOT.NE.0)GO TO 365		0451	
1145	CALL PLOT(XP,YP,3)		0452	
1146	NPLOT=1		0453	
1147	GO TO 370		0454	
1150	365 CALL PLOT(XP,YP,2)		0455	
1151	370 XFCN=XFCN+DELTA X		0456	
1152	IF(XFCN.GT.XEND)GO TO 375		0457	
1155	GO TO 360		0458	
1156	375 CALL PLOT(XL+5.,0.,-3)		0459	
1157	GO TO 2135		0460	
C			0461	
C	FORMAT STATEMENTS		0462	
C			0463	
1160	500 FORMAT(1H150X30H*** ITERATION CALCULATIONS ***)		0464	
1161	501 FORMAT(48H INSUFFICIENT DATA DEFINING EXPONENTIAL)		0465	
1162	520 FORMAT(11,1X13A6)		0466	
1163	528 FORMAT(1H026X13A6)		0467	
1164	701 FORMAT(1H1,40X,21HANALYZER DATA LISTING)		0468	
1165	704 FORMAT(1H0,3(3X,5HIDENT,7X,4HTIME,9X,4HDATA,6X)///)		0469	
1166	706 FORMAT(15,6E10,5)		0470	
1167	707 FORMAT(8(16,1X))		0471	
1170	709 FORMAT(3(110,2E14,7))		0472	
1171	783 FORMAT(715,2E10,5)		0473	
1172	812 FORMAT(1H0,13HTEST ON ALPHA,3X,4HDIFF,3X,E14,7,13H AND STD DEV ,3		0474	
	1X,E14,7)		0475	
1173	822 FORMAT(15)		0476	
1174	1124 FORMAT(1H0,3X,19HWARNING C X TAU IS,F6.3,3X,20HCONVERGENCE IN DO		0477	
	1UBT)		0478	
1175	1211 FORMAT(1H1,50X,18HGRIPE II ANALYSIS)		0479	
1176	1212 FORMAT(1H0,10X,16HINPUT PARAMETERS)		0480	
1177	1213 FORMAT(1H0,15X,10HRATE WIDTH,7X,F14,8,24X,10HTIME BASE ,11X,F14,8)		0481	
1200	1214 FORMAT(1H0,15X,10HPULSE RATE,7X,F14,8,24X,10HPULSE NO. ,11X,F14,8)		0482	
1201	1216 FORMAT(1H0,15X,14HRESOLVING TIME,3X,F14,8,24X,8HTAU EST ,15X,14,2		0483	
	1X//16X,11HFRONT SUR ,8X,14,32X,8HBACK SUB,15X,14)		0484	
1202	1217 FORMAT(1H0,10X,13HDATA ANALYSIS)		0485	
1203	1218 FORMAT(1H0,15X,14HDECAY CONSTANT,9X,F14,8,18X,13HONE STD. DEV.,7X		0486	
	1,F14,8//16X,16HDELAY BACKGROUND,7X,E14,8,18X,13HONE STD. DEV.,7X,E		0487	
	214,8)		0488	
1204	1219 FORMAT(1H0,15X,19HTIME TO REACH DECAY,4X,F14,8,18X,16HCHI SQ. FOR		0489	
	1 FIT ,4X,F14,8//16X,15HTZERO INTERCEPT,8X,E14,8,18X,15HDEG. OF FRE		0490	
	2EDOM,5X,F14,0//16X,21HMEAN VALUE PULSE BACK,2X,F14,8,18X,20HMEAN V		0491	
	3ALUE REAC BACK,F14,8//16X,13HCHI SQUARE ,10X,F14,8,18X,13HCHI SQ		0492	
	4UARE ,7X,F14,8//16X,15HDEG. OF FREEDOM,8X,F14,0,18X,15HDEG. OF F		0493	
	5HEDOM,5X,F14,0//)		0494	

GRUPE II	ISN	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/04/67	PAGE 10
1205	1221	FORMAT(1H0,10X,12HFINAL VALUES)		0495	
