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**Theory and Use of GIRAFFE for
Analysis of Decay Characteristics of
Delayed-neutron Precursors in an LMFB**

by

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Prepared for the U. S. DEPARTMENT OF ENERGY

under Contract W-31-109-Eng-38

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ANL-80-55

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EBR-II Project

July 1980

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ABSTRACT

In this report we discuss implementation and application of the computer code GIRAFFE (General Isotope Release Analysis For Failed Elements) written in FORTRAN IV. GIRAFFE was designed to provide parameter estimates of the nonlinear discrete-measurement models that govern the transport and decay of delayed-neutron precursors in a liquid-metal fast breeder reactor (LMFBR). The code has been organized into a set of small, relatively independent and well-defined modules to facilitate modification and maintenance. The program logic, the numerical techniques, and the methods of solution used by the code are presented, and the functions of the MAIN program and of each subroutine are discussed.

I. INTRODUCTION

The fuel-element rupture detector (FERD)¹⁻⁵ has been used since 1964 at EBR-II to monitor the condition of breached fuel elements that release delayed-neutron (DN) emitters to the primary coolant. Two important diagnostic parameters can be computed from FERD data and used as an aid in identification and characterization of exposed-fuel experiments in a liquid-metal fast breeder reactor (LMFBR). These are (1) the transit time for DN emitters traveling from the fission source to the inlet of the FERD loop, and (2) the effective isotopic holdup time for DN emitters and their fission-produced precursors released from nonrecoil fission sources. The model for isotopic transport and decay that is used to compute the values of these parameters is described in detail in Ref. 6. The GIRAFFE (General Isotope Release Analysis For Failed Elements) code incorporates that physical model into a systematic regression algorithm that enables the user to determine the values of the transport and release parameters described above. The code also computes the values of several descriptive statistics that provide additional diagnostic information for interpreting the DN signals and characterizing the condition of the breach.

Section II summarizes the principal model equations that have been coded into GIRAFFE. Readers interested in the formal development of the model equations and a fuller description of EBR-II's FERD system are referred to Ref. 6.

All mathematical derivations are presented in FORTRAN-statement form using standard FORTRAN-supplied functions. Variable names correspond to those used in the code, and wherever possible the final form of each equation is presented exactly as it appears in GIRAFFE.

Section III describes the development of the mathematical formulism embodied in GIRAFFE's two principal numerical subroutines, TRANSIT and LMBDAE. Two simulation studies are presented as an aid in examining the step-by-step implementation of those two subroutines.

Section IV discusses programming details and computational strategies for the MAIN program segment and for GIRAFFE's nine subroutines. The program structure is modular to facilitate straightforward interfacing with user-supplied subroutines. Efforts have been made to implement to the fullest extent possible the recommendations of ANSI-N413-1974 (Ref. 7) to improve the design and utility of the program. Machine dependencies have been minimized in GIRAFFE so that potential users should find the code completely transportable. There are no machine-dependent constants, no character manipulation, no EQUIVALENCE statements, and no mixed-mode arithmetic.

Section V provides four example problems complete with user input and edited code output. Appendix A presents a detailed FORTRAN flowchart of the MAIN program segment, Appendix B shows a documented FORTRAN listing of GIRAFFE, and Appendixes C and D give the flowcharts for GIRAFFE's two principal numerical subroutines.

II. SUMMARY OF EQUATIONS FOR DN TRANSPORT AND DECAY

The current version of GIRAFFE accommodates nine parent-daughter decay chains. (The term daughter will be used throughout to signify the principal DN-emitting isotopes. The term parent refers to the primary fission products that decay to daughter isotopes.) Table I lists the 18 isotopes together with

TABLE I. Reference Nuclear Data for Decay Calculations

Group Number	Parents			Daughters		
	Parent Isotope	Half-life, s	Decay Constant, s^{-1}	Daughter Isotope	Half-life, s	Decay Constant, s^{-1}
1	^{87}Se	5.59	0.124	^{87}Br	55.7	0.0124
2	^{88}Se	1.50	0.462	^{88}Br	15.9	0.0436
3	^{136}Sb	0.82	0.850	^{136}Te	21.0	0.0330
4	^{137}Te	3.50	0.198	^{137}I	24.6	0.0282
5	^{89}Se	0.41	1.691	^{89}Br	4.5	0.1540
6	^{93}Kr	1.27	0.546	^{93}Rb	5.8	0.1195
7	^{138}Te	1.60	0.433	^{138}I	6.5	0.1066
8	^{94}Kr	0.21	3.301	^{94}Rb	2.8	0.2477
9	^{139}Te	0.01	100	^{139}I	2.4	0.2888

their associated half-lives and decay constants. The Arrhenius-model⁸ equations governing the release and transport of those isotopes in a fast-reactor system are summarized below. Each equation is expressed in FORTRAN-statement form using standard single-precision FORTRAN library functions.

A. Isotopic Decay Rates at Point of Detection

By use of the notation conventions established in Ref. 6, the activity of the parent isotope of species I in the FERD-loop sodium at the point of detection is predicted with the equation

$$P(I) = LMBDAE * LP(I) * SP(I) * EXP(-LP(I) * (TRANS + TFL)) / ((LP(I) + LMBDAE) * FP) \quad (1)$$

and, for the daughter isotopes, with the equation

$$D(I) = LP(I) * LD(I) * LMBDAE * SP(I) * (EX1(I) - EX2(I)) / ((LD(I) - LP(I)) * (LP(I) + LMBDAE) * FP) + (LMBDAE / (LD(I) + LMBDAE) / FP) * EX2(I) * LD(I) * ((LP(I) / (LP(I) + LMBDAE) * SP(I) + SD(I))), \quad (2)$$

where

TRANS = transit time in sodium from core to inlet of FERD loop, s,

TFL = transit time in FERD loop from inlet to detector, s,

LMBDAE = isotopic escape-rate coefficient for the fission source, s^{-1} ,

SP(I), SD(I) = fission production rates for parent and daughter isotopes of species I, atoms/s,

LP(I), LD(I) = decay coefficients for parent and daughter isotopes of species I, s^{-1} ,

FP = primary-coolant flow rate,

and the linear arrays EX1 and EX2 are defined by

$$EX1(I) = EXP(-LP(I) * (TRANS + TFL)) \quad (3)$$

and

$$EX2(I) = EXP(-LD(I) * (TRANS + TFL)). \quad (4)$$

In Eq. 1, TFL is a control variable that is adjusted experimentally by sequentially increasing (or decreasing) the flow rate F of sodium in the FERD

loop during a FERD flow-reduction (FFR) test.^{5,9} The transit time, TRANS, and the escape-rate coefficient, LMBDAE, are the unknown system parameters whose values are to be computed.

B. Total DN Activity

The total DN activity (AP) at the FERD detector is obtained by summation of products of individual decay rates for the daughter isotopes times the respective neutron-emission probabilities for the daughter isotopes, PN(I):

$$AP = AP + (D(I)*PN(I)) \quad (I = 1, 2, \dots, 9). \quad (5)$$

C. Effective Isotopic Holdup Time

The effective isotopic holdup time, TH, is equal by definition to the reciprocal of the isotopic escape-rate coefficient, i.e.,

$$TH = 1./LMBDAE. \quad (6)$$

D. Tramp Background Activity

The DN activity attributable to the fissioning of tramp uranium was computed with Eq. 5 as a discrete function of FERD flow rate F. For this calculation, the entire range of F was partitioned into 50 disjoint intervals F(I) (I = 1, 2, ..., 50). The values of TRANS and TH were set to 15.0 s and 0 s⁻¹, respectively,⁸ and an array of background activities was generated by repetitive application of Eq. 5:

$$BKG(I) = AP(I) \quad (I = 1, 2, \dots, 50), \quad (7)$$

where AP is evaluated with parameter set

$$[TRANS=15.0, LMBDAE=100s^{-1}, F=F(I)]. \quad (8)$$

The values held in array BKG were then normalized to agree with four activities that were measured during a reduced-flow test with tramp background (i.e., with no subassembly DN leakers in the core).⁹ The resulting array is stored in an interface file that is accessed by GIRAFFE during execution. Figure 1 is a plot of array BKG as a function of FERD flow rate.

Fig. 1

Plot of Elements of Array BKG
for Background DN Activity

III. BASIC GIRAFFE ALGORITHMS

A. Description of Numerical Techniques

The model equations summarized in Sec. II have been incorporated into a systematic regression algorithm that computes the optimum values of the unknown system parameters TRANS and TH. Since the model equations involve transcendental expressions in both these variables, numerical-approximation techniques are used to perform the calculations. As a first step we make a linearizing transformation¹⁰ by requiring the following relationship to hold between the DN activity measured by FERD and the activity predicted by the analytical transport-and-decay model:

$$AM(F) - BKG(F) = C \cdot AP(TRANS, LMBDAE, F) + GAMMA, \quad (9)$$

where

AM = measured DN activity at FERD flow rate F,

BKG = background DN activity at flow rate F due to fissioning of tramp fuel,

AP = model-predicted activity from Eq. 5,

C = dimensionless proportionality constant,

and

GAMMA = activity due to gamma background (assumed constant during FFR experiment).

Equation 9 describes a linear dynamic system that is a function of the continuous driver variable F. In principle, analog simulation could be applied directly to Eq. 9 to determine the optimum values of TRANS and LMBDAE. In practice, however, the response function AM has been observed to exhibit a dynamic component¹¹ that is independent of F (or may indirectly depend upon F in a way that is not now understood.)

To overcome these difficulties, we discretize Eq. 9 by requiring it to apply to time-averaged ensembles of the response variables AM and BKG at several constant levels of F. This makes possible the application of discrete parameter-estimation techniques. Specifically, the method devised for GIRAFFE is one of a class of techniques known as pseudomaximum likelihood techniques.¹⁰ If we denote by F(K) the time-averaged value of the FERD flow rate at flow step K, then the left side of Eq. 9 can be represented conveniently by a discrete array of constants:

$$A(K) = AM(F(K)) - BKG(F(K)), \quad (10)$$

where the index K ranges from one to the total number of flow steps, $NSTEP$. The values of the model parameters $TRANS$ and $LMBDAE$ can now be determined with a regression algorithm that minimizes an error function of the form

$$E(TRANS, LMBDAE) = SUM + (W(K) * (A(K) - AP(K)))^2 \quad (K = 1, 2, \dots, NSTEP), \quad (11)$$

where

E = multivariate objective function to be minimized with respect to $TRANS$ or $LMBDAE$,

$AP(K)$ = functional value of predicted activity at flow rate $F(K)$,

$A(K)$ = corrected activity at flow rate $F(K)$ (from Eq. 10),

SUM = dummy summation scalar, assumed initialized to zero,

and

$W(K)$ = weighting function assigned to $AP(K)$.

Equation 11 cannot be applied to compute $TRANS$ and $LMBDAE$ simultaneously. Two closely related algorithms have therefore been coded into GIRAFFE. The first algorithm, implemented in GIRAFFE subroutine TRANSIT, accepts a constant value of $LMBDAE$ as input and computes the optimum value of $TRANS$. This algorithm is described in Sec. III.B below. The second algorithm, described later in Sec. III.C, determines the optimum value of $LMBDAE$ for a constant value of $TRANS$. This algorithm is implemented in GIRAFFE subroutine LMBDA. Specific examples will be presented in both subsections that follow to illustrate the numerical properties of each algorithm.

B. Determination of TRANS

A flow-reduction test that is performed at $NSTEP$ flow steps will produce $NSTEP$ time-averaged measured DN signals. The tramp-background function, $BKG(F)$, is well known (cf. Fig. 1 and the remarks preceding it). The constant term in Eq. 9, $GAMMA$, can remain unknown, and its value will be determined by the subsequent regression analysis. Alternatively, the FERD flow rate can be reduced to zero, and $GAMMA$ can be measured directly, to increase the degrees of freedom in the regression analysis by one. For the discussion that follows, $GAMMA$ is assumed to be unknown.

The $NSTEP$ measured activities from the FFR test together with the $NSTEP$ tramp-background values define, through Eq. 10, an array of $NSTEP$ corrected DN signals $A(K)$ ($K = 1, 2, \dots, NSTEP$). Using the analytical decay model developed in Sec. II, we can compute an array of $NSTEP$ corresponding predicted activities, $AP(K)$ ($K = 1, 2, \dots, NSTEP$). To make use of Eq. 5, however, the user must supply a starting value for the unknown transit time $TRANS$. We call

this initial value $T(1)$. A regression analysis is performed in which a linear coefficient of correlation is computed for the arrays of measured and predicted values. We denote by $COR(1)$ the value of the computed correlation coefficient, where the subscript (1) signifies that this value was obtained from the first guess of TRANS. $COR(1)$ provides a suitable quantitative measure of how close a plot of measured versus predicted data is to a straight line.

A second guess of TRANS is obtained by adding a small increment DT to the initial guess, i.e., $T(2) = T(1) + DT$. The second guess is input to the decay model to generate NSTEP new predicted activities, and a new correlation coefficient $COR(2)$ is computed.

We repeat this procedure NREP times, producing a sequence of NREP time values $T(I)$ ($I = 1, 2, \dots, NREP$). This generates a vector of correlation coefficients $COR(I)$ ($I = 1, 2, \dots, NREP$). These values define a discrete function $COR(T)$. Theoretical considerations reveal that $COR(T)$ is a unimodal concave function of T . Determination of the maximum of COR , therefore, uniquely defines the optimum value of the independent variable T .

The last step of the procedure is to invoke the decay equations once more, using as input the optimum value of TRANS. This produces NSTEP final elements of the linear activity array $AP(K)$ ($K = 1, 2, \dots, NSTEP$). A straight line is fit through the NSTEP points $(A(K), AP(K))$ ($K = 1, 2, \dots, NSTEP$), and the values of the overall correlation coefficient $XFIT$ and the residuals $RES(K)$ ($K = 1, 2, \dots, NSTEP$) are computed. The slope of the straight line is equal to the value of the dimensionless proportionality coefficient C introduced when we made the linearizing transformation that led to Eq. 9. The intercept of the straight line with the vertical axis determines the value of the constant term in Eq. 9, which was defined in Sec. III.A to be the gamma background signal GAMMA. Reference 6 discusses the diagnostic uses of the information encoded in $XFIT$ and RES and the physical significance of the slope C .

An optimization algorithm has been devised in which $T = T(1), T(2), \dots, T(NREP)$ and $COR = COR(1), COR(2), \dots, COR(NREP)$ are generated as described above. Once this generation has been accomplished, a central-difference technique¹² is applied to differentiate the discrete function COR with respect to the independent variable T . Results are stored in the array DCDT. An inverse Lagrangian interpolation technique¹³ is then used to numerically compute the root of $DCDT = 0$. The value of T at which this derivative vanishes defines the true transit time TRANS.

The algorithm just described for computing the transit time TRANS has been incorporated into the GIRAFFE subroutine TRANSIT. Figure 2 is a simplified flowchart for the TRANSIT subroutine displayed in the form of a Nassi-Schneiderman diagram. [Nassi-Schneiderman charts are a system of stylized flowcharts designed for use with structured programming techniques. The chart is read from top to bottom (see Ref. 14).]

Fig. 2. Flowchart for TRANSIT Algorithm

C. Application of TRANSIT Algorithm to Simulation-test Data

We illustrate the above method by an example calculation that uses the simulation-test data displayed in Table II. These data were generated in a simulated FFR test, using the decay-model equations summarized in Sec. II. Values of 0 and 15.0 s were assigned to the model parameters TH and TRANS, respectively. The contribution due to gamma activity was assumed to be 20.0 counts/s. Use of the exact, error-free data of Table II will permit us to demonstrate conveniently the step-by-step implementation of the TRANSIT algorithm while examining the numerical properties of the solution procedure. In Sec. V, we will apply the algorithm to actual FFR test data.

TABLE II. Flow Rates and Corresponding Activities for Simulated FFR Test No. 1

Flow Step	FERD Flow, L/s	Simulated Activity, counts/s	Flow Step	FERD Flow, L/s	Simulated Activity, counts/s
1	5.68	954.0	5	3.15	707.4
2	5.05	905.9	6	2.52	615.0
3	4.42	850.2	7	1.89	500.2
4	3.79	784.9	8	1.26	353.5

Treating T as an adjustable parameter, we select as our initial estimate $T(1) = 12.0$ s. This value is substituted into Eq. 5 to generate the vector of predicted activities shown in the third column of Table III. If we correlate those predicted activities with the simulated measured activities of Table II, we obtain a correlation coefficient of $COR(1) = 0.99896$.