1206	1222	FORMAT(1H0,15X,10H(THERE WAS,15,4X,14HROOT POSSIBLE))		0496	
1207	1223	FORMAT(1H0,18X,19HDOLLARS SUBCRITICAL,7X,F14,8,12X,14HINV. GEN, T		0497	
		1ME,9X,F14,8)		0498	
1210	1226	FORMAT(6X,E14,7,6X,E14,7)		0499	
1211	1229	FORMAT(1H0,18X,22HONE STANDARD DEVIATION,4X,F14,8,12X,22HONE STAN		0500	
		DARD DEVIATION,1X,F14,8//)		0501	
1212	1224	FORMAT(2A6,8X,2A6)		0502	
1213	4881	FORMAT(1H0,10X,18HSECOND EXPONENTIAL//16X,22HSECOND DECAY CONSTAN		0503	
		1T,3X,F14,8,15X,13HONE STD. DEV.,5X,F14,8//16X,16HSECOND INTERCEPT		0504	
		2,9X,E14,8,15X,13HONE STD. DEV.,5X,E14,8//16X,15HCHI SQ. FOR FIT,10		0505	
		3X,F14,8,15X,15HDEG. OF FREEDOM,3X,F14,0)		0506	
1214	4882	FORMAT(1H0,15X,25HEXTRAPOLATED-AREA-RATIO //18X,19HDOLLARS SUBCR		0507	
		ITICAL,7X,F14,8,12X,14HINV. GEN. TIME,9X,F14,8//18X,22HONE STANDAR		0508	
		2D DEVIATION,4X,F14,8,12X,22HONE STANDARD DEVIATION,1X,F14,8)		0509	
1215	4883	FORMAT(1H0,10X,40H ONE EXPONENTIAL ANALYSIS WAS REQUESTED)		0510	
1216	4884	FORMAT(1H0,10X,40H TWO EXPONENTIAL ANALYSIS WAS REQUESTED)		0511	
1217	4886	FORMAT(1H0,15X,15HGARELIS=RUSSELL)		0512	
	C			0513	
	C	SUMMARIZE DATA ANALYSIS AND PERFORM E.A.R.METHOD CALCULATION		0514	
	C			0515	
1220	10	CONTINUE		0516	
1221		ALFA=ABS(SUIT)		0517	
1222		IF(WZZK.E0.2,0)GO TO 4779		0518	
1225		GW=DLTA		0519	
1226		STAR=EXP(ATTLE)		0520	
1227		PASIT=STAR		0521	
1230		DCYT=ALFA		0522	
1231		STAR=STAR/GW		0523	
1232		ROPYE= STAR*ROPYE		0524	
1233		POLKY= POLKY*STAR*STAR		0525	
1234		DN=ABS(DN)		0526	
1235		CNTX=(GRXT/DN)		0527	
1236		DN=DN/GW		0528	
1237		GRXT=DN*CNTX		0529	
1240		VARX=ALFA*AUFK		0530	
1241		RORRD=0,0		0531	
1242		RORRE=0,0		0532	
1243		NSC=0		0533	
1244		HSLST=(HSLST**2,0)*SUSXT/HXLXT		0534	
1245		IF(VXLXT,LE.0,0)GO TO 4119		0535	
1250		VSLST=(VSLST**2,0)*SKKPA/VXLXT		0536	
1251	4119	CONTINUE		0537	
1252		IF(SKKPP,GT,2,0) SXH=SXM*(SKKPP-2,0)		0538	
1255		IF(SKKPP,GT,2,0)SKKPP=SKKPP-2,0		0539	
1260		RORR=0,0		0540	
1261		WRITE(6,1211)		0541	
1262		WRITE(6,1212)(TITLE(I),I=1,13)		0542	
1267		WRITE(6,1212)		0543	
1270		WRITE(6,1213) DLTA,TTB		0544	
1271		WRITE(6,1214) PR,PON		0545	
1272		WRITE(6,1216)RSTX,LFM,LZLZ,KZKZ		0546	
1273		WRITE(6,1217)		0547	
1274		WRITE(6,1218) ALFA,VARX,DN,GRXT		0548	
1275		WRITE(6,1219)TAU,RAJ,STAR,SKKPP,HXLXT,VXLXT,HSLST,VSLST,SUSXT,SKK		0549	

GRUPE II	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/04/67	PAGE 11
ISN				
	1PA		0550	
1276	IF(KXXA,EO,0) GO TO 654		0551	
1301	WRITE(6,1221)		0552	
1302	DN=DN*WZAP		0553	
1303	EXARM=(PR*STAR)/(ALFA*DN)		0554	
1304	DXAR=SQRT((AUFK**2,0)+(POLKY/(STAR**2,0))*2.0*ROPYE/(STAR*ALFA))		0555	
1305	DXAR=SQRT((CNTX**2,0)+(DXAR**2,0))		0556	
1306	DEXAR=EXARM*DXAR		0557	
1307	GENNI=ALFA/(1.0+EXARM)		0558	
1310	DGENN=(AUFK**2,0)*((DEXAR/(EXARM+1,0))**2,0)		0559	
1311	DGENN=DGENN+2.0*(EXARM/(EXARM+1,0))*(AUFK**2,0)		0560	
1312	DGENN=DGENN+2.0*(EXARM/(EXARM+1,0))*ROPYE/(STAR*ALFA)		0561	
1313	DGENN=GENNI*SQRT(DGENN)		0562	
1314	WRITE(6,4882) EXARM,GENNI,DEXAR,DGENN		0563	
	C		0564	
	C	BEGIN GARELIS-RUSSELL ANALYSIS	0565	
	C		0566	
1315	MOSE=TAU/TTB		0567	
1316	KAN= MOSE/2.0		0568	
1317	KANDO =(KAN*2)+1		0569	
1320	DO 602 IA=1,KANDO		0570	
1321	TIMR(IA)=TIMRX(IA)		0571	
1322	COUNT(IA)=XKT(IA)		0572	
1323	002 CONTINUE		0573	
1325	DO 968 IB=1,KANDO		0574	
1326	COUNT(IB) = COUNT(IB)/GW		0575	
1327	968 CONTINUE		0576	
1331	TIR=TIMR(KANDO)		0577	
1332	SSN =EXP(*ALFA*TIR)		0578	
	C		0579	
	C	BEGIN NUMERICAL INTEGRATIONS	0580	
	C		0581	
1333	LX= KANDO-1		0582	
1334	DO 616 IXT=1,5		0583	
1335	TX=IXT		0584	
1336	KB=1		0585	
1337	TOT(IXT)= COUNT(KB)*(TIMR(KB)**TX)		0586	
1340	617 KB=KB+1		0587	
1341	TOT(IXT)=TOT(IXT)+4.0*COUNT(KB)*(TIMR(KB)**TX)		0588	
1342	IF(KB,EO,LX)GO TO 618		0589	
1345	KB=KB+1		0590	
1346	TOT(IXT)=TOT(IXT)+2.0*COUNT(KB)*(TIMR(KB)**TX)		0591	
1347	GO TO 617		0592	
1350	618 KB=KB+1		0593	
1351	TOT(IXT)=TOT(IXT)+COUNT(KB)*(TIMR(KB)**TX)		0594	
1352	ROT(IXT)=((TOT(IXT)*TTB)/3.0)		0595	
1353	ROT(IXT)=ROT(IXT)+((COUNT(1)*((TTB/4.0)**TX)*TTB)/8.0)		0596	
1354	616 CONTINUE		0597	
1356	NSC=NSC+1		0598	
1357	MXT=0		0599	
	C		0600	
	C	COMPUTE COEFFICIENTS	0601	
	C		0602	
1360	AXL(1)= -(ROT(5)/120.0)		0603	
1361	AXL(2)=(ALFA*ROT(5)/120.0)-(ROT(4)/24.0)		0604	

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	1362	AXL(2)=AXL(2)+(STAR*(TIR**5,0)*SSN/120,0)	0605	
	1363	AXL(3)=(ALFA*ROT(4)/24,0)-(ROT(3)/6,0)	0606	
	1364	AXL(3)=AXL(3)+(STAR*(TIR**4,0)*SSN/24,0)	0607	
	1365	AXL(4)=(ALFA*ROT(3)/6,0)-(ROT(2)/2,0)	0608	