TABLE III. Predicted Activities for First Iteration of TRANSIT Algorithm with $T(1) = 12.0$ s

Flow Step	FERD Flow, L/s	Predicted Activity, counts/s	Flow Step	FERD Flow, L/s	Predicted Activity, counts/s
1	5.68	1115.0	5	3.15	784.2
2	5.05	1115.0	6	2.52	665.8
3	4.42	972.9	7	1.89	525.9
4	3.79	885.6	8	1.26	357.1

For subsequent estimates of independent variables, we specify a constant time increment of $DT = 0.25$ s. Thus, for the second iteration we set $T(2) = T(1) + DT = 12.25$ s. Table IV shows the results of substituting $T(2)$ into Eq. 5. Correlation of the predicted activities of Table IV with the simulated measured activities of Table II produces a correlation coefficient of 0.99913. This value is stored in the second element in array COR .

TABLE IV. Predicted Activities for Second Iteration of TRANSIT Algorithm with $T(2) = 12.25$ s

Flow Step	FERD Flow, L/s	Predicted Activity, counts/s	Flow Step	FERD Flow, L/s	Predicted Activity, counts/s
1	5.68	1094.1	5	3.15	772.9
2	5.05	1029.9	6	2.52	657.2
3	4.42	956.4	7	1.89	520.2
4	3.79	871.5	8	1.26	353.9

We repeat this procedure for 25 iterations, adding 0.25 s each time to the previous estimate of T and computing a new value of COR. Figure 3 plots the results. Figure 4 graphically depicts the results of numerically differentiating COR with respect to T. Note that the derivative vanishes at $T = 15.0$ s, which is the exact value of TRANS assumed when generating the vector of measured activities in Table II.

Fig. 3
Correlation Coefficient
as a Function of Time

Fig. 4
Derivative of Correlation Vec-
tor with Respect to Time

D. Determination of LMBDAE

Subroutine LMBDA has been written to treat the problem of determining the optimum value of the escape-rate coefficient LMBDAE (and hence also the holdup time TH), given the value of the transit time TRANS. Solution of this problem required only a minor modification to the TRANSIT algorithm developed in Sec. III.B above. The time parameter is now treated as an input constant, while the independent variable LMBDAE is treated as an adjusted parameter that is varied with each successive iteration of the regression procedure. Aside from this modification, the structure of the LMBDA algorithm is identical to that developed for TRANSIT. Figure 5 shows a Nassi-Schneiderman diagram¹⁴ of the LMBDA algorithm.

Fig. 5. Flowchart for LMBDA Algorithm

E. Application of LMBDA Algorithm to Simulation-test Data

We illustrate the implementation of the LMBDA algorithm by a second simulated TFR experiment that uses as input the data displayed in Table V. The data shown were generated using the calculational model of Sec. II with TRANS = 15.0 s and LMBDAE = 0.10 s⁻¹. The gamma background activity was assumed to be 20.0 counts/s.

TABLE V. Flow Rates and Corresponding Activities
for Simulated TFR Test No. 2

Flow Step	FERD Flow, L/s	Simulated Activity, counts/s	Flow Step	FERD Flow, L/s	Simulated Activity, counts/s
1	5.68	647.3	5	3.15	507.7
2	5.05	621.1	6	2.52	450.7
3	4.42	590.2	7	1.89	377.0
4	3.79	553.1	8	1.26	275.6

Fig. 6. Correlation Coefficient as a Function of LMBDAE

Figure 6 shows the results of applying the LMBDA algorithm to the data of Table V. Note that the shape of the curve traced out by successive elements of the array of correlation coefficients defines a unimodal concave function of the independent variable LMBDAE. This is an important feature from a theoretical standpoint because it permits us to assume that any maximum identified is a global maximum and, moreover, that multiple zeros of the derivative vector are not possible.

The derivative of the array of correlation coefficients with respect to independent variable LMBDAE has been computed and is plotted in Fig. 7. Note that the derivative vanishes at $\text{LMBDAE} = 0.10 \text{ s}^{-1}$, as expected.

Fig. 7
Derivative of Correlation Vector with Respect to LMBDAE

I". PROGRAMMING DETAILS

A. General Description of Code

The program consists of one main program and nine FORTRAN subroutines. The program is solved entirely in the core. The main, or driver, program controls the initial assignment of all data values, checks input data for consistency and completeness, and controls the calling sequence of the required subroutines in accordance with the user's problem definition. If necessary, error messages flagging missing, inconsistent, or out-of-bound data are provided, and the user is given the option of terminating execution at the conclusion of the checking. Two output options are provided. The short-form output includes only a tabulation of the computed results. The long-form output includes a listing of the user's input, a tabulation of all reference parameter arrays, an iteration log displaying intermediate values of certain computed parameters, and a summary table providing case description, key input, computed results, and processing anomalies.

Recommended documentation procedures^{7,15} have been followed throughout the development of the program. The overall organization of the FORTRAN statements has been strongly influenced by TAMPR, a software development system created by Boyle and Dritz.¹⁶ Anyone reading the FORTRAN source code for the GIRAFFE subroutines will find the loops and logical structures clearly delineated by the TAMPR indentation convention illustrated in Fig. 8.

```

      DC 10 I=1,N
        DO 20 J=1,N
          DO 30 K=1,N
            A(I,J,K) = . . .
            .
            .
            .
30      CONTINUE
          B(I,J) = . . .
          .
          .
          .
20      CONTINUE
        C(I) = . . .
        .
        .
        .
10      CONTINUE

```

Fig. 8

FORTRAN Indentation Con-
vention Used in GIRAFFE

GIRAFFE is constructed as a series of modules with a consistent set of dimensional units to minimize core storage requirements and to provide flexibility in model usage and ease of code updating when models are revised. The simplified block diagram of Fig. 9 depicts the relationship between the

Fig. 9. Block Diagram for GIRAFFE Code

MAIN program and each subroutine. Appendix A lists a complete FORTRAN flowchart for the MAIN program. Appendix B gives a copiously documented listing of the FORTRAN source statements.

B. Subroutines

1. Subroutine INPUT

INPUT is the first subroutine called. This subroutine performs presetting of data and zeroing of arrays, and then prompts the user, in the interactive mode, for all user-input data. All values entered are checked internally to confirm that they are within acceptable bounds and consistent with other input data. The user is given the option of terminating the execution at the conclusion of the checking. The subroutine

is constructed so that all input data are checked before program termination, even when fatal errors have been detected. Error messages flagging missing, inconsistent, or out-of-bound data are provided.

2. Subroutine LMBDA

This subroutine determines the optimum value of the effective isotopic-removal coefficient LMBDAE. The routine sets up the numerical calculations in accordance with the user problem definition, partitions the domain of the control variable LMD into equally spaced intervals, and then calls the appropriate calculational routines. Independent variable partitioning is controlled by the values of three user-supplied input variables: LEI, DLE, and NREP, where

LEI = initial value of independent variable, s^{-1} ,

DLE = constant scaler step size, s^{-1} ,

and

NREP = number of repetitions of regression algorithm.

In accordance with these definitions of input variables, the total width of the regression domain (i.e., the interval over which a search is made for the optimum value of LMBDAE) is from LEI to $(LEI + DLE \cdot (NREP - 1))$. The

overall accuracy of the solution procedure is controlled by the magnitude of the step size DLE. Specification of a smaller step size will improve the accuracy of the estimates, but will increase execution time correspondingly.

If no optimum can be located after NREP iterations, diagnostic information is printed at the user's terminal, and execution is terminated in LMBDA. When this occurs the user should adjust the values of LEL, DLE, and/or NREP for a larger regression domain and reexecute the program.

Results from LMBDA are transferred back to MAIN by labeled common blocks.

Appendix C contains a detailed FORTRAN flowchart for subroutine LMBDA.

3. Subroutine TRANSIT

TRANSIT determines the transit time, in seconds, required for DN emitters to travel from the fission source to the point of detection. The structure and the calling sequence for calculational routines are similar to those of subroutine LMBDA; however, specification of control variables includes a separate calculation correcting for the flow-dependent transit time in the FERD loop.

The regression domain is controlled through user specification of the code variables TSTART, DT, and NREP, where

TSTART = initial value of independent variable T, s,

DT = constant scaler step size, s,

and NREP has the same function as in subroutine LMBDA. The values of TSTART, DT, and NREP are input by the user at the time of execution.

Appendix D lists a detailed FORTRAN flowchart of the TRANSIT routine.

4. Subroutine FERD

This subroutine computes a vector of predicted activities AP(I) (I = 1, 2, ..., NSTEP) using the Arrhenius decay model summarized in Sec. II. Required nuclear-decay constants are transferred to FERD by labeled COMMON AREAL.

5. Subroutine REGRESS

REGRESS produces the best fit between the measured and predicted activities and computes goodness-of-fit parameters. Values of the residuals are stored in the linear array RES. These values represent the vertical deviations of the measured activities from the best-fit line (see Sec. III.B). The units are counts/s. RESP holds the values of the residuals expressed as a percentage of the corresponding measured activities.

The square of the linear correlation coefficient is stored in the scalar COR and returned to the calling program (either LMBDA or TRANSIT) as an argument in the subroutine statement. The correlation coefficient for the input arrays X and Y is determined by computing the fraction NUM/DENOM, where

$$\text{NUM} = \text{SUM}((\text{X(I)} - \text{AVERAGE(X)}) * (\text{Y(I)} - \text{AVERAGE(Y)})) \quad (12)$$

and

$$\text{DENOM} = \text{SQRT}(\text{SUM}((\text{X(I)} - \text{AVERAGE(X)}) ** 2) * \text{SUM}((\text{Y(I)} - \text{AVERAGE(Y)}) ** 2)), \quad (13)$$

and each SUM is taken from I = 1 to I = NSTEP.

6. Subroutine DER

This subroutine numerically computes the derivative of the vector of correlation coefficients. The method used for the interior points is a five-point formula¹⁷ obtained from differentiation of the least-squares parabola. Near the ends of the data interval, four-point formulas are applied. This method avoids problems of error magnification associated with formulas derived from collocation polynomials.¹⁸

Accuracy of the differentiation process is controlled by the input scalar H, which defines the step length. This parameter is equal in magnitude to the regression partition parameters DLE in subroutine LMBDA and DT in subroutine TRANSIT.

For problems requiring more space for storage in subroutine DER, the value of the dimension parameter NDIM must be changed in the driver program before execution.

7. Subroutine ROOTS

ROOTS embodies an inverse Lagrangian interpolation algorithm¹³ that determines the optimum value of LMBDAE or TRANS at which the derivative of the vector of correlation coefficients vanishes. Processing begins by checking to see if there is a change of sign in the elements of the input derivative vector. If a change of sign has occurred, then a root has been bracketed and the subroutine proceeds to compute the value of the root. If no change of sign has occurred, the value of the integer flag NROOT is set to zero and returned to the calling program.

Accuracy of the algorithm is controlled by the number of repetitions NREP as specified in the calling program (either LMBDA and TRANS). The degree of the Lagrangian polynomial generated is NREP - 1. The current version of GIRAFFE accommodates up to a 49th-degree polynomial interpolation.

8. Subroutine YIELDS

This subroutine computes the weighted fission yields based on the user-supplied input variable FPU. FPU is the best estimate of the fraction of fissions occurring in plutonium. All fission-yield data were obtained from Ref. 19. If the long-form output option is in effect, YIELDS prints out a table of reference yield data (stored internally by the program) and a table of corrected fission yields.

9. Subroutine OUTPUT

OUTPUT produces a formatted printout that includes case description, a summary of user-input variables, and a listing of all computed results. Results from subroutine REGRESS are passed to OUTPUT by labeled COMMON AREA3. Results from LMBDA or TRANSIT are passed to OUTPUT by labeled COMMON AREA2. There is no return from OUTPUT to the MAIN segment.

C. Description of Principal Parameters

Several of the most important input and output parameters used in GIRAFFE are defined below. Other, less significant parameters that have local definitions in individual routines are defined by comment statements in the FORTRAN source listing (see Appendix B).

- A = Vector of corrected activities (AM - BKG), counts per second
- AM = Vector of experimentally measured DN activities, counts per second
- AP = Vector of predicted activities from model, counts per second
- BKG = Vector of tramp-background values, counts per second
- COR = Computed vector of linear correlation coefficients, dimensionless
- F = Input vector of FERD-loop flow rates, gpm
- FPU = Dimensionless input scaler containing the user estimate of the fraction of fissions occurring in ^{239}Pu
- GAMMA = Output constant determined by intercept of measured-versus-predicted curve; equals activity due to gamma flux, counts per second
- LMBDAE = Effective isotopic-removal coefficient for the fission source, inverse seconds
- NDIM = Positive integer and input variable, used for execution-time dimensioning of arrays in all subroutines
- NREP = Number of repetitions of regression algorithm in TRANSIT or LMBDA

NROOT = Integer variable containing the number of roots identified in
 subroutine ROOTS
 NSTEP = Number of flow steps in FFR experiment; cannot be greater than
 NDIM
 PN = Neutron-emission probabilities for daughter isotopes, percent
 RC = Vector of experimentally measured recoil correction factors
 RES = Vector of residuals, in counts per second, from subroutine
 REGRESS
 SP,SD = Fission-source terms for parent and daughter isotopes, atoms
 per second
 TF = Computed vector of FERD-loop transit times, seconds
 TH = Effective isotopic holdup time for the fuel, seconds
 TRANS = Transit time, in seconds, for DN emitters to travel from site of
 defect to outlet of IHX
 XFIT = Overall multiple correlation coefficient
 YP,YD = Fast-fission independent yields for parent and daughter isotopes,
 percent

D. DIMENSION Requirements

The DIMENSION statements in the driver program accommodate problems involving up to 10 FERD-flow steps and up to 50 independent-variable divisions in the numerical-analysis routines. The parameters included in the following DIMENSION statements conform to the input-parameter definitions above:

```

DIMENSION TF(10),TT(50),COR(50),BKG(50),A(10),BK(10)
DIMENSION RES(10),RESP(10),F2(10),T(10),F(10),AP(10),AM(10)
REAL LMBDAE,SP(9),SD(9),LD(9),YD(9),RC(9),PN(9),LP(9),YPC(9)
  
```

The DIMENSION statements in all subroutines use execution-time dimensioning of arrays whenever possible. The storage requirements for those arrays are determined through the integer input variable NDIM in the driver program.

E. System-dependent Features

The code uses one interface file, BKG.DAT. This file is accessed in the driver routine with the statement CALL IFILE2(1,'BKG'). The file is closed with the statement ENDFILE(1). The name of the file as well as the methods of opening and closing the file should be modified to conform to the requirements of the user's operating system.

F. Summary of User Requirements

1. Adjust DIMENSION statements if the number of low steps is to be greater than 10 or if the number of calculation intervals desired in the numerical-analysis routines is to be greater than 50.

2. Adjust FORMAT statements if desired.

3. Specify values for NSTEP, F, and A. In the interactive mode, the user selects among various options and is prompted for the remaining input values as required by the calculational routines.

V. SAMPLE PROBLEMS

Four sample problems are provided to demonstrate operation of GIRAFFE. The first two examples demonstrate application of the code to data obtained during an FFR test performed with a recoil fission source in the core. In these examples the holdup time, TH, is set equal to zero, and subroutine TRANSIT is called to compute the transit time from the core to the inlet of the FERD loop. Examples 3 and 4 consider a problem involving a nonrecoil fission source. Subroutine LMBDA is used in these two examples to evaluate the isotopic holdup time for the DN-emitting fission products.

A. Example 1

Examples 1 and 2 both use as input the FFR-test results listed in Table VI. Example 1 illustrates the information produced when the user specifies the short-form output option. Since the FFR test was performed with a recoil fission source, the value of the holdup time is zero. Therefore the user arbitrarily enters 100 s^{-1} when the code prompts for the value of LMBDAE. (Any value of LMBDAE entered that is greater than about 10 s^{-1} is effectively equal to infinity.)

TABLE VI. Results from FFR Test
Performed on August 27, 1979

Flow Step	FERD Flow, L/s	Measured Activity, counts/s
1	5.7	528.7
2	5.0	499.4
3	4.4	462.1
4	3.8	430.2
5	3.1	376.1
6	0.0	20.5

Figure 10 supplies the complete code printout produced by GIRAFFE for Example 1.