	1366	AXL(4)=AXL(4)+(STAR*(TIR**3,0)*SSN/6,0)	0609	
	1367	AXL(5)=(ALFA*ROT(2)/2,0)-(ROT(1))	0610	
	1370	AXL(5)=AXL(5)+(STAR*(TIR**2,0)*SSN/2,0)	0611	
	1371	AXL(6)=(ALFA*ROT(1))+(STAR*TIR*SSN)+(STAR*SSN/ALFA)+(DN/PR)	0612	
	1372	AXL(7)=-(DN*ALFA/PR)	0613	
C			0614	
C		DOUBLE PRECISION POLYANNA	0615	
C		BASIC NEWTON AND BAIRSTOW ITERATIVE METHODS ARE USED TO DETERMINE	0616	
C		THE ROOTS OF N-TM DEGREE POLYNOMIAL EQUATION.	0617	
C			0618	
	1373	DOUBLE PRECISION T(100),G(100),Z(100),E(100),U(100),V(100),	0619	
	1	H(100),CONVK,PS,OS,P8,OT,SS,R,SN,P,0,D(100)	0620	
	1374	DOUBLE PRECISION DSORT,DLOG,DEXP,DABS	0621	
	1375	DIMENSION DATE(2),CONV(100)	0622	
C			0623	
C		READ IN DEGREE OF POLYNOMIAL,COEFFICIENTS,NO. OF SIGNIFICANT	0624	
C		FIGURES DESIRED,AND NUMBER OF ITERATIONS TO BE ALLOWED.	0625	
C			0626	
	1376	N=6	0627	
	1377	NF=14	0628	
	1400	NUMIT=20	0629	
	1401	M=N+3	0630	
	1402	N1=N	0631	
	1403	M1=M	0632	
	1404	DO 651 J=3,9	0633	
	1405	IMPX=1-2	0634	
	1406	H(1)=AXL(IMPX)	0635	
	1407	651 CONTINUE	0636	
	1411	DO 1 J=1,2	0637	
	1412	T(J)=0,0	0638	
	1413	G(J)=0,0	0639	
	1414	1 Z(J)=0,0	0640	
	1416	D(2)=0,0	0641	
	1417	E(2)=0,0	0642	
	1420	DO 45 J=3,M	0643	
	1421	45 T(J)=H(J)/H(3)	0644	
	1423	NCHK=1	0645	
	1424	CONVK=10,**NF	0646	
C			0647	
C		TEST FOR ZERO COEFFICIENTS BEGINNING WITH THE CONSTANT TERM.	0648	
C		ADJUST THE ORDER OF THE POLYNOMIAL ACCORDINGLY.	0649	
C			0650	
	1425	4 IF(T(M).NE.0,0) GO TO 3	0651	
	1430	U(M)=0,0	0652	
	1431	V(M)=0,0	0653	
	1432	CONV(M)=CONVK	0654	
	1433	M=M-1	0655	
	1434	N=N-1	0656	
	1435	GO TO 4	0657	
	1436	3 CONTINUE	0658	
	1437	200 IF(M.E0,3)GO TO 101	0659	

GRIPE II

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ISN	SOURCE STATEMENT	
C		0660
C	INITIALIZE	0661
C		0662
1442	PS=0.0	0663
1443	QS=0.0	0664
1444	PS=0.0	0665
1445	QT=0.0	0666
1446	SS=0.0	0667
1447	REV=1.0	0668
1450	CONVK=10.0*NF	0669
1451	IF(M,NE,4)GO TO 2	0670
1454	R=(T(4)/T(3))	0671
1455	GO TO 90	0672
C		0673
C	SCALE COEFFICIENTS BY THEIR GEOMETRIC MEAN	0674
C		0675
1456	2 DO 5 J=3,M	0676
1457	IF(T(J),EQ,0.0) GO TO 5	0677
1462	SS= SS+DLUG(DABS(T(J)))	0678
1463	5 CONTINUE	0679
1465	SNRN=1	0680
1466	SS=SS/SN	0681
1467	SS=DEXP(SS)	0682
1470	DO 6 J=3,M	0683
1471	6 T(J)=T(J)/SS	0684
C		0685
C	REVERSE THE COEFFICIENTS IF NECESSARY,	0686