B. Example 2

In this example, GIRAFFE is applied to solve the same test case as considered in Example 1, but the long-form-output option is specified to demonstrate the additional diagnostic information made available. Figure 11 supplies the code printout for this example.

ENTER ONE-LINE CASE DESCRIPTION

8/27/79 FFR TEST ANALYSIS

INPUT NUMBER OF FLOW STEPS IN FLOW REDUCTION TEST

6

ENTER THE 6 FLOW RATES IN GPM

90.2 79.9 69.8 59.9 49.6 0

ENTER 6 CORRESPONDING MEASURED ACTIVITIES

528.7 499.4 462.1 430.2 376.1 20.5

ENTER FFU, THE FRACTION OF FISSIONS OCCURRING IN PLUTONIUM

0

TRANSIT TIME CALCULATIONS (1), OR
DIFFUSION HOLDUP-TIME CALCULATIONS (2) ?

1

LONG OR SHORT OUTPUT? (1 OR 2)

2

SUMMARY OF USER INPUT VALUES

NSTEP = 6

STEP NO.	FLOW (GPM)	RATE (L/S)	MEASURED ACTIVITY
1	90.2	5.7	528.7
2	79.9	5.0	499.4
3	69.8	4.4	462.1
4	59.9	3.8	430.2
5	49.6	3.1	376.1
6	0.0	0.0	20.5

FFU = 0.00

TRANSIT TIME CALCULATIONS SELECTED

SHORT FORM OUTPUT REQUESTED

CASE DESCRIPTION:

8/27/79 FFR TEST ANALYSIS

OPTIONS:

- (1) INITIATE PROCESSING OF GIRAFFE CALCULATIONS
- (2) SOME INPUT VALUES FAULTY--WOULD LIKE TO RE-ENTER INPUT
- (3) TERMINATE EXECUTION

ENTER OPTION NUMBER

1

ENTER VALUE OF EFFECTIVE ESCAPE-RATE COEFFICIENT
LAMDAE, IN SECONDS-1

100

ENTER STARTING VALUE FOR INDEPENDENT VARIABLE T

11

ENTER INCREMENT DT

.15

ENTER THE TOTAL NUMBER OF ITERATIONS, NREP

10

Fig. 10. Short-form GIRAFFE Output for Example 1

Fig. 10 (Contd.)

***** R E S U L T S *****

FERD FLOW GPM	FERD FLOW L/S	MEASURED ACTIVITY COUNTS/S	CORRECTED ACTIVITY COUNTS/S	PREDICTED ACTIVITY COUNTS/S	RESIDUALS COUNTS/S	RESIDUALS OF MEASURED
90.2	5.69	528.7	496.7	1082.3	0.6	0.1
79.9	5.04	499.4	469.6	1017.5	-0.8	-0.2
69.8	4.40	462.1	434.3	944.5	2.3	0.5
59.9	3.78	430.2	404.8	861.8	-4.6	-1.1
49.6	3.13	376.1	353.4	761.5	2.6	0.7
0.0	0.00	20.5	20.5	0.0	-0.1	-0.3

TRANSIT TIME = 12.4 S

C = SLOPE = 0.44
STANDARD DEVIATION OF SLOPE = 0.001

GAMMA = Y INTERCEPT = 20.4 COUNTS/S
STANDARD DEVIATION OF GAMMA = 2.9 COUNTS/S

COEFFICIENT OF CORRELATION, XFIT = 0.99978

8/27/79 FFR TEST ANALYSIS

Fig. 10 (Contd.)

LONG FORM OUTPUT REQUESTED

CASE DESCRIPTION:
8/27/79 FFR TEST ANALYSIS

ENTER ONE-LINE CASE DESCRIPTION

8/27/79 FFR TEST ANALYSIS

INPUT NUMBER OF FLOW STEPS IN FLOW REDUCTION TEST

6

ENTER THE 6 FLOW RATES IN GPM

90.2 79.9 69.8 59.9 49.6 0

ENTER 6 CORRESPONDING MEASURED ACTIVITIES

528.7,499.4,462.1,430.2,376.1,20.5

ENTER FPU, THE FRACTION OF FISSIONS OCCURRING IN PLUTONIUM

0

TRANSIT TIME CALCULATIONS (1), OR
DIFFUSION HOLDUP-TIME CALCULATIONS (2) ?

1

LONG OR SHORT OUTPUT? (1 OR 2)

1

SUMMARY OF USER INPUT VALUES

NSTEP = 6

STEP NO.	FLOW RATE		MEASURED ACTIVITY
	(GPM)	(L/S)	
1	90.2	5.7	528.7
2	79.9	5.0	499.4
3	69.8	4.4	462.1
4	59.9	3.8	430.2
5	49.6	3.1	376.1
6	0.0	0.0	20.5

FPU = 0.00

TRANSIT TIME CALCULATIONS SELECTED

OPTIONS:

- (1) INITIATE PROCESSING OF GIRAFFE CALCULATIONS
- (2) SOME INPUT VALUES FAULTY--WOULD LIKE TO RE ENTER INPUT
- (3) TERMINATE EXECUTION

ENTER OPTION NUMBER

1

OUTPUT FROM YIELDS

TABLE OF REFERENCE DATA (GLEANED FROM MEEK & RIDER YIELD COMPILATIONS)

GROUP NO.	DAUGHTER ISOTOPE	Y I E L D		PARENT ISOTOPE	Y I E L D	
		U235	PU239		U235	PU-239
1	BR-87	1.305	0.442	SE-87	0.6045	0.572E-03
2	BR-88	1.609	0.267	SE-88	0.2543	0.114E-03
3	TE-136	1.189	0.491	SB-136	0.0139	0.236E-04
4	I-137	2.411	1.597	TE-137	0.2972	0.847E-03
5	BR-89	1.094	0.120	SE-89	0.0590	0.160E-04
6	BR-93	2.564	0.704	KR-93	0.2815	0.191E-03
7	I-138	1.264	0.597	TE-138	0.0537	0.119E-03
8	BR-94	1.555	0.294	KR-94	0.0920	0.407E-04
9	I-139	0.424	0.181	TE-139	0.0018	0.120E-04

Fig. 11. Long-form GIRAFFE Output for Example 2

Fig. 11 (Contd.)

TABLE OF CORRECTED YIELDS
BASED ON FPU = 0.00

GROUP NO.	DAUGHTER ISOTOPE	YIELD	PARENT ISOTOPE	YIELD
1	BR-87	1.305	SE-87	0.6045
2	BR-88	1.609	SE-88	0.2543
3	TE-136	1.189	SB-136	0.0139
4	I-137	2.421	TE-137	0.2972
5	BR-89	1.084	SE-89	0.0590
6	RB-93	2.564	KR-93	0.2815
7	I-138	1.264	TE-138	0.0537
8	RB-94	1.555	KR-94	0.0920
9	I-139	0.424	TE-139	0.0058

.....
.....TABLE OF REFERENCE NUCLEAR CONSTANTS.....
.....

GROUP NO.	PARENT ISOTOPE	HALF LIFE (SECONDS)	DECAY CONSTANT (1/S)	DAUGHTER ISOTOPE	HALF LIFE (SECONDS)	DECAY CONSTANT (1/S)
1	SE-87	5.59	0.124	BR-87	55.7	0.0124
2	SE-88	1.50	0.462	BR-88	15.9	0.0436
3	SB-136	0.82	0.850	TE-136	21.0	0.0330
4	TE-137	3.50	0.198	I-137	24.6	0.0282
5	SE-89	0.41	1.691	BR-89	4.5	0.1540
6	KR-93	1.27	0.546	RB-93	5.8	0.1195

Fig. 11 (Contd.)

7	TE-138	1.60	0.433	I-138	6.5	0.1066
8	KR-94	0.21	3.301	RB-94	2.8	0.2477
9	TE-139	0.01	100.000	I-139	2.4	0.2888
.....						

ENTER VALUE OF EFFECTIVE ESCAPE RATE COEFFICIENT
LAMDAE, IN SECONDS-1

100

ENTER STARTING VALUE FOR INDEPENDENT VARIABLE T

11.0

ENTER INCREMENT DT

0.25

ENTER THE TOTAL NUMBER OF ITERATIONS, NREP

10

*****ITERATION LOG FROM SUBROUTINE TRANSIT*****

ITERATION NUMBER	INDEPENDENT VARIABLE	FLOW STEP	PREDICTED ACTIVITY	CORRECTED ACTIVITY	CORRELATION COEFFICIENT
1	11.000	1	1207.0	496.7	0.99941
		2	1129.3	469.6	
		3	1042.4	434.3	
		4	944.9	404.8	
		5	827.9	353.4	
		6	0.0	20.5	
2	11.250	1	1183.2	496.7	0.99954
		2	1108.0	469.6	
		3	1023.8	434.3	
		4	929.1	404.8	
		5	815.4	353.4	
		6	0.0	20.5	
3	11.500	1	1160.1	496.7	0.99963
		2	1087.4	469.6	
		3	1005.7	434.3	
		4	913.9	404.8	
		5	803.3	353.4	
		6	0.0	20.5	

Fig. 11 (Contd.)

CORRELATION COEFFICIENTS AND FIRST DERIVATIVES FROM SUBROUTINE DER												
		ITERATION		CORRELATION		FIRST						
		NUMBER		COEFFICIENT		DERIVATIVE						
4	11.750	1	1137.8	496.7	0.99970	1	0.99941	0.548E-03				
		2	1067.4	469.6		2	0.99954	0.443E-03				
		3	988.2	434.3		3	0.99963	0.339E-03				
		4	899.0	404.8		4	0.99970	0.240E-03				
		5	791.4	353.4		5	0.99975	0.145E-03				
		6	0.0	20.5		6	0.99978	0.550E-04				
5	12.000	1	1116.2	496.7	0.99975	7	0.99978	-0.300E-04				
		2	1048.0	469.6		8	0.99976	-0.110E-03				
		3	971.3	434.3		9	0.99972	-0.188E-03				
		4	884.6	404.8		10	0.99967	-0.263E-03				
		5	779.9	353.4								
		6	0.0	20.5								
6	12.250	1	1095.3	496.7	0.99978							
		2	1029.2	469.6								
		3	954.8	434.3								
		4	870.6	404.8								
		5	768.6	353.4								
		6	0.0	20.5								
DERIVATIVE VECTOR VANISHES AT LMBDAE= 12.41 SECONDS												
***** R E S U L T S *****												
7	12.500	1	1075.1	496.7	0.99978	FERD	FERD	MEASURED	CORRECTED	PREDICTED	RESIDUALS	RESIDUALS
		2	1011.0	469.6		FLOW	FLOW	ACTIVITY	ACTIVITY	ACTIVITY	RESIDUALS	OF
		3	938.8	434.3		GPM	L/S	COUNTS/S	COUNTS/S	COUNTS/S	COUNTS/S	MEASURED
		4	857.0	404.8		90.2	5.69	528.7	496.7	1082.3	0.6	0.1
		5	757.6	353.4		79.9	5.04	499.4	469.6	1017.5	-0.8	-0.2
		6	0.0	20.5		69.8	4.40	462.1	434.3	944.5	2.3	0.5
8	12.750	1	1055.5	496.7	0.99976	59.9	3.78	430.2	404.8	861.8	-4.6	-1.1
		2	993.4	469.6		49.6	3.13	376.1	353.4	761.5	2.6	0.7
		3	923.2	434.3		0.0	0.00	20.5	20.5	0.0	-0.1	-0.3
		4	843.7	404.8		TRANSIT TIME = 12.4 S						
		5	746.9	353.4		C = SLOPE = 0.44						
		6	0.0	20.5		STANDARD DEVIATION OF SLOPE = 0.001						
9	13.000	1	1036.5	496.7	0.99972	GAMMA = Y INTERCEPT = 20.4 COUNTS/S						
		2	976.2	469.6		STANDARD DEVIATION OF GAMMA = 2.9 COUNTS/S						
		3	908.1	434.3		COEFFICIENT OF CORRELATION, XFIT = 0.99978						
		4	830.8	404.8		8/27/79 FFR TEST ANALYSIS						
		5	736.5	353.4		*****						
		6	0.0	20.5		*****						
10	13.250	1	1018.1	496.7	0.99967							
		2	959.6	469.6								
		3	893.5	434.3								
		4	818.2	404.8								
		5	726.3	353.4								
		6	0.0	20.5								

Fig. 11 (Contd.)

Fig. 11 (Contd.)

C. Example 3

Examples 3 and 4 both use as input the FFR test results listed in Table VII. Example 3 illustrates the information generated when the user specifies the short-form output option for a problem requiring subroutine LMBDA. Note that the user assigned a value of $TRANS = 15.0$ s for the DN-precursor transit time. Also, the user estimated $FPU = 0.30$ as the fraction of fissions attributable to plutonium in the fission source irradiated during the FFR test. Figure 12 shows the code printout for Example 3.

TABLE VII. Results from FFR Test Performed on October 3, 1979

Flow Step	FERD Flow, L/s	Measured Activity, counts/s	Flow Step	FERD Flow, L/s	Measured Activity, counts/s
1	5.7	1941.0	4	3.8	1678.9
2	5.0	1856.6	5	3.1	1525.8
3	4.4	1709.6	6	0.0	20.0

```

ENTER ONE LINE CASE DESCRIPTION
10/23/79 FFR TEST ANALYSIS
INPUT NUMBER OF FLOW STEPS IN FLOW REDUCTION TEST

ENTER THE 6 FLOW RATES IN GPM
90.0 80.0 70.3 59.9 49.7 0

ENTER 6 CORRESPONDING MEASURED ACTIVITIES
1941.0 1856.6 1709.6 1678.9 1525.8 20.0

ENTER FPU, THE FRACTION OF FISSIONS OCCURRING IN PLUTONIUM
0.3

TRANSIT TIME CALCULATIONS (1), OR
DIFFUSION HOLDUP-TIME CALCULATIONS (2) ?
2

LONG OR SHORT OUTPUT? (1 OR 2)
2

-----
SUMMARY OF USER INPUT VALUES
-----

NSTEP      6

STEP  FLOW  RATE  MEASURED
NO.   (GPM) (L/S)  ACTIVITY
1     90.0  5.7   1941.0
2     80.0  5.0   1856.6
3     70.3  4.4   1709.6
4     59.9  3.8   1678.9
5     49.7  3.1   1525.8
6       0.0  0.0     20.0

```

Fig. 12
Short-form GIRAFFE Out-
put for Example 3

FFU = 0.30

HOLDUP-TIME CALCULATIONS SELECTED

SHORT FORM OUTPUT REQUESTED

CASE DESCRIPTION:

10/3/79 FER TEST ANALYSIS

OPTIONS:

- (1) INITIATE PROCESSING OF GIRAFFE CALCULATIONS
- (2) SOME INPUT VALUES FAULTY--WOULD LIKE TO RE-ENTER INPUT
- (3) TERMINATE EXECUTION

ENTER OPTION NUMBER

1

ENTER CORE-SODIUM TRANSPORT TIME IN SECONDS

15.0

ENTER STARTING VALUE FOR INDEPENDENT VARIABLE LAMDAE

.005

ENTER INCREMENT DLE

.02

ENTER THE TOTAL NUMBER OF ITERATIONS, NREP

5

Fig. 12 (Contd.)

***** R E S U L T S *****

FEED FLOW GPM	FEED FLOW L/S	MEASURED ACTIVITY COUNTS/S	CORRECTED ACTIVITY COUNTS/S	PREDICTED ACTIVITY COUNTS/S	RESIDUALS COUNTS/S	RESIDUALS OF MEASURED
90.0	3.68	1941.0	1909.0	422.3	18.2	-1.0
80.0	3.07	1856.6	1826.4	410.9	-7.3	-0.4
70.3	4.44	1709.6	1681.4	392.1	55.1	3.3
59.5	3.78	1628.9	1653.5	367.5	-24.4	-1.5
49.7	3.14	1525.8	1503.1	337.5	-5.4	0.4
0.0	0.00	20.0	20.0	0.0	0.3	1.4

LMBDAE 0.069 SECONDS-1

HOLDUP TIME 1/LMBDAE 14.4 S

E SLOPE 4.38

STANDARD DEVIATION OF SLOPE 0.037

GAMMA Y INTERCEPT 20.3 COUNTS/S

STANDARD DEVIATION OF GAMMA 31.8 COUNTS/S

COEFFICIENT OF CORRELATION, XFEED = 0.99838

10/3/79 FFR TEST ANALYSIS

Fig. 12 (Contd.)

D. Example 4

This example uses the same FFR-test input data as Example 3, above. The long-form output option is selected to illustrate the additional diagnostic information made available from subroutine LMBDA. Figure 13 shows the GIRAFFE printout for this example.

```

ENTER ONE-LINE CASE DESCRIPTION
10/3/79 FFR TEST ANALYSIS

INPUT NUMBER OF FLOW STEPS IN FLOW REDUCTION TEST
6

ENTER THE 6 FLOW RATES IN GPM
90.0,80.0,70.3,59.9,49.7,0

ENTER 6 CORRESPONDING MEASURED ACTIVITIES
1941.0,1856.6,1709.6,1678.9,1525.8,20.0

ENTER FPU, THE FRACTION OF FISSIONS OCCURRING IN PLUTONIUM
0.3

TRANSIT TIME CALCULATIONS (1), OR
DIFFUSION HOLDUP-TIME CALCULATIONS (2) ?
2

LONG OR SHORT OUTPUT? (1 OR 2)
1

-----
SUMMARY OF USER INPUT VALUES
-----

NSTEP = 6

STEP      FLOW  RATE
NO.      (GPM) (L/S)    MEASURED
        ACTIVITY
  1      90.0   5.7    1941.0
  2      80.0   5.0    1856.6
  3      70.3   4.4    1709.6
  4      59.9   3.8    1678.9
  5      49.7   3.1    1525.8
  6       0.0   0.0     20.0

FPU = 0.30

HOLDUP-TIME CALCULATIONS SELECTED

```

Fig. 13. Long-form GIRAFFE Output for Example 4

LONG FORM OUTPUT REQUESTED

CASE DESCRIPTION:
10/3/79 PER TEST ANALYSIS

OPTIONS:

- (1) INITIATE PROCESSING OF GIRAFFE CALCULATIONS
- (2) SOME INPUT VALUES FAULTY--WOULD LIKE TO RE-ENTER INPUT
- (3) TERMINATE EXECUTION

ENTER OPTION NUMBER

1

OUTPUT FROM YIELDS

TABLE OF REFERENCE DATA (GLEANED FROM MEEK & RIDER YIELD COMPILATIONS)

GROUP NO.	DAUGHTER ISOTOPE	Y I E L D		PARENT ISOTOPE	Y I E L D	
		U235	PU239		U235	PU-239
1	BR-87	1.305	0.442	SE-87	0.6045	0.572E-03
2	BR-88	1.609	0.267	SE-88	0.2543	0.114E-03
3	TE-136	1.189	0.491	SR-136	0.0139	0.236E-04
4	I-137	2.421	1.597	TE-137	0.2972	0.847E-03
5	BR-89	1.084	0.120	SE-89	0.0590	0.160E-04
6	BR-93	2.564	0.704	KR-93	0.2815	0.291E-03
7	I-138	1.264	0.597	TE-138	0.0537	0.119E-03
8	BR-94	1.555	0.294	KR-94	0.0920	0.402E-04
9	I-139	0.424	0.181	TE-139	0.0058	0.120E-04

Fig. 13 (Contd.)

 TABLE OF CORRECTED YIELDS
 BASED ON FPU = 0.30

GROUP NO.	DAUGHTER ISOTOPE	YIELD	PARENT ISOTOPE	YIELD
1	BR-87	1.046	SE-87	0.4233
2	BR-88	1.206	SE-88	0.1780
3	TE-136	0.980	SB-136	0.0097
4	I-137	2.174	TE-137	0.2083
5	BR-89	0.795	SE-89	0.0413
6	RB-93	2.006	KR-93	0.1971
7	I-138	1.064	TE-138	0.0776
8	RB-94	1.177	KR-94	0.0644
9	I-139	0.351	TE-139	0.0041

.....
TABLE OF REFERENCE NUCLEAR CONSTANTS.....

GROUP NO.	PARENT ISOTOPE	HALF LIFE (SECONDS)	DECAY CONSTANT (1/S)	DAUGHTER ISOTOPE	HALF LIFE (SECONDS)	DECAY CONSTANT (1/S)
1	SE-87	5.59	0.124	BR-87	55.7	0.0124
2	SE-88	1.50	0.462	BR-88	15.9	0.0436
3	SB-136	0.82	0.850	TE-136	21.0	0.0330
4	TE-137	3.50	0.198	I-137	24.6	0.0282
5	SE-89	0.41	1.691	BR-89	4.5	0.1540
6	KR-93	1.27	0.546	RB-93	5.8	0.1195
7	TE-138	1.60	0.433	I-138	6.5	0.1066
8	KR-94	0.21	3.301	RB-94	2.8	0.2477
9	TE-139	0.01	100.000	I-139	2.4	0.2888

.....

Fig. 13 (Contd.)

15.0

ENTER STARTING VALUE FOR INDEPENDENT VARIABLE LAMDAE

0.025

ENTER INCREMENT DLE

0.01

ENTER THE TOTAL NUMBER OF ITERATIONS, NREF

10

*****ITERATION LOG FROM SUBROUTINE LMBDA*****

ITERATION NUMBER	INDEPENDENT VARIABLE	FLOW STEP	PREDICTED ACTIVITY	CORRECTED ACTIVITY	CORRELATION COEFFICIENT
1	0.0250	1	266.4	1909.0	0.99803
		2	257.2	1826.4	
		3	246.6	1681.4	
		4	232.6	1653.5	
		5	215.3	1503.1	
		6	0.0	20.0	
2	0.0350	1	318.9	1909.0	0.99820
		2	307.6	1826.4	
		3	294.4	1681.4	
		4	277.2	1653.5	
		5	256.0	1503.1	
		6	0.0	20.0	
3	0.0450	1	359.1	1909.0	0.99830
		2	346.0	1826.4	
		3	330.9	1681.4	
		4	311.0	1653.5	
		5	286.7	1503.1	
		6	0.0	20.0	
4	0.0550	1	391.2	1909.0	0.99835
		2	376.6	1826.4	
		3	359.7	1681.4	
		4	337.7	1653.5	
		5	310.8	1503.1	
		6	0.0	20.0	

Fig. 13 (Contd.)

5	0.0650	1	417.5	1909.0	0.99837
		2	401.6	1826.4	
		3	383.3	1681.4	
		4	359.4	1653.5	
		5	330.3	1503.1	
		6	0.0	20.0	
6	0.0750	1	439.5	1909.0	0.99838
		2	422.5	1826.4	
		3	402.9	1681.4	
		4	377.5	1653.5	
		5	346.5	1503.1	
		6	0.0	20.0	
7	0.0850	1	458.3	1909.0	0.99836
		2	440.3	1826.4	
		3	419.6	1681.4	
		4	392.8	1653.5	
		5	360.1	1503.1	
		6	0.0	20.0	
8	0.0950	1	474.6	1909.0	0.99834
		2	455.7	1826.4	
		3	434.0	1681.4	
		4	405.9	1653.5	
		5	371.8	1503.1	
		6	0.0	20.0	
9	0.1050	1	488.8	1909.0	0.99831
		2	469.1	1826.4	
		3	446.0	1681.4	
		4	417.4	1653.5	
		5	382.0	1503.1	
		6	0.0	20.0	
10	0.1150	1	501.4	1909.0	0.99827
		2	481.0	1826.4	
		3	457.6	1681.4	
		4	427.5	1653.5	
		5	390.9	1503.1	
		6	0.0	20.0	

Fig. 13 (Contd.)

CORRELATION COEFFICIENTS AND FIRST DERIVATIVES FROM SUBROUTINE DER

ITERATION NUMBER	CORRELATION COEFFICIENT	FIRST DERIVATIVE
1	0.99803	0.199E-01
2	0.99820	0.138E-01
3	0.99830	0.847E-02
4	0.99835	0.423E-02
5	0.99837	0.146E-02
6	0.99838	-0.407E-03
7	0.99836	-0.169E-02
8	0.99834	-0.257E-02
9	0.99831	-0.325E-02
10	0.99827	-0.382E-02

DERIVATIVE VECTOR VANISHES AT LMBDAE= 0.7248E-01 SECONDS-1

***** R E S U L T S *****

FERD FLOW GPM	FERD FLOW L/S	MEASURED ACTIVITY COUNTS/S	CORRECTED ACTIVITY COUNTS/S	PREDICTED ACTIVITY COUNTS/S	RESIDUALS COUNTS/S	RESIDUALS OF MEASURED
90.0	5.68	1941.0	1909.0	434.3	-17.4	-0.9
80.0	5.05	1856.6	1826.4	417.5	-6.9	-0.4
70.3	4.44	1709.6	1681.4	398.3	55.1	3.3
59.9	3.78	1678.9	1653.5	373.2	-24.9	-1.5
49.7	3.14	1525.8	1503.1	342.6	-6.4	-0.4
0.0	0.00	20.0	20.0	0.0	0.5	2.7

LMBDAE = 0.072 SECONDS-1

HOLDUP TIME 1/LMBDAE = 13.8 S

C = SLOPE = 4.31

STANDARD DEVIATION OF SLOPE = 0.036

GAMMA = Y INTERCEPT = 20.5 COUNTS/S

STANDARD DEVIATION OF GAMMA = 31.8 COUNTS/S

COEFFICIENT OF CORRELATION, XF11 = 0.99838

10/3/79 FFR TEST ANALYSIS

APPENDIX A

FORTRAN Flowchart for MAIN Program

ENTRANCE

V

V

```

*****
*C*****
*C***** G I R A F F E *****
*C*****
*   EDM
*C
*C THE GIRAFFE CODE COMPUTES THE TRANSIT TIME FROM THE CORE
*C TO THE IHX OUTLET FOR DN EMITTERS IN EBR-2 PRIMARY SODIUM.
*C ALSO CAN BE EMPLOYED TO DETERMINE EFFECTIVE ISOTOPIC
*C HOLDUP TIME FOR FISSION SOURCE.
*C
*C   DEFINITION OF PRINCIPAL CODE VARIABLES:
*C
*C   LD AND LP ARE REAL ARRAYS CONTAINING DECAY CONSTANTS FOR
*C   DAUGHTER AND PARENT ISOTOPES, RESPECTIVELY, IN SEC-1.
*C   VALUES ARE FROM MEEK AND RIDER.
*C   YD CONTAINS INDEPENDENT FAST FISSION YIELDS FOR DAUGHTERS ISOTOPES
*C   YP CONTAINS CUMULATIVE YIELDS FOR PARENT ISOTOPES
*C
*C   PARENT ISOTOPES (PRIMARY FISSION PRODUCTS) ARE:
*C   BR-87, BR-88, TE-136, I-137, BR-89, RB-93, I-138,
*C   RB-94, I-139
*C   DAUGHTER ISOTOPES (DN EMITTERS) ARE:
*C   SE-87, SE-88, SR-136, TE-137, SE-89, KR-93, TF-138,
*C   KR-94, TE-139
*C
*C   PN IS A 9-ELEMENT ARRAY OF EMISSION PROBABILITIES IN %'S
*C   RC = VECTOR OF EXPERIMENTALLY MEASURED RECOIL
*C   CORRECTION FACTORS (DIMENSIONLESS)
*C   SP AND SD CONTAIN ARE THE FISSION-PRODUCT SOURCE TERMS FOR
*C   THE PARENT AND DAUGHTER SPECIES, RESPECTIVELY.
*C   UNITS ARE FISSIONS PER S.
*C   NSTEP IS THE NUMBER OF FLOW STEPS IN THE FFR TEST.
*C   F IS AN INPUT VECTOR OF FERD-LOOP FLOW RATES.
*C   AM IS AN INPUT VECTOR OF MEASURED ACTIVITIES, IN COUNTS/S.
*C   TFL IS A VECTOR OF DIMENSION NOT LESS THAN NSTEP. TFL(I)
*C   CONTAINS THE FERD-LOOP TRANSIT TIME FROM THE IHX OUTLET
*C   TO THE FERD DETECTORS AT FLOW RATE F(I)
*C   BK(I) CONTAINS THE TRAMP BACKGROUND, IN COUNTS/S, AT F(I)
*C   A(I) CONTAINS THE CORRECTED ACTIVITY (MEASURED MINUS
*C   TRAMP) AT FLOW RATE F(I)
*C   FPU IS AN INPUT CONSTANT CONTAINING THE FRACTION
*C   OF FISSIONS OCCURRING IN PU-239.
*C
*   DIMENSION TFL(10),TT(50),COR(50),BKG(50),A(10),BK(10)
*   DIMENSION RES(10),RESP(10),F2(10),T(10),F(10),AP(10),AM(10)

```



```

*****
                                U
                                U
                                U
*****
*      IF (IDUT.EQ.2) GO TO 39
*****
                                U
                                U
                                U
*****
*      WRITE(S,19)
*19  FORMAT(' ',//)
*      WRITE(S,19)
*      WRITE(S,18)
*      WRITE(S,17)
*17  FORMAT(' ',15(' '), 'TABLE OF REFERENCE NUCLEAR
*      & CONSTANTS',14(' '),
*C    CALCULATE HALF LIVES AND STORE IN 2-D ARRAY THALF
*C
*****
                                U
                                U
                                U
*****
*      DO 43 I=1,9
*****
                                U
                                U
                                U
*****
*      THALF(1,I)=0.693/LP(I)
*      THALF(2,I)=0.693/LD(I)
*****
                                U
                                U
                                U
*****
*43  CONTINUE
*****
                                U
                                U
                                U
*****
*      WRITE(S,42)
*      FORMAT(' ',//,29X, 'DECAY',25X, 'DECAY')
*      WRITE(S,41)
*41  FORMAT(' ', 'GROUP',3X, 'PARENT',2X, 'HALF LIFE',1X,
*      & 'CONSTANT',3X, 'DAUGHTER',2X, 'HALF LIFE', 'CONSTANT')
*      WRITE(S,40)
*40  FORMAT(' NO.',4X, 'ISOTOPE',2X, '(SECONDS)',3X, '(1/S)',
*      & 4X, 'ISOTOPE',3X, '(SECONDS)',3X, '(1/S)')
*****
                                U
                                U
                                U
*****
*      DO 44 I=1,9
*****
                                U
                                U
                                U
*****
*      WRITE(S,45) I, IS01(I), THALF(1,I), LP(I), IS02(I),
*      & THALF(2,I), LD(I)
*****

```

```

*****
      U
      U
      U
*****
.....*44  CONTINUE
*****
      U
      U
      U
*****
*45  FORMAT('0',I3,5X,A6,F9.2,F10.3,5X,A6,F9.1,F11.4)
*    WRITE(L,18)
*18  FORMAT(' ',45(' '))
*    WRITE(S,46)
*46  FORMAT(' ',///)
*****
      U
      U
      U
.....*34  CONTINUE
*34  CONTINUE
*34  ASSIGN VALUES FOR PARENT AND DAUGHTER FISSION SOURCE TERMS
*34  VALUES ARE HELD IN REAL 1-D ARRAYS SP AND SD
*34  THESE ARRAYS ARE USED IN SUBROUTINE FERD. THEIR VALUES
*34  ARE NOT CHANGED DURING EXECUTION
*34
*****
      U
      U
      U
.....*    DO 2 I=1,9
*****
      U
      U
      U
*****
*    SP(I) = YPC(I) * RC(I) * 1.354E7
*    SD(I) = YD(I) * RC(I) * 1.354E7
*****
      U
      U
      U
.....*2  CONTINUE
*****
      U
      U
      U
*****
*34  COMPUTE FERD-LOOP TRANSIT TIMES, IN SECS, AND STORE IN THE
*34  FIRST NSTEP ELEMENTS OF THE 1-D ARRAY TFL
*34
*****
      U
      U
      U
.....*    DO 1 I=1,NSTEP
*****
      U
      U
      U

```



```

*11      FORMAT(5F)
*0
*0      CLOSE INTERFALE FILE BKG
*0
*0      ENDFILE(1)
*0
*0      COMPUTE NSTEP TRAMP BACKGROUND VALUES AND STORE IN
*0      ARRAY BK.  THESE VALUES CORRESPOND TO THE NSTEP FLOW
*0      RATES F.  BK ARRAY IS THEN USED TO COMPUTE NET ACTIVITY.  A
*0
*****
*0
*0      DO 3 I=1,NSTEP
*0
*****
*0
*0      ITFL=IFIX(F(I)/2.)
*0
*****
*0
*0      IF(ITFL)4,4,5
*0
*****
*0
*0      A(I)=AM(I)
*0
*****
*0
*0      GOTO 3
*0
*****
*0
*0      D' .....
*0
*****
*0
*0      CONTINUE
*0      BK(I)=BKG(ITFL)
*0      A(I)=AM(I)-BK(I)
*0
*****
*0
*0      D' .....
*0
*****
*0
*0      CONTINUE
*0
*****
*0
*0      D' .....
*0
*****
*0
*0      CORRECTED ACTIVITIES (I.E. MEASURED VALUES MINUS TRAMP
*0      BACKGROUND) ARE STORED IN THE FIRST NSTEP ELEMENTS OF
*0      1-D ARRAY A.
*0      A IS THEN USED AS AN INPUT VECTOR TO SUBROUTINE TRANSIT
*0      OR LMBDA.  A IS NOT DESTROYED DURING EXECUTION.
*0

```

```

*****
      U
      U
      U
*****
*      IF (ISWITCH,EQ,2) GOTO 38      *.....0
*****
      U
      U
      U
*****
*      CALL TRANSIT (IOUT,RES,RESP,IFL,T,F,AF,A,NDIM,NSTEP)      *
*      CALL OUTPUT (F,FSI,AF,AM,... RES,RESP,ISWITCH,NSTEP,NDIM)      *
*****
      U
      U
      U
*****
*      STOP      *
*****
      0 .....0
      U
*****
*38      CONTINUE      *
*      CALL LMRDA (IOUT,RES,RESP,IFL,F,AF,A,NDIM,T,NSTEP)      *
*      CALL OUTPUT (F,FSI,AF,AM,A RES,RESP,ISWITCH,NSTEP,NDIM)      *
*****
      U
      U
      U
*****
*      STOP      *
*****
*      FND      *
*****

```

LIST OF STATEMENT NUMBERS USED IN THE ABOVE ROUTINE.