C		0687
1473	IF (DABS(T(4)/T(3)),GE,DABS(T(M-1)/T(M))) GO TO 7	0688
1476	41 NCHEK=NCHEK	0689
1477	NSUS=(M-1)/2	0690
1500	DO 40 J=1,NSUS	0691
1501	JIMP=J+2	0692
1502	JSUN=M-J+1	0693
1503	SS=T(JIMP)	0694
1504	T(JIMP)=T(JSUN)	0695
1505	40 T(JSUN)=SS	0696
1507	7 CONTINUE	0697
1510	30 IF(QS,EQ,0.0)GO TO 8	0698
1513	P=PS	0699
1514	Q=QS	0700
1515	GO TO 80	0701
1516	8 CONTINUE	0702
C		0703
C	CALCULATE CORRECTION FOR P AND Q	0704
C		0705
1517	IF(T(M-2),EQ,0.) GO TO 9	0706
1522	Q=T(M)/T(M-2)	0707
1523	P=(T(M-1)-Q*T(M-3))/T(M-2)	0708
1524	GO TO 757	0709
1525	9 Q=1.000	0710
1526	P=-2.000	0711
1527	757 IF(M,EQ,5)GO TO 70	0712
1532	R=U	0713
C		0714

GRIDE II ISN	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/04/67	PAGE 14
C	BEGIN ITERATIONS,		0715	
C			0716	
1533	80 DO 11 I=1,NUMIT		0717	
C			0718	
C	BAIRSTON ITERATIVE PROCESS,		0719	
C			0720	
1534	DO 12 J=3,M		0721	
1535	G(J)=T(J)-P*G(J-1)-Q*G(J-2)		0722	
1536	12 Z(J)=G(J)-P*Z(J-1)-Q*Z(J-2)		0723	
1540	IF(T(M-1),EQ,0,0) GO TO 60		0724	
1543	IF(G(M-1),EQ,0,0) GO TO 60		0725	
C			0726	
C	TEST REMAINDER TERMS IN THE QUADRATIC DIVISION FOR SUFFICIENTLY		0727	
C	SMALL MAGNITUDES,		0728	
C			0729	
1546	IF(DABS(T(M-1)/G(M-1)),LT,CONVK) GO TO 50		0730	
1551	G(M)=T(M)-Q*G(M-2)		0731	
1552	60 CONTINUE		0732	
1553	IF(G(M),EQ,0,0) GO TO 70		0733	
1556	IF(CONVK,LT,DABS(T(M)/G(M))) GO TO 70		0734	
C			0735	
C	NEWTON ITERATIVE PROCESS,		0736	
C			0737	
1561	50 DO 13 J=3,M		0738	
1562	D(J)=T(J)+R*D(J+1)		0739	
1563	13 E(J)=D(J)+R*E(J+1)		0740	
C			0741	
C	TEST REMAINDER TERM IN LINEAR DIVISION,		0742	
C			0743	
1565	IF(D(M),EQ,0,0) GO TO 90		0744	
1570	IF(CONVK,LT,DABS(T(M)/D(M))) GO TO 90		0745	
C			0746	
C	COMPUTE THE CORRECTED VALUES FOR P,Q,R AND BEGIN ITERATION PROCESS		0747	
C	AGAIN,		0748	
C			0749	
1573	Z(M-1)=-P*Z(M-2)-Q*Z(M-3)		0750	
1574	SS=Z(M-2)*Z(M-2)-Z(M-1)*Z(M-3)		0751	
1575	IF(SS,EQ,0,0) GO TO 14		0752	
1600	P=P*(G(M-1)*Z(M-2)-G(M)*Z(M-3))/SS		0753	
1601	Q=Q*(G(M-1)*Z(M-1)+G(M)*Z(M-2))/SS		0754	
1602	GO TO 15		0755	
1603	14 P=P+2,00		0756	
1604	Q=Q*(Q+1,000)		0757	
1605	15 IF(E(M-1),EQ,0,0) GO TO 16		0758	
1610	R=R-D(M)/E(M-1)		0759	
1611	GO TO 11		0760	
1612	16 R=R+1,000		0761	
1613	11 CONTINUE		0762	
1615	17 PS=P8		0763	