[illegible]

APPENDIX B

FORTRAN Listing of GIRAFFE Code

```

10  C*****
20  C***** G I R A F F E *****
30  C*****
40  C
50  C
60  C THE GIRAFFE CODE COMPUTES THE TRANSIT TIME FROM THE CORE
70  C TO THE IHX OUTLET FOR DN EMITTERS IN EBR-2 PRIMARY SODIUM.
80  C ALSO CAN BE EMPLOYED TO DETERMINE EFFECTIVE ISOTOPIC
90  C HOLDUP TIME FOR FISSION SOURCE.
100 C
110 C  DEFINITION OF PRINCIPAL CODE VARIABLES:
120 C
130 C  LD AND LP ARE REAL ARRAYS CONTAINING DECAY CONSTANTS FOR
140 C    DAUGHTER AND PARENT ISOTOPES, RESPECTIVELY, IN SEC-1.
150 C    VALUES ARE FROM MEEK AND RIDER.
160 C  YD CONTAINS INDEPENDENT FISSION YIELDS FOR DAUGHTERS ISOTOPES
170 C  YP CONTAINS CUMULATIVE YIELDS FOR PARENT ISOTOPES
180 C
190 C  PARENT ISOTOPES (PRIMARY FISSION PRODUCTS) ARE:
200 C  BR-87, BR-88, TE-136, I-137, BR-89, RB-93, I-138,
210 C  RB-94, I-139
220 C  DAUGHTER ISOTOPES (DN EMITTERS) ARE:
230 C  SE-87, SE-88, SB-136, TE-137, SE-89, KR-    , TE-138,
240 C  KR-94, TE-139
250 C
260 C  FN IS A 9-ELEMENT ARRAY OF EMISSION PROBABILITIES IN %'S
270 C  RC = VECTOR OF EXPERIMENTALLY MEASURED RECOIL
280 C    CORRECTION FACTORS (DIMENSIONLESS)
290 C  SP AND SD CONTAIN ARE THE FISSION-PRODUCT SOURCE TERMS FOR
300 C  THE PARENT AND DAUGHTER SPECIES, RESPECTIVELY.
310 C  UNITS ARE FISSIONS PER S.
320 C  NSTEP IS THE NUMBER OF FLOW STEPS IN THE FFR TEST.
330 C  F IS AN INPUT VECTOR OF FERD-LOOP FLOW RATES.
340 C  AM IS AN INPUT VECTOR OF MEASURED ACTIVITIES, IN COUNTS/S.
350 C  TFL IS A VECTOR OF DIMENSION NOT LESS THAN NSTEP.  TFL(I)
360 C    CONTAINS THE FERD-LOOP TRANSIT TIME FROM THE IHX OUTLET
370 C    TO THE FERD DETECTORS AT FLOW RATE F(I)
380 C  BK(I) CONTAINS THE TRAMP BACKGROUND, IN COUNTS/S, AT F(I)
390 C  A(I) CONTAINS THE CORRECTED ACTIVITY (MEASURED MINUS
400 C    TRAMP) AT FLOW RATE F(I)
410 C  FPU IS AN INPUT CONSTANT CONTAINING THE FRACTION
420 C    OF FISSIONS OCCURRING IN PU-239.
430 C
440 C  DIMENSION TFL(10),TT(50),COR(50),BKG(50),A(10),BK(10)
450 C  DIMENSION RES(10),RESP(10),F2(10),T(10),F(10),AP(10),AM(10)
460 C  REAL LE,SP(9),SD(9),LD(9),YD(9),RC(9),FN(9),LP(9),YPC(9)
470 C  DIMENSION XLD(9),XRC(9),XFN(9),XLP(9),FSI(10),THALF(2,10)
480 C  DATA XLD/.01244,.04359,.03301,.02818,.154,.1195,.1066,

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```

490      &      .2477,.2888/
500      DATA XRC/.9657,.9611,.7444,.8738,.9569,.9433,.7253,.9399,.8422/
510      DATA XPN/.0235,.0550,.0075,.0665,.136,.0173,.0514
520      &      ,0.093,0.139/
530      DATA XLP/.124,.462,.850,.198,1.691,.546,.433,3.301,100./
540      DOUBLE PRECISION ISO1(9),ISO2(9)
550      DO 53 I=1,9
560          LD(I)=XLD(I)
570          RC(I)=XRC(I)
580          PN(I)=XPN(I)
590          LP(I)=XLP(I)
600      53 CONTINUE
610      C
620      C  CONSTANTS REQUIRED FOR DECAY CALCULATIONS ARE PASSED
630      C  TO SUBROUTINE FERD VIA COMMON AREA1
640      C
650      COMMON AREA1/LD,SD,RC,PN,LP,SF
660      C
670      C  AREA CONTAINS THE COMPUTED RESULTS FROM SUBROUTINES
680      C  TIME AND LMBDA
690      C
700      COMMON/AREA2/TRANS,XFIT,SLOPE,GAMMA,LE
710      C
720      C  NDIM IS A NONNEGATIVE INTEGER THAT IS USED IN
730      C  EXECUTION TIME DIMENSIONING OF ARRAYS IN SUBROUTINES,
740      C  NDIM CANNOT BE LESS THAN NSTEP,
750      C
760      NDIM=10
770      C
780      C  CALL SUBROUTINE INPUT TO ASSIGN VALUES TO ALL USER INPUT
790      C  VARIABLES,
800      C
810      CALL INPUT(NSTEP,F,AM,FSI,FFU,ISWITCH,IOUT,NDIM)
820      C
830      C  A CALL IS MADE TO SUBROUTINE YIELDS TO COMPUTE THE WEIGHTED
840      C  YIELDS FOR PARENT AND DAUGHTER ISOTOPES, BASED ON
850      C  THE FRACTION OF FISSIONS OCCURRING IN PLUTONIUM, FFU,
860      C
870      CALL YIELDS(FFU,IOUT,YD,YFC,ISO1,ISO2)
880      C
890      C  IF LONG-FORM OUTPUT REQUESTED, PRODUCE TABLE OF REFERENCE
900      C  NUCLEAR CONSTANTS FOR PARENT AND DAUGHTER ISOTOPES
910      C
920      IF(IOUT.EQ.2) GO TO 39
930      WRITE(5,19)
940      19 FORMAT(' ',//)
950      WRITE(5,19)
960      WRITE(5,18)
970      WRITE(5,17)

```

```

980      17 FORMAT(' ',15(' '), 'TABLE OF REFERENCE NUCLEAR
990      & CONSTANTS',14(' '))
1000     C
1010     C  CALCULATE HALF LIVES AND STORE IN 2-D ARRAY THALF
1020     C
1030     DO 43 I=1,9
1040         THALF(1,I)=0.693/LP(I)
1050         THALF(2,I)=0.693/LD(I)
1060     43 CONTINUE
1070     WRITE(5,42)
1080     42 FORMAT(' ',//,29X,'DECAY',25X,'DECAY')
1090     WRITE(5,41)
1100     41 FORMAT(' ', 'GROUP',3X,'PARENT',2X,'HALF LIFE',1X,
1110     & 'CONSTANT',3X,'DAUGHTER',2X,'HALF LIFE', 'CONSTANT')
1120     WRITE(5,40)
1130     40 FORMAT(' NO.',4X,'ISOTOPE',2X,'(SECONDS)',3X,'(1/S)',
1140     & 4X,'ISOTOPE',3X,'(SECONDS)',3X,'(1/S)')
1150     DO 44 I=1,9
1160         WRITE(5,45)I,IS01(I),THALF(1,I),LP(I),IS02(I),
1170         & THALF(2,I),LD(I)
1180     44 CONTINUE
1190     45 FORMAT('0',I3,5X,A6,F9.2,F10.3,5X,A6,F9.1,F11.4)
1200     WRITE(5,18)
1210     18 FORMAT(' ',65(' '))
1220     WRITE(5,46)
1230     46 FORMAT(' ',//)
1240     39 CONTINUE
1250     C
1260     C  ASSIGN VALUES FOR PARENT AND DAUGHTER FISSION SOURCE TERMS
1270     C  VALUES ARE HELD IN REAL 1-D ARRAYS SP AND SD
1280     C  THESE ARRAYS ARE USED IN SUBROUTINE FERD. THEIR VALUES
1290     C  ARE NOT CHANGED DURING EXECUTION
1300     C
1310     DO 2 I=1,9
1320         SP(I) = YPC(I) * RC(I) * 1.354E7
1330         SD(I) = YD(I) * RC(I) * 1.354E7
1340     2 CONTINUE
1350     C
1360     C  COMPUTE FERD-LOOP TRANSIT TIMES, IN SECS, AND STORE IN THE
1370     C  FIRST NSTEP ELEMENTS OF THE 1-D ARRAY TFL
1380     C
1390     DO 1 I=1,NSTEP
1400         TFL(I)=593.03/F(I)
1410     1 CONTINUE
1420     C
1430     C  READ IN 50 VALUES FOR TRAMP BACKGROUND ARRAY BKG
1440     C  VALUES ARE IN UNITS OF COUNTS/S, AND CORRESPOND TO FERD
1450     C  FLOW RATES OF 2,4,6,...,100 GPM.
1460     C
1470     CALL IFILE2(1,'BKG.DAT')
1480     READ(1,11,ERR=12,END=35)BKG

```

```

1490      GO TO 13
1500      12 WRITE(5,14)
1510      14 FORMAT(' ', 'BAD DATA IN BKG FILE', //, 'VALUES READ ARE:')
1520      WRITE(5,15)BKG
1530      15 FORMAT(' ', (5F10.3))
1540      WRITE(5,50)
1550      50 FORMAT(' EXECUTION TERMINATING')
1560      STOP
1570      35 WRITE(5,36)
1580      36 FORMAT(' ', 'REACHED END OF FILE IN BKG FILE')
1590      WRITE(5,37)
1600      37 FORMAT(' ', 'VALUES READ ARE:')
1610      WRITE(5,15)BKG
1620      WRITE(5,50)
1630      STOP
1640      13 CONTINUE
1650      11 FORMAT(5F)
1660      C
1670      C   CLOSE INTERFACE FILE BKG
1680      C
1690      ENDFILE(1)
1700      C
1710      C   COMPUTE NSTEP TRAMP BACKGROUND VALUES AND STORE IN
1720      C   ARRAY BK.  THESE VALUES CORRESPOND TO THE NSTEP FLOW
1730      C   RATES F.  BK ARRAY IS THEN USED TO COMPUTE NET ACTIVITY, A
1740      C
1750      DO 3 I=1,NSTEP
1760          ITFL=IFIX(F(I)/2.)
1770          IF(ITFL)4,4,5
1780      4   A(I)=AM(I)
1790          GOTO 3
1800      5   CONTINUE
1810          BK(I)=BKG(ITFL)
1820          A(I)=AM(I)-BK(I)
1830      3   CONTINUE
1840      C
1850      C   CORRECTED ACTIVITIES (I.E. MEASURED VALUES MINUS TRAMP
1860      C   BACKGROUND) ARE STORED IN THE FIRST NSTEP ELEMENTS OF
1870      C   1-D ARRAY A.
1880      C   A IS THEN USED AS AN INPUT VECTOR TO SUBROUTINE TRANSIT
1890      C   OR LMBDA.  A IS NOT DESTROYED DURING EXECUTION.
1900      C
1910      IF(ISWITCH.EQ.2)GOTO 38
1920      CALL TRANSIT(IOUT,RES,RESP,TFL,T,F,AP,A,NDIM,NSTEP)
1930      CALL OUTPUT(F,FSI,AP,AM,A,RES,RESP,ISWITCH,NSTEP,NDIM)
1940      STOP
1950      38 CONTINUE
1960      CALL LMBDA(IOUT,RES,RESP,TFL,F,AP,A,NDIM,T,NSTEP)
1970      CALL OUTPUT(F,FSI,AP,AM,A,RES,RESP,ISWITCH,NSTEP,NDIM)
1980      STOP
1990      END

```

```

2000 C
2010 C***** T R A N S I T *****
2020 C
2030 SUBROUTINE TRANSIT(IDUT,RES,RESP,TF,T,F,AP,A,NDIM,NSTEP)
2040 C
2050 C THIS SUBROUTINE COMPUTES THE NET TRANSIT TIME FROM THE
2060 C CORE TO THE INLET OF THE FERD LOOP
2070 C
2080 C RES = OUTPUT VECTOR OF RESIDUALS, IN CPS
2090 C RESP = OUTPUT VECTOR OF RESIDUALS, EXPRESSED AS A PERCENT
2100 C OF MEASURED COUNTS
2110 C RES AND RESP ARE COMPUTED IN SUBROUTINE REGRESS
2120 C
2130 C TF = INPUT VECTOR OF FERD-LOOP TRANSIT TIMES
2140 C F = INPUT VECTOR OF FLOW RATES, GPM
2150 C AP = OUTPUT VECTOR OF PREDICTED COUNTRATES
2160 C A = INPUT VECTOR OF CORRECTED COUNTRATES (MEASURED-TRAMP)
2170 C NDIM = INTEGER DIMENSION VARIABLE, NOT LESS THAN NSTEP
2180 C T = LINEAR WORK ARRAY OF DIMENSION NDIM, ON OUTPUT T
2190 C CONTAINS THE TOTAL TRANSIT TIME FROM THE CORE TO THE
2200 C DETECTORS AS A FUNCTION OF FERD FLOW.
2210 C DT = INTERVAL WIDTH FOR PARTITIONING OF REGRESSION DOMAIN
2220 C
2230 DIMENSION RES(NDIM),RESP(NDIM),TF(NDIM),COR(50),COR2(50)
2240 DIMENSION TT(50),T(NDIM),F(NDIM),AP(NDIM),A(NDIM)
2250 REAL LE
2260 C
2270 C PRINCIPAL COMPUTED PARAMETERS ARE PASSED TO MAIN PROGRAM
2280 C VIA COMMON AREA2
2290 C
2300 COMMON/AREA2/TRANS,XFIT,SLOPE,GAMMA,LE
2310 C
2320 C STATISTICAL PARAMETERS FROM SUBROUTINE REGRESS ARE STORED
2330 C IN LABELED COMMON AREA3
2340 C
2350 COMMON/AREA3/B0,B1,STD,STDC
2360 WRITE(5,15)
2370 15 FORMAT(' ENTER VALUE OF EFFECTIVE ESCAPE-RATE COEFFICIENT'
2380 & ,//,' LAMDAE, IN SECONDS-1'//)
2390 21 READ(5,16)LE
2400 16 FORMAT(F)
2410 IF(LE)17,17,18
2420 17 WRITE(5,19)
2430 19 FORMAT(' VALUE OF LAMDAE MUST BE A POSITIVE REAL CONSTANT')
2440 WRITE(5,20)
2450 20 FORMAT(' RE-ENTER LAMDAE',//)
2460 GO TO 21
2470 18 CONTINUE
2480 WRITE(5,95)
2490 95 FORMAT(' ENTER STARTING VALUE FOR INDEPENDENT VARIABLE T'//)
2500 READ(5,16)TSTART

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2500 READ(5,16)TSTART
2510 WRITE(5,96)
2520 96 FORMAT(' ENTER INCREMENT DT',//)
2530 READ(5,16)DT
2540 WRITE(5,97)
2550 97 FORMAT(' ENTER THE TOTAL NUMBER OF ITERATIONS, NREP',//)
2560 45 READ(5,98) NREP
2570 98 FORMAT(I)
2580 IF(NREP.GT.4)GO TO 42
2590 WRITE(5,43)
2600 43 FORMAT(' NREP MUST BE AN INTEGER GREATER THAN FOUR')
2610 WRITE(5,44)
2620 44 FORMAT(' RE-ENTER NREP',//)
2630 GO TO 45
2640 42 CONTINUE
2650 IF(IOUT.EQ.2) GO TO 31
2660 WRITE(5,30)
2670 30 FORMAT(' ',//,15('*'),' ITERATION LOG FROM SUBROUTINE TRANSIT',
2680 & 14('*'),//)
2690 WRITE(5,25)
2700 25 FORMAT(' ITERATION INDEPENDENT FLOW PREDICTED CORRECTED'
2710 & , ' CORRELATION')
2720 WRITE(5,26)
2730 26 FORMAT(' NUMBER VARIABLE STEP ',2(' ACTIVITY'),
2740 & ' COEFFICIENT')
2750 31 CONTINUE
2760 DO 7 KEN=1,NREP
2770 C
2780 C INCREMENT INDEPENDENT VARIABLE TT
2790 C
2800 TT(KEN)=TSTART+(KEN-1)*DT
2810 DO 8 KEN2=1,NSTEP
2820 T(KEN2)=TT(KEN)+TF(KEN2)
2830 8 CONTINUE
2840 C
2850 C SUBROUTINE FERD IS CALLED TO COMPUTE PREDICTED ACTIVITY
2860 C
2870 CALL FERD(LE,NSTEP,T,AP,NDIM)
2880 C
2890 C SUBROUTINE REGRESS COMPUTES AN ARRAY OF CORRELATION
2900 C COEFFICIENTS COR.
2910 C NOTE THAT ALL OTHER OUTPUT PARAMETERS FROM REGRESS
2920 C ARE NOT USED AT THIS POINT AND ARE OVER-WRITTEN AT
2930 C EACH SUBSEQUENT CALL IN CURRENT LOOP.
2940 C
2950 CALL REGRESS(AP,A,NSTEP,RES,RESP,COR(KEN),NDIM)
2960 IF(IOUT.EQ.2)GO TO 7
2970 C
2980 C IF LONG FORM OUTPUT REQUESTED, PRINT ITERATION LOG DIS-
2990 C PLAYING INTERMEDIATE VALUES OF KEY PARAMETERS.

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3000      C
3010      WRITE(5,27)KEN,TT(KEN),1,AP(1),A(1),COR(KEN)
3020      27 FORMAT('0',I5,F13.3,I7,2F10.1,F11.5)
3030      DO 29 J=2,NSTEP
3040          WRITE(5,28)J,AP(J),A(J)
3050      28 FORMAT(' ',22X,I3,2F10.1)
3060      29 CONTINUE
3070      7 CONTINUE
3080      C
3090      C COMPUTE THE DERIVATIVE OF THE COR ARRAY WITH RESPECT TO
3100      C THE INDEPENDENT VARIABLE TT AND STORE IN THE FIRST NREP
3110      C ELEMENTS OF ARRAY COR2
3120      C
3130      CALL DER(COR,COR2,IT,NREP)
3140      IF(IOUT.EQ.2)GOTO 32
3150      WRITE(5,41)
3160      41 FORMAT(' ',//)
3170      WRITE(5,41)
3180      WRITE(5,40)
3190      40 FORMAT(' ',65(' '))
3200      WRITE(5,33)
3210      33 FORMAT(' ', 'CORRELATION COEFFICIENTS AND FIRST
3220      & DERIVATIVES FROM SUBROUTINE DER')
3230      WRITE(5,40)
3240      WRITE(5,41)
3250      WRITE(5,34)
3260      34 FORMAT(' ITERATION CORRELATION    FIRST')
3270      WRITE(5,35)
3280      35 FORMAT(' NUMBER    COEFFICIENT DERIVATIVE')
3290      DO 36 I=1,NREP
3300          WRITE(5,37)I,COR(I),COR2(I)
3310      37 FORMAT('0',I4,F15.5,E13.3)
3320      36 CONTINUE
3330      32 CONTINUE
3340      C
3350      C A CALL IS MADE TO SUBROUTINE ROOTS TO COMPUTE
3360      C THE VALUE OF TT AT WHICH THE DERIVATIVE VECTOR
3370      C COR2 VANISHES. THE ROOT IS RETURNED AS THE SINGLE
3380      C PRECISION SCALAR TRANS.
3390      C
3400      CALL ROOTS(NROOT,COR2,TT,NREP,TRANS)
3410      C
3420      C INTEGER NROOT CONTAINS NUMBER OF ROOTS (ZERO OR ONE)
3430      C
3440      IF(NROOT)14,14,3
3450      C
3460      C NO ROOT WAS FOUND WITHIN SPECIFIED TIME INTERVAL
3470      C OUTPUT DIAGNOSTIC INFORMATION AND TERMINATE EXECUTION
3480      C

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3490      14 WRITE(5,4)
3500      4 FORMAT(' NO ROOTS WERE FOUND WITHIN SPECIFIED TIME INTERVAL')
3510      WRITE(5,5)
3520      5 FORMAT(' ', 'VALUES OF TIME AND CORRESPONDING VECTOR
3530      & OF DERIVATIVES'//, ' ARE AS FOLLOWS:')
3540      6 FORMAT(' ', 'ARE AS FOLLOWS:')
3550      DO 10 I=1,NREP
3560          WRITE(5,11)I,IT(I),COR(I)
3570      10 CONTINUE
3580      11 FORMAT(' ',I3,F10.2,F10.4)
3590      WRITE(5,12)
3600      12 FORMAT(' ', 'ADJUST INPUT VARIABLES NREP, TSTART, AND/OR DT')
3610      WRITE(5,13)
3620      13 FORMAT(' ', 'FOR A WIDER REGRESSION DOMAIN AND RE-RUN')
3630      WRITE(5,94)
3640      94 FORMAT(' EXECUTION TERMINATING IN SUBROUTINE TRANSIT')
3650      STOP
3660      3 CONTINUE
3670      IF(IOUT.EQ.1) WRITE(5,93) TRANS
3680      93 FORMAT(' ',//, ' DERIVATIVE VECTOR VANISHES AT LMRDAE='
3690      & ,F10.2, ' SECONDS')
3700      WRITE(5,41)
3710      C
3720      C TOTAL TRANSIT TIME FROM CORE TO DETECTOR IS SUM OF
3730      C TRANS AND THE FERD LOOP TRANSIT TIME TF.
3740      C
3750      DO 9 I=1,NSTEP
3760          T(I)=TRANS+TF(I)
3770      9 CONTINUE
3780      C
3790      C A FINAL CALL TO FERD COMPUTES THE PREDICTED ACTIVITY AP
3800      C AT THE OPTIMUM VALUE OF T
3810      C
3820      CALL FERD(LE,NSTEP,T,AP,NDIM)
3830      C
3840      C REGRESS IS NOW CALLED TO COMPUTE OVERALL REGRESSION
3850      C COEFFICIENT XFIT, RESIDUALS, AND LINEAR FIT PARAMETERS
3860      C B0 AND B1.
3870      C
3880      CALL REGRESS(AP,A,NSTEP,RES,RESP,XFIT,NDIM)
3890      C
3900      C B0 AND B1 PASSED BY LABELED COMMON
3910      C
3920      GAMMA=B0
3930      SLOPE=B1
3940      RETURN
3950      END
3960      C
3970      C***** I N P U T *****
3980      C
3990      SUBROUTINE INPUT(NSTEP,F,AM,FSI,FFU,ISWITCH,IOUT,NDIM)

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4000      C
4010      C  THIS SUBROUTINE IS INVOKED ONCE AT THE BEGINNING OF
4020      C  EXECUTION TO ASSIGN VALUES TO USER INPUT VARIABLES
4030      C
4040      DIMENSION FSI(NDIM),F(NDIM),AM(NDIM)
4050      C
4060      C  NDIM IS AN INTEGER CONSTANT THAT IS USED FOR EXECUTION-
4070      C  TIME DIMENSIONING OF ARRAYS.  MUST BE GREATER OR EQUAL
4080      C  TO NUMBER OF FLOW STEPS.
4090      C
4100      COMMON/AREA4/CASE(6)
4110      C
4120      C  LINEAR ARRAY CASE IS USED TO STORE THE CASE DESCRIPTION
4130      C  DESCRIPTION CAN BE UP TO 30 CHARACTERS
4140      C  CASE IS PASSED DIRECTLY TO SUBROUTINE OUTPUT VIA LARELED
4150      C  COMMON AREA4
4160      C
4170      77 CONTINUE
4180      WRITE(5,90)
4190      WRITE(5,92)
4200      92 FORMAT(' ENTER ONE-LINE CASE DESCRIPTION//')
4210      READ(5,93)CASE
4220      93 FORMAT(6A5)
4230      90 FORMAT(' ',6(/))
4240      WRITE(5,17)
4250      17 FORMAT(' ','INPUT NUMBER OF FLOW STEPS IN FLOW
4260      & REDUCTION TEST//')
4270      24 READ(5,18)NSTEP
4280      18 FORMAT(I)
4290      IF(NSTEP.GT.2)GOTO 22
4300      WRITE(5,23)
4310      23 FORMAT(' ','NSTEP MUST BE AT LEAST 3',/, ' REENTER',/)
4320      GOTO 24
4330      22 CONTINUE
4340      IF(NSTEP.LE.NDIM)GOTO 31
4350      WRITE(5,32)
4360      32 FORMAT(' NSTEP CANT BE GREATER THAN NDIM. EXECUTION
4370      & TERMINATING')
4380      WRITE(5,33)
4390      33 FORMAT(' ','CHANGE DIMENSIONS AND RE-RUN, OR RE-RUN WITH')
4400      WRITE(5,34)
4410      34 FORMAT(' ','CORRECT VALUE OF NSTEP')
4420      STOP
4430      31 CONTINUE
4440      WRITE(5,19)NSTEP
4450      19 FORMAT(' ','ENTER THE',I2,' FLOW RATES IN GPM',/)
4460      7 READ(5,52)(F(I),I=1,NSTEP)
4470      52 FORMAT(10F)
4480      C
4490      C  CHECK TO MAKE SURE INPUT FLOW-RATE VALUES LIE IN THE

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4500 C ACCEPTABLE RANGE OF 0 - 100 GPM (0 - 6.31 L/S)
4510 C
4520 DO 1 I=1,NSTEP
4530 IF(F(I).LT.0.OR.F(I).GT.105) GO TO 2
4540 1 CONTINUE
4550 GO TO 3
4560 2 CONTINUE
4570 C
4580 C A FLOW VALUE IS OUT OF RANGE
4590 C
4600 WRITE(5,4)
4610 4 FORMAT(' A FLOW VALUE IS OUTSIDE THE 0 TO 100 GPM RANGE')
4620 WRITE(5,5)(F(I),I=1,NSTEP)
4630 5 FORMAT(' THE VALUES ENTERED ARE:',/,10F7.1)
4640 WRITE(5,6)NSTEP
4650 6 FORMAT(' RE-ENTER ALL',I2,' VALUES',/)
4660 GOTO 7
4670 3 CONTINUE
4680 C
4690 C CONVERT FLOW VALUES TO SI UNITS
4700 C
4710 DO 80 I=1,NSTEP
4720 FSI(I) = F(I) * .06309
4730 80 CONTINUE
4740 C
4750 C CHECK FOR POSSIBLE ZERO FLOW-RATE VALUES. SET ANY
4760 C SUCH VALUES TO A SMALL FINITE VALUE TO PREVENT
4770 C OVERFLOW ERRORS IN SUBSEQUENT CALCULATIONS.
4780 C
4790 DO 8 I=1,NSTEP
4800 IF(F(I).EQ.0)F(I)=0.010
4810 8 CONTINUE
4820 WRITE(5,20)NSTEP
4830 20 FORMAT(' ENTER',I3,' CORRESPONDING MEASURED ACTIVITIES',/)
4840 13 READ(5,52)(AM(I),I=1,NSTEP)
4850 DO 9 I=1,NSTEP
4860 IF(AM(I).LT.0)GOTO 10
4870 9 CONTINUE
4880 11 GOTO 89
4890 10 WRITE(5,12)
4900 12 FORMAT(' A BAD VALUE WAS INPUT FOR THE MEASURED ACTIVITY')
4910 WRITE(5,5)(AM(I),I=1,NSTEP)
4920 WRITE(5,6)NSTEP
4930 GO TO 13
4940 89 CONTINUE
4950 WRITE(5,43)
4960 43 FORMAT(' ','ENTER FPU, THE FRACTION OF FISSIONS
4970 8 OCCURRING IN PLUTONIUM'//)
4980 37 READ(5,44)FPU
4990 44 FORMAT(F)
5000 IF(ABS(FPU-.5).LE.0.5)GOTO 45

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5000 IF(ABS(FPU-.5).LE.0.5)GOTO 45
5010 WRITE(5,46)
5020 46 FORMAT(' MUST BE A FRACTION BETWEEN 0 AND 1. REENTER.',/)
5030 GOTO 47
5040 45 CONTINUE
5050 WRITE(5,25)
5060 25 FORMAT(' ','TRANSIT TIME CALCULATIONS (1), OR')
5070 WRITE(5,26)
5080 26 FORMAT(' ','DIFFUSION HOLDUP-TIME CALCULATIONS (2) ?',/)
5090 29 READ(5,27) ISWITCH
5100 27 FORMAT(1)
5110 GOTO(28,28).ISWITCH
5120 WRITE(5,30)
5130 30 FORMAT(' ','MUST ENTER 1 OR 2',/)
5140 GOTO 29
5150 28 CONTINUE
5160 WRITE(5,48)
5170 48 FORMAT(' LONG OR SHORT OUTPUT? (1 OR 2)',///)
5180 49 READ(5,27)IOUT
5190 GOTO(51,51)IOUT
5200 WRITE(5,30)
5210 GO TO 49
5220 51 CONTINUE
5230 C
5240 C OUTPUT BRIEF SUMMARY OF USER INPUT FOR CHECKING.
5250 C OFFER OPTION OF RE-ENTERING VALUES OR EXITING IF ANY
5260 C MISTAKES ARE DISCOVERED.
5270 C
5280 WRITE(5,91)
5290 WRITE(5,14)
5300 14 FORMAT(' ',2X,'SUMMARY OF USER INPUT VALUES')
5310 WRITE(5,91)
5320 91 FORMAT(' ',2X,28(' '))
5330 WRITE(5,15)NSTEP
5340 15 FORMAT(' ',/, ' NSTEP =',13,/)
5350 WRITE(5,81)
5360 81 FORMAT(' ',8X,'FLOW RATE')
5370 WRITE(5,16)
5380 16 FORMAT(' ',/STEP',3X,'-----',5X,'MEASURED')
5390 WRITE(5,53)
5400 53 FORMAT(' ',/ NO.',3X,'(GPM) (L/S)',5X,'ACTIVITY')
5410 DO 54 I=1,NSTEP
5420 WRITE(5,55)I,F(I),FSI(I),AM(I)
5430 54 CONTINUE
5440 55 FORMAT(' ',I3,F9.1,F6.1,F12.1)
5450 WRITE(5,56)FPU
5460 56 FORMAT(' ',/,/, ' FPU =',F7.2,/)
5470 GOTO(57,58)ISWITCH
5480 57 WRITE(5,59)
5490 59 FORMAT(' TRANSIT TIME CALCULATIONS SELECTED',/)
5500 GO TO 60

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5510      58 WRITE(5,61)
5520      61 FORMAT(' HOLDUP-TIME CALCULATIONS SELECTED',/)
5530      60 CONTINUE
5540      GOTO(62,63)IOUT
5550      62 WRITE(5,64)
5560      64 FORMAT(' LONG FORM OUTPUT REQUESTED')
5570      60 TO 65
5580      63 WRITE(5,66)
5590      66 FORMAT(' SHORT FORM OUTPUT REQUESTED')
5600      65 CONTINUE
5610      WRITE(5,94)CASE
5620      94 FORMAT(' ',//,' CASE DESCRIPTION:',// ' ',6A5)
5630      WRITE(5,67)
5640      67 FORMAT(' ',///,' OPTIONS:',//)
5650      WRITE(5,68)
5660      68 FORMAT(' (1)  INITIAIE PROCESSING OF GIRAFFE CALCULATIONS')
5670      WRITE(5,69)
5680      69 FORMAT(' ', '(2)  SOME INPUT VALUES FAULTY---WOULD LIKE
5690      8 TO RE-ENTER INPUT')
5700      WRITE(5,70)
5710      70 FORMAT(' ', '(3)  TERMINATE EXECUTION')
5720      WRITE(5,71)
5730      71 FORMAT(' ',//,' ENTER OPTION NUMBER'//)
5740      76 READ(5,18) L
5750      GOTO(72,77,74) L
5760      WRITE(5,75)
5770      75 FORMAT(' MUST INPUT THE SINGLE INTEGER 1, 2, OR 3',//)
5780      60 TO 76
5790      72 RETURN
5800      74 CONTINUE
5810      WRITE(5,78)
5820      78 FORMAT(' ', 'EXECUTION TERMINATING IN SUBROUTINE INPUT')
5830      STOP
5840      END
5850      C
5860      C***** R E G R E S S *****
5870      C
5880      SUBROUTINE REGRESS(X,Y,NSTEP,RES,RESP,COR,NDIM)
5890      C
5900      C  PRODUCES BEST FIT BETWEEN MEASURED AND PREDICTED ACTIVITIES
5910      C
5920      DIMENSION X(NDIM),Y(NDIM),YHAT(20),RES(NDIM),RESP(NDIM)
5930      C
5940      C  RESIDUALS ARE PUT IN ARRAY RES.  VALUES REPRESENT VERTICAL
5950      C  DEVIATIONS OF MEASURED ACTIVITES FROM BEST-FIT LINE.
5960      C
5970      C  RESP HOLDS THE VALUES OF THE RESIDUALS EXPRESSED AS A
5980      C  PERCENT OF THE CORRESPONDING MEASURED ACTIVITIES.
5990      C
6000      C  ON OUTPUT COR EQUALS THE SQUARE OF THE LINEAR CORRELATION
6010      C  COEFFICIENT.

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6020      C
6030      C
6040      COMMON/AREA A3/R0,B1,STD,STDC
6050      C
6060      C
6070      C  NSTEP MUST NOT EXCEED NDIM
6080      C
6090      IF (NSTEP.NDIM)4,4,5
6100      5 CONTINUE
6110      WRITE(5,6)
6120      6 FORMAT(' NUMBER OF FLOW STEPS EXCEEDS DIMENSIONS IN REGRESS')
6130      WRITE(5,7)
6140      7 FORMAT(' ','EXECUTION TERMINATING IN SUBROUTINE REGRESS')
6150      STOP
6160      4 CONTINUE
6170      C
6180      C  INITIALIZE SUMMATION VARIABLES
6190      C
6200      SUMXY=0.
6210      SUMX=0.
6220      SUMY=0.
6230      SUMXX=0.
6240      SUMX=0.
6250      SUMRES=0.
6260      SUMRES2=0.
6270      SUMY2=0.
6280      DO 1 I=1,NSTEP
6290          SUMXY=SUMXY+X(I)*Y(I)
6300          SUMX=SUMX+X(I)
6310          SUMY=SUMY+Y(I)
6320          SUMXX=SUMXX+X(I)**2
6330      1 CONTINUE
6340      AVGY=SUMY/FLOAT(NSTEP)
6350      C
6360      C  SLOPE  CORRECTED SUM OF CROSS PRODUCTS DIVIDED BY
6370      C          THE CORRECTED SUM OF SQUARES OF X'S
6380      C
6390      B1=(SUMXY-SUMX*SUMY/FLOAT(NSTEP))/(SUMXX-SUMX*SUMX/FLOAT(NSTEP))
6400      B0=AVGY-B1 * SUMX/FLOAT(NSTEP)
6410      DO 2 I=1,NSTEP
6420      C
6430      C  COMPUTE PREDICTED OR "FITTED" VALUES OF Y AND RESIDUALS
6440      C
6450          YHAT(I)=B0+B1*X(I)
6460          RES(I)=YHAT(I)-Y(I)
6470          RESF(I)=RES(I)/Y(I)*100
6480          SUMRES=SUMRES+RES(I)
6490          SUMRES2=SUMRES2+RES(I)**2
6500      2 CONTINUE
6510      F=FLOAT(NSTEP-2)
6520      C