1616	QS=QT		0764	
1617	QT=Q		0765	
1620	IF(REV,LT,0,0) CONVK=CONVK/10,		0766	
1623	P8=P		0767	
1624	REV=-REV		0768	
1625	GO TO 41		0769	

GRUPE II	ISN	SOURCE STATEMENT	FORTRAN SOURCE LIST	04/04/67	PAGE 13
1626	90	IF(NCHEK,LT,0)R=1,0D0/R	0770		
1631		U(M)=R	0771		
1632		V(M)=0	0772		
1633		CONV(M)=CONVK	0773		
1634		M=M-1	0774		
1635		N=N-1	0775		
1636		DO 18 J=3,M	0776		
1637		IF(DABS(T(J)/D(J)),LT,CONVK) GO TO 1002	0777		
1642		T(J)=0,0	0778		
1643		GO TO 18	0779		
1644	1002	T(J)=D(J)	0780		
1645	18	CONTINUE	0781		
1647		IF(M,EQ,3)GO TO 101	0782		
1652		CONVK=10,00NF	0783		
1653		GO TO 80	0784		
	C		0785		
	C	CALCULATE REAL AND COMPLEX ROOTS ACCORDING TO THE QUADRATIC	0786		
	C	FORMULA,	0787		
	C		0788		
1654	70	IF(NCHEK,GE,0)GO TO 19	0789		
1657		P=P/Q	0790		
1660		Q=1,0D0/Q	0791		
1661	19	CONTINUE	0792		
1662		IF((Q-(P/2,0D0)**2),GT,0,0)GO TO 20	0793		
1665		SS=DSQRT((P/2,0D0)**2-Q)	0794		
1666		IF(P,LT,0,0)GO TO 21	0795		
1671		U(M)=P/2,0D0-SS	0796		
1672	2000	U(M-1)=Q/U(M)	0797		
1673		V(M)=0,0	0798		
1674		V(M-1)=0,0	0799		
1675		GO TO 22	0800		
1676	20	U(M)=P/2,0D0	0801		
1677		U(M-1)=U(M)	0802		
1700		SS=DSQRT(Q-(P/2,0D0)**2)	0803		
1701		V(M)=SS	0804		
1702		V(M-1)=-SS	0805		
1703		GO TO 22	0806		
1704	21	U(M)=P/2,0D0+SS	0807		
1705		GO TO 2000	0808		
1706	22	CONV(M)=CONVK	0809		
1707		CONV(M-1)=CONVK	0810		
1710		M=M-2	0811		
1711		N=N-2	0812		
1712		DO 23 J=3,M	0813		
1713		IF(DABS(T(J)/G(J)),LT,CONVK) GO TO 1001	0814		
1716		T(J)=0,0	0815		
1717		GO TO 23	0816		
1720	1001	T(J)=G(J)	0817		
1721	23	CONTINUE	0818		
1723		GO TO 200	0819		
1724	101	CONTINUE	0820		
1725		M=M1	0821		
1726		N=N1	0822		
1727		DO 807 I=1,N	0823		
1730		M1=I+3	0824		

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	1731	IF(V(M1),EQ,0,0) GO TO 659	0825	
	1734	GO TO 661	0826	
	1735	659 IF(U(M1),GT,ZEUSA) GO TO 661	0827	
	1740	IF(U(M1),GT,ZFUS) GO TO 662	0828	
	1743	GO TO 661	0829	
	1744	662 MXT=MXT+1	0830	
	1745	SLTX(MXT)=U(M1)	0831	
	1746	661 CONTINUE	0832	
	1747	807 CONTINUE	0833	
	C		0834	
	C	PRINT OUT RESULTS	0835	
	C		0836	
	1751	IF(NSC,EQ,2) GO TO 1311	0837	
	1754	IF(NSC,EQ,3) GO TO 1312	0838	
	1757	IF(NSC,EQ,4) GO TO 1313	0839	
	1762	WRITE(6,4886)	0840	
	1763	WRITE(6,1222) MXT	0841	