```



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6530 C STD = STANDARD DEVIATION OF INDIVIDUAL OBSERVATIONS (ASSUMES
6540 C ERRORS ARE RANDOM EVENTS DRAWN FROM A NORMAL PROBABILITY
6550 C DISTRIBUTION)
6560 C
6570 STD=SQRT(SUMRES2/F)
6580 C
6590 C STDC STANDARD DEVIATION OF SLOPE
6600 C
6610 STDC=STD/SQRT(SUMXX)
6620 C
6630 C COMPUTE CORRELATION COEFFICIENT, COR, AND RETURN
6640 C
6650 AVGRES=SUMRES/FLOAT(NSTEP)
6660 STDRS=SQRT(SUMRES2/FLOAT(NSTEP-1))
6670 DO 3 1=1,NSTEP
6680 SUMY2=SUMY2+(AVGY-Y(I))**2
6690 3 CONTINUE
6700 STDY=SQRT(SUMY2/FLOAT(NSTEP-1))
6710 COR=1-(STDRS/STDY)**2
6720 RETURN
6730 END
6740 C
6750 C***** R O O T S *****
6760 C
6770 C SUBROUTINE ROOTS(NROOT,X,Y,NREP,ROOT)
6780 C
6790 C COMPUTES VALUE OF Y AT WHICH X VANISHES
6800 C METHOD EMPLOYED IS INVERSE LAGRANGIAN INTERPOLATION
6810 C
6820 C UP TO 49TH DEGREE LAGRANGIAN POLYNOMIAL CAN BE EMPLOYED
6830 C
6840 C DIMENSION X(50),Y(50)
6850 C
6860 C THE FIRST NREP VALUES IN ARRAY X CONTAIN THE DERIVATIVES
6870 C OF THE ARRAY OF CORRELATION COEFFICIENTS WITH RESPECT TO
6880 C THE INDEPENDENT VARIABLE TIME OR LAMBDA
6890 C
6900 C ARRAY Y CONTAINS THE CORRESPONDING NREP VALUES OF THE
6910 C DEPENDENT VARIABLE AT WHICH D(COR)/DT WAS COMPUTED
6920 C
6930 C CHECK TO SEE IF ANY ROOTS EXIST
6940 C
6950 IF(X(1)*X(NREP))3,4,4
6960 4 CONTINUE
6970 C
6980 C NO ROOTS EXIST IN SPECIFIED INTERVAL
6990 C SET NROOT = 0 AND RETURN
7000 C
7010 NROOT=0
7020 RETURN
7030 3 CONTINUE

```

```

7040      C
7050      C  EXACTLY 1 ROOT EXISTS WITHIN SPECIFIED INTERVAL
7060      C
7070      NR00T=1
7080      C
7090      C  ROOT IS AN OUTPUT VARIABLE THAT CONTAINS THE COMPUTED
7100      C  VALUE OF  Y  AT WHICH  X = 0.
7110      C
7120      ROOT=0.0
7130      DO 1 I=1,NREP
7140          TERM=Y(I)
7150          DO 2 J=1,NREP
7160              IF (I-J) 9,2,9
7170              9      TERM=TERM*(-X(J)/(X(I)-X(J)))
7180              2      CONTINUE
7190          1      ROOT=ROOT+TERM
7200      RETURN
7210      END
7220      C
7230      C***** D E R *****
7240      C
7250      SUBROUTINE DER(Y,Y1,H,NREP)
7260      C
7270      C  COMPUTES DERIVATIVE OF Y WITH RESPECT TO X
7280      C
7290      C  METHOD USED FOR INTERIOR POINTS IS A 5-POINT FORMULA
7300      C  FROM DIFFERENTIATION OF THE LEAST-SQUARES PARABOLA.
7310      C  NEAR THE ENDS OF THE DATA INTERVAL 4-POINT PARABOLA FORMULAS
7320      C  ARE APPLIED.
7330      C
7340      C  THIS METHOD AVOIDS ERROR MAGNIFICATION PROBLEMS
7350      C  ASSOCIATED WITH FORMULAS DERIVED FROM COLOCATION
7360      C  POLYNOMIALS.
7370      C
7380      DIMENSION Y(50),Y1(50)
7390      C
7400      C  Y CONTAINS INPUT VECTOR OF CORRELATION COEFFICIENTS
7410      C  Y1 CONTAINS OUTPUT DERIVATIVE VECTOR
7420      C  H IS THE (CONSTANT) INTERVAL BETWEEN DATA POINTS (STEP LENGTH)
7430      C  NREP IS THE NUMBER OF POINTS (MUST BE AT LEAST 5)
7440      C
7450      IF (NREP-5) 1,2,2
7460      1      CONTINUE
7470      WRITE(5,3)NREP
7480      3      FORMAT(' ', 'NUMBER OF POINTS TRANSMITTED TO DER IS', I5)
7490      WRITE(5,4)
7500      4      FORMAT(' ', 'MUST HAVE AT LEAST 5 POINTS', 'CHECK
7510      & INPUT VARIABLE NREP AND RE-RUN')
7520      STOP
7530      2      CONTINUE
7540      C

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7550 C USE 4-POINT FORMULAS FOR 1ST AND 2ND POINTS
7560 C
7570 Y1(1) = (1./(20.*H))*(-21.*Y(1) + 13.*Y(2) +
7580 & 17.*Y(3) - 9.*Y(4))
7590 Y1(2) = (1./(20.*H))*(-11.*Y(1) + 3.*Y(2) + 7.*Y(3) + Y(4))
7600 C
7610 C 5-POINT FORMULA FOR INTERIOR POINTS
7620 C
7630 M=NREP-2
7640 DO 5 I=3,M
7650 Y1(I) = (1./(10.*H))*(-2.*Y(I-2)-Y(I-1) + Y(I+1) + 2.*Y(I+2))
7660 5 CONTINUE
7670 C
7680 C 4-POINT FORMULAS FOR LAST TWO POINTS
7690 C
7700 Y1(NREP-1) = (1./(20.*H))*(-11.*Y(NREP) - 3.*Y(NREP-1)
7710 & 7.*Y(NREP-2) - Y(NREP-3))
7720 Y1(NREP) = (1./(20.*H))*(-21.*Y(NREP)-13.*Y(NREP-1)-17.*Y(NREP-2)
7730 & + 9.*Y(NREP-3))
7740 RETURN
7750 END
7760 I
7770 I***** F L R D *****
7780 C
7790 SUBROUTINE FERD(LMBDAE, NSTEP, T, AP, NDIM)
7800 C
7810 C PERFORMS DECAY CALCULATIONS
7820 C
7830 REAL LMBDAE, K2(9), K3(9), K4(9), LMBDAD(9), LMBDAP(9)
7840 DIMENSION FN(9), SP(9), RC(9), SD(9)
7850 DIMENSION AP(NDIM), T(NDIM), TERM1(20), TERM2(20)
7860 COMMON/AREA1/LMBDAD, SD, RC, FN, LMBDAP, SP
7870 C
7880 C INITIALIZE ACCUMULATION ARRAYS
7890 C
7900 DO 2 I = 1, NSTEP
7910 TERM1(I) = 0
7920 TERM2(I) = 0
7930 2 CONTINUE
7940 I
7950 I INTERMEDIATE TERMS STORED IN REAL ARRAYS K2, K3, AND K4
7960 C CAN BE OUTPUT FOR DIAGNOSTIC PURPOSES OR PARAMETRIC STUDY
7970 C (E.G. TO COMPARE RELATIVE SIGNIFICANCE OF INDIVIDUAL
7980 C ISOTOPES AT, SAY, LOW VS. HIGH FERD FLOW RATES)
7990 I
8000 DO 10 I=1,9
8010 K2(I) = LMBDAP(I)*SP(I)
8020 K3(I) = FN(I)*LMBDAD(I)
8030 K4(I) = LMBDAE / (LMBDAD(I) - LMBDAP(I)) * (LMBDAP(I) + LMBDAE)
8040 10 CONTINUE
8050 DO 1 J = 1, NSTEP

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8060      DO 9 I = 1,9
8070      C
8080      C      CHECK MAGNITUDE OF EXPONENTS TO PREVENT OVERFLOW ERRORS
8090      C
8100          A = LMBDA(I)*T(J)
8110          IF (A-15.)3,3,4
8120      3      EX1 = EXP(-A)
8130          GOTO 5
8140      4      EX1 = 0.0
8150      5      CONTINUE
8160          A = LMBDA(I)*T(J)
8170          IF (A-15.)6,6,7
8180      6      EX2 = EXP(-A)
8190          GOTO 8
8200      7      EX2 = 0.0
8210      8      CONTINUE
8220          TERM1(J)=TERM1(J)+K3(I)*K2(I)*(EX2-EX1)*K4(I)
8230          TERM2(J)=TERM2(J)+K3(I)*(K2(I)/(LMBDA(I)+LMBDAE)+SD(I))
8240      &      *EX1/(LMBDA(I) + LMBDAE)*LMBDAE
8250          AP(J) = TERM1(J) + TERM2(J)
8260      9      CONTINUE
8270      1      CONTINUE
8280      RETURN
8290      END
8300      C
8310      C***** L M B D A *****
8320      C
8330      SUBROUTINE LMBDA(IOUT,RES,RESP,TF,F,AP,A,NDIM,T,NSTEP)
8340      DIMENSION RES(NDIM),RESP(NDIM),TF(NDIM),COR(50),COR2(50)
8350      DIMENSION LMD(50),T(NDIM),F(NDIM),AP(NDIM),A(NDIM)
8360      C
8370      C      THIS SUBROUTINE COMPUTES THE ISOTOPIC ESCAPE RATE
8380      C      COEFFICIENT FOR DN PRECURSORS EMITTED FROM THE FUEL
8390      C      TO THE COOLANT.
8400      C
8410      C      RES      OUTPUT VECTOR OF RESIDUALS, IN CPS
8420      C      RESP = OUTPUT VECTOR OF RESIDUALS, EXPRESSED AS A PERCENTAGE
8430      C      OF MEASURED COUNTS
8440      C      RES AND RESP ARE COMPUTED IN SUBROUTINE REGRESS
8450      C
8460      C      TF      = INPUT VECTOR OF FWD-LOOP TRANSIT TIMES
8470      C      F      = INPUT VECTOR OF FLOW RATES, GPM
8480      C      AP      = OUTPUT VECTOR OF PREDICTED COUNTRATES
8490      C      A      = INPUT VECTOR OF CORRECTED COUNT RATES (MEASURED-TRAMP)
8500      C      NDIM    INTEGER DIMENSION VARIABLE, NOT LESS THAN NSTEP
8510      C      I      AUXILIARY WORK ARRAY OF DIMENSION NDIM. ON OUTPUT T
8520      C      CONTAINS THE TOTAL TRANSIT TIME FROM THE CORE TO THE
8530      C      DETECTORS AS A FUNCTION OF FWD FLOW.
8540      C
8550      REAL LMBDAE,LMD,LE1
8560      COMMON /AREA2/TRANS,XFIT,SLOPE,GAMMA,LMBDAE