	1764	IF(MXT,EQ,0) GO TO 654	0842	
	1767	DO 663 LAD=1,MXT	0843	
	1770	DOLL=(ALFA-SLTX(LAD))/SLTX(LAD)	0844	
	1771	WRITE(6,1223)DOLL,SLTX(LAD)	0845	
	1772	TTRZT=TAU*SLTX(LAD)	0846	
	1773	IF(TTRZT,GT,0.7)WRITE(6,1124)TTRZT	0847	
	1776	663 CONTINUE	0848	
	2000	RORRE=SLTX(1)	0849	
	2001	ALFA=1,01*ALFA	0850	
	2002	GO TO 616	0851	
	2003	1311 RORRE=SLTX(1)-RORRE	0852	
	2004	RORRE=RORRE/(0,01*ALFA)	0853	
	2005	RORRD=SLTX(1)	0854	
	2006	DN=1,01*DN	0855	
	2007	GO TO 616	0856	
	2010	1312 RORRD=SLTX(1)-RORRD	0857	
	2011	RORRD=RORRD/(0,01*DN)	0858	
	2012	RBRR=SLTX(1)	0859	
	2013	STAR=1,01*STAR	0860	
	2014	GO TO 616	0861	
	2015	1313 RBRR=SLTX(1)-RBRR	0862	
	2016	RBRR=RBRR/(0,01*STAR)	0863	
	2017	GBLXX=(RORRE+RORRE*VARX*VARX)+(RORRD+RORRD*GRXT*GRXT)	0864	
	2020	GBLXX=GBLXX+(RBRR*RBRR*POLKY)+2,0*(RORRE*RBRR*ROPYE)	0865	
	2021	GBLXE=SQRT(GBLXX)	0866	
	2022	DOLEX=(GBLXX/(SLTX(1)*SLTX(1)))+AUFK*AUFK	0867	
	2023	DOLEX=DOLEX*2,0*(RBRR*ROPYE-RORRE*VARX*VARX)/(SLTX(1)*ALFA)	0868	
	2024	DOLER=SQRT(DOLEX)*(DOLL+1,0)	0869	
	2025	WRITE(6,1229)DOLER,GBLXE	0870	
	2026	654 CONTINUE	0871	
	C		0872	
	C	FIND SECOND EXPONENTIAL	0873	
	C		0874	
	2027	IF(WZZK,EQ,0,0)WRITE(6,4883)	0875	
	2032	IF(WZZK,EQ,1,0)WRITE(6,4884)	0876	
	2035	IF(WZZK,EQ,0,0)GO TO 656	0877	
	2040	DO 4666 JXN=LFM,NDP	0878	
	2041	LPS=JXN-LFM+1	0879	

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		Y(LPS)=XKT(JXN)*PASIT*EXP(-DCYT*THRX(JXN))	0880	
2042		X(LPS,1)=THRX(JXN)	0881	
2043		IF(Y(LPS),LE,0,0)GO TO 4667	0882	
2044		SXM=SXM/SKKPP	0883	
2047		W(LPS)=(XKT(JXN)+HXLXT+HSLST+HXLXT/SUSXT+(XKT(JXN)-Y(LPS))*SXM)	0884	
2050		W(LPS)=(Y(LPS)+2,0)/W(LPS)	0885	
2051		Y(LPS)=ALOG(Y(LPS))	0886	
2052		CONTINUE	0887	
2053	4666	NDP=JXN-1	0888	
2055	4667	NFL=NDP-LFM	0889	
2056		VARX=0,0	0890	
2057		SUIT=0,0	0891	
2060		NODATA=NFL	0892	
2061		ROPEX=0,0	0893	
2062		POLKX=0,0	0894	
2063		KZKZ=1	0895	
2064		LZLZ=1	0896	
2065		WZZK=2,0	0897	
2066		GO TO 814	0898	
2067		CONTINUE	0899	
2070	4779	SUIT=ABS(SUIT)	0900	
2071		ATTLE=EXP(ATTLE)/GW	0901	
2072		ERR=SUIT*AUFK	0902	
2073		REAR=ATTLE*SQR(POLKY)	0903	
2074		IF(SKKPP,GT,2,0)SKKPP=SKKPP+2,0	0904	
2075		SXM=SXM*SKKPP	0905	
2100		WRITE(6,4881) SUIT,ERR,ATTLE,REAR,RA3,SKKPP	0906	
2101		CONTINUE	0907	
2102	656	END	0908	
2104				