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8570      C
8580      C  STATISTICAL PARAMETERS FROM SUBROUTINE REGRESS STORED IN
8590      C  LABELED COMMON AREA3
8600      COMMON/AREA3/B0,B1,STD,STDC
8610      WRITE(5,7)
8620      7 FORMAT(' ENTER CORE-SODIUM TRANSPORT TIME IN SECONDS'//)
8630      9 READ(5,8)TRANS
8640      8 FORMAT(I)
8650      IF(TRANS)20,20,21
8660      20 WRITE(5,22)
8670      22 FORMAT(' VALUE OF TRANS MUST BE A POSITIVE REAL CONSTANT')
8680      WRITE(5,23)
8690      23 FORMAT(' RE-ENTER TRANS'//)
8700      GO TO 9
8710      21 CONTINUE
8720      WRITE(5,15)
8730      15 FORMAT(' ENTER STARTING VALUE FOR INDEPENDENT VARIABLE
8740      & LAMDAE',//)
8750      46 READ(5,8)LE1
8760      IF(LE1)42,42,43
8770      42 WRITE(5,44)
8780      44 FORMAT(' VALUE MUST BE GREATER THAN ZERO'//)
8790      WRITE(5,45)
8800      45 FORMAT(' RE-ENTER STARTING VALUE IN SECONDS-1'//)
8810      GO TO 46
8820      43 CONTINUE
8830      WRITE(5,16)
8840      16 FORMAT(' ENTER INCREMENT DLE',//)
8850      49 READ(5,8)DLE
8860      IF(DLE)47,47,50
8870      47 WRITE(5,44)
8880      WRITE(5,48)
8890      48 FORMAT(' RE-ENTER INCREMENT DLE IN SECONDS-1'//)
8900      GOTO 49
8910      50 CONTINUE
8920      WRITE(5,17)
8930      17 FORMAT(' ENTER THE TOTAL NUMBER OF ITERATIONS, NREP',//)
8940      54 READ(5,18) NREP
8950      18 FORMAT(I)
8960      IF(NREP.GE.5)GOTO 51
8970      WRITE(5,52)
8980      52 FORMAT(' NREP MUST BE AN INTEGER GREATER THAN FOUR')
8990      WRITE(5,53)
9000      53 FORMAT(' RE-ENTER NREP'//)
9010      GO TO 54
9020      51 CONTINUE
9030      IF(IOUT.EQ.2) GO TO 31
9040      C
9050      C  IF LONG FORM OUTPUT REQUESTED, PRINT ITERATION LOG
9060      C  DISPLAYING INTERMEDIATE VALUES OF KEY PARAMETERS
9070      C
9080      WRITE(5,30)

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9090      30 FORMAT(' ',//,15('*'),'ITERATION LOG FROM SUBROUTINE LMBDA',
9100          & 14('*'),//)
9110      WRITE(5,25)
9120      25  FORMAT(' ITERATION INDEPENDENT FLOW  PREDICTED CORRECTED'
9130          & ', ' CORRELATION')
9140      WRITE(5,26)
9150      26  FORMAT('  NUMBER      VARIABLE      STEP ',2(' ACTIVITY'),
9160          & ' COEFFICIENT')
9170      31 CONTINUE
9180      C
9190      C INCREMENT INDEPENDENT VARIABLE LMD
9200      C
9210      DO 1 I=1,NREP
9220          LMD(I)=(LMD1+(I-1)*DLF
9230      1  CONTINUE
9240      C
9250      C TOTAL TRANSIT TIME FROM CORE TO DETECTOR T IS SUM OF
9260      C TRANS AND THE FERD LOOP TRANSIT TIME TF.
9270      C
9280      DO 2 I=1,NSTEP
9290          T(I)=TRANS+TF(I)
9300      2  CONTINUE
9310      DO 3 I=1,NREP
9320          LMBDAE=LMD(I)
9330      C
9340      C SUBROUTINE FERD IS CALLED TO COMPUTE PREDICTED ACTIVITIES
9350      C USING CURRENT VALUE OF LAMDAE
9360      C
9370      CALL FERD(LMBDAE,NSTEP,T,AP,NDIM)
9380      C
9390      C SUBROUTINE REGRESS COMPUTES AN ARRAY OF CORRELATION
9400      C COEFFICIENTS COR.
9410      C NOTE THAT ALL OTHER OUTPUT PARAMETERS FROM REGRESS
9420      C ARE NOT USED AT THIS POINT AND ARE OVER-WRITTEN AT
9430      C EACH SUBSEQUENT CALL IN CURRENT LOOP.
9440      C
9450      CALL REGRESS(AP,A,NSTEP,RES,RESP,COR(I),NDIM)
9460      IF(IOUT.EQ.2)GO TO 3
9470      WRITE(5,27)I,LMBDAE,1,AP(1),A(1),COR(I)
9480      27  FORMAT('0',I5,F13.4,I7,2F10.1,F11.5)
9490      DO 29 J=2,NSTEP
9500          WRITE(5,28)J,AP(J),A(J)
9510      28  FORMAT(' ',22X,I3,2F10.1)
9520      29  CONTINUE
9530      3  CONTINUE
9540      C
9550      C COMPUTE THE DERIVATIVE OF THE COR ARRAY WITH RESPECT TO
9560      C THE INDEPENDENT VARIABLE LMD AND STORE IN THE FIRST NREP
9570      C ELEMENTS OF ARRAY COR2
9580      C

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9590    CALL DER(COR,COR2,DLE,NREP)
9600    C
9610    IF(IOUT.EQ.2)GOTO 32
9620    WRITE(5,41)
9630    41 FORMAT(' ',//)
9640    WRITE(5,40)
9650    40 FORMAT(' ',65(' '))
9660    WRITE(5,33)
9670    33 FORMAT(' ','CORRELATION COEFFICIENTS AND FIRST
9680    & DERIVATIVES FROM SUBROUTINE DER')
9690    WRITE(5,40)
9700    WRITE(5,41)
9710    WRITE(5,34)
9720    34 FORMAT(' ITERATION CORRELATION    FIRST')
9730    WRITE(5,35)
9740    35 FORMAT('    NUMBER    COEFFICIENT DERIVATIVE')
9750    DO 36 I=1,NREP
9760        WRITE(5,37)I,COR(I),COR2(I)
9770    37 FORMAT('0',I4,F15.5,E13.3)
9780    36 CONTINUE
9790    32 CONTINUE
9800    C
9810    C  A CALL IS MADE TO SUBROUTINE ROOTS TO COMPUTE
9820    C  THE VALUE OF TT AT WHICH THE DERIVATIVE VECTOR
9830    C  COR2 VANISHES.  THE ROOT IS RETURNED AS THE SINGLE
9840    C  PRECISION SCALAR LMBDAE.
9850    C
9860    CALL ROOTS(NROOT,COR2,LMD,NREP,LMBDAE)
9870    IF(NROOT)24,24,19
9880    C
9890    C  NO ROOT WAS FOUND WITHIN SPECIFIED TIME INTERVAL
9900    C  OUTPUT DIAGNOSTIC INFORMATION AND TERMINATE EXECUTION
9910    C
9920    24 WRITE(5,4)
9930    4 FORMAT(' ',//,'NO ROOTS FOUND WITHIN SPECIFIED REGRESSION
9940    & DOMAIN')
9950    WRITE(5,5)
9960    5 FORMAT(' ','VALUES OF LMBDAE AND CORRESPONDING VECTOR
9970    & OF DERIVATIVES'//,' ARE AS FOLLOWS:')
9980    6 FORMAT(' ','ARE AS FOLLOWS:')
9990    DO 10 I=1,NREP
10000        WRITE(5,11)I,LMD(I),COR(I)
10010    10 CONTINUE
10020    11 FORMAT(' ',I3,F10.2,F10.4)
10030    WRITE(5,12)
10040    12 FORMAT(' ','ADJUST INPUT VARIABLES NREP, LE1, AND/OR DLE')
10050    WRITE(5,13)
10060    13 FORMAT(' ','FOR A WIDER REGRESSION DOMAIN AND RE-RUN')
10070    WRITE(5,39)
10080    39 FORMAT(' ',//,' EXECUTION TERMINATING IN SUBROUTINE LMBDA')
10090    STOP

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10110 IF(IOUT.EQ.1)WRITE(5,38)LMBDAE
10120 38 FORMAT(' ',//,' DERIVATIVE VECTOR VANISHES AT LMBDAE='E14.4
10130 & , ' SECONDS-1')
10140 C
10150 C A FINAL CALL TO FERD COMPUTES THE PREDICTED ACTIVITY AP
10160 C AT THE OPTIMUM VALUE OF LAMDAE
10170 C
10180 CALL FERD(LMBDAE,NSTEP,T,AP,NDIM)
10190 C
10200 C REGRESS IS NOW CALLED TO COMPUTE OVERALL REGRESSION
10210 C COEFFICIENT XFIT, RESIDUALS, AND LINEAR FIT PARAMETERS
10220 C B0 AND B1.
10230 C
10240 CALL REGRESS(AP,A,NSTEP,RES,RESP,XFIT,NDIM)
10250 C
10260 C B0 AND B1 PASSED BY LABELED COMMON
10270 C
10280 GAMMA=B0
10290 SLOPE=B1
10300 RETURN
10310 END
10320 C
10330 C***** Y I E L D S *****
10340 C
10350 SUBROUTINE YIELDS(FPU,IOUT,YD,YPC,IS01,IS02)
10360 C
10370 C COMPUTES WEIGHTED FISSION YIELDS BASED ON FRACTION
10380 C OF FISSIONS OCCURRING IN PLUTONIUM
10390 C
10400 DIMENSION YDU235(9),YDFU239(9),YPU235(9),YPPU(9),YD(9),YPC(9)
10410 DOUBLE PRECISION D(9),P(9),IS01(9),IS02(9)
10420 C
10430 C DEFINE DAUGHTER ISOTOPES
10440 C
10450 DATA D/'BR-87', 'BR-88', 'TE-136', 'I-137',
10460 &'BR-89', 'RB-93', 'I-138', 'RB-94',
10470 &'I-139' //
10480 C
10490 C DEFINE PARENT ISOTOPES
10500 C
10510 DATA P/'SE-87', 'SE-88', 'SB-136', 'TE-137',
10520 &'SE-89', 'KR-93', 'TE-138', 'KR-94',
10530 &'TE-139' //
10540 C
10550 C YDU235 = DAUGHTER YIELDS FROM U235 FISSIONS
10560 C YDFU239 = DAUGHTER YIELDS FROM PU239 FISSIONS
10570 C YPU235 = PARENT YIELDS FROM U235 FISSIONS
10580 C YPPU = PARENT YIELDS FROM PU239 FISSIONS
10590 C
10600 DATA YDU235/1.305,1.609,1.189,2.421,1.084,2.564,1.264,1.555
10610 & ,0.424/

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10620 DATA YDFU239/0.442,0.267,0.491,1.597,0.120,0.704,
10630 & 0.597,0.294,0.181/
10640 DATA YFU235/0.6045,0.2543,0.0139,0.2972,0.05901
10650 & ,0.2815,0.05367,0.09197,0.005797/
10660 DATA YFPU/5.724E-4,1.137E-4,2.357E-5,8.471E-4,1.60E-5
10670 & ,2.911E-4,1.186E-4,4.02E-5,1.196E-5/
10680 C
10690 C CHECK IF LONG OR SHORT OUTPUT SPECIFIED
10700 C
10710 IF(IOUT.EQ.2)GOTO 2
10720 WRITE(5,19)
10730 19 FORMAT(' ',//)
10740 WRITE(5,19)
10750 WRITE(5,20)
10760 20 FORMAT(' ',15X,18(' - '))
10770 WRITE(5,1)
10780 1 FORMAT(' ',15X,'OUTPUT FROM YIELDS')
10790 WRITE(5,20)
10800 WRITE(5,19)
10810 WRITE(5,3)
10820 3 FORMAT(' TABLE OF REFERENCE DATA (GLEANED FROM MEEK &
10830 & RIDER YIELD COMPILATIONS)')
10840 WRITE(5,15)
10850 15 FORMAT(' ',17X,'Y I E L D',18X,'Y I E L D')
10860 WRITE(5,7)
10870 7 FORMAT(' ', 'GROUP', ' DAUGHTER ',12(' - '),4X,'PARENT',
10880 & 3X,18(' - '))
10890 WRITE(5,8)
10900 8 FORMAT(' ', ' NO.',2X,'ISOTOPE', ' U235',3X,'PU239',3X
10910 & , 'ISOTOPE',4X,'U235',5X,'PU-239')
10920 DO 5 I=1,9
10930 WRITE(5,6)I,D(I),YDU235(I),YDFU239(I),P(I),YFU235(I),
10940 & YFPU(I)
10950 6 FORMAT('0',I3,4X,A6,2F7.3,4X,A6,F9.4,E12.3)
10960 5 CONTINUE
10970 2 CONTINUE
10980 DO 4 I=1,9
10990 YD(I)=(1.- FPU) * YDU235(I) + FPU * YDFU239(I)
11000 YFC(I)=(1.- FPU) * YFU235(I) + FPU * YFPU(I)
11010 4 CONTINUE
11020 IF(IOUT.EQ.2)GOTO 17
11030 C
11040 C OUTPUT TABLE OF WEIGHTED YIELDS AND RETURN
11050 C
11060 WRITE(5,19)
11070 WRITE(5,19)
11080 WRITE(5,21)
11090 21 FORMAT(' ',6X,25(' - '))
11100 WRITE(5,14)
11110 14 FORMAT(' ',6X,'TABLE OF CORRECTED YIELDS')
11120 WRITE(5,9)FPU

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11130      9 FORMAT(' ',8X,'BASED ON FPU =',F7.2)
11140      WRITE(5,21)
11150      WRITE(5,11)
11160      11 FORMAT(' ',//,' GROUP',' DAUGHTER',10X,'PARENT')
11170      WRITE(5,12)
11180      12 FORMAT(' ', ' NO.',2X,' ISOTOPE   YIELD   ISOTOPE   YIELD')
11190      DO 10 I=1,9
11200          WRITE(5,13)I,D(I),YD(I),P(I),YFC(I)
11210      10 CONTINUE
11220      13 FORMAT('0',I3,4X,A6,F7.3,4X,A6,F9.4)
11230      17 CONTINUE
11240      C
11250      C  CONVERT YIELDS FROM PERCENT TO FRACTION
11260      C
11270      DO 18 I=1,9
11280          YD(I)=YD(I)/100.
11290          YFC(I)=YFC(I)/100.
11300      18 CONTINUE
11310      C
11320      C  COPY ISOTOPE NAMES TO ISO1 AND ISO2 FOR TRANSFER TO MAIN
11330      C
11340      DO 16 I=1,9
11350          ISO1(I)=P(I)
11360          ISO2(I)=D(I)
11370      16 CONTINUE
11380      RETURN
11390      END
11400      C
11410      C***** O U T P U T *****
11420      C
11430      SUBROUTINE OUTPUT(F,FSI,AP,AM,A,RES,RESP,ISWITCH,NSTEP,NDIM)
11440      C
11450      C  PRINTS OUT SUMMARY TABLE OF COMPUTED RESULTS AND SELECTED
11460      C  DIAGNOSTIC STATISTICS
11470      C
11480      DIMENSION F(NDIM),FSI(NDIM),AP(NDIM),AM(NDIM),A(NDIM)
11490      DIMENSION RES(NDIM),RESP(NDIM)
11500      REAL LMBDAE
11510      COMMON/AREA2/TRANS,XFIT,SLOPE,GAMMA,LMBDAE
11520      COMMON/AREA3/DUMMY1,DUMMY2,STD,STDC
11530      C
11540      C  LINEAR ARRAY CASE IS USED TO STORE THE CASE DESCRIPTION
11550      C  CASE IS PASSED DIRECTLY FROM SUBROUTINE INPUT VIA
11560      C  LABELED COMMON AREA4
11570      C
11580      COMMON/AREA4/CASE(6)
11590      WRITE(5,23)
11600      23 FORMAT(' ',//)
11610      WRITE(5,22)
11620      22 FORMAT(' ',69(' '))
11630      WRITE(5,1)

```

```

11640      1 FORMAT(' ',27('*'),' R E S U L T S ',27('*'))
11650      WRITE(5,22)
11660      WRITE(5,2)
11670      2 FORMAT(' ',//,' FERD',3X,'FERD',3X,'MEASURED',2X,' CORRECTED'
11680      8 ,2X,'PREDICTED',12X,'RESIDUALS')
11690      WRITE(5,3)
11700      3 FORMAT(' FLOW FLOW',3(' ACTIVITY'),3X,'RESIDUALS',5X,'OF')
11710      WRITE(5,4)
11720      4 FORMAT(' GPM L/S',1X,4(' COUNTS/S'),2X,'MEASURED')
11730      DO 6 I=1,NSTEP
11740          WRITE(5,5)F(I),FSI(I),AM(I),A(I),AP(I),RES(I),RESP(I)
11750      6 CONTINUE
11760      5 FORMAT('0',F5.1,F7.2,F10.1,2F11.1,2F10.1)
11770      WRITE(5,22)
11780      16 FORMAT(' ',/,69('*'))
11790      IF(ISWITCH.EQ.2)GO TO 7
11800      WRITE(5,9)TRANS
11810      9 FORMAT(' ',//,' TRANSIT TIME =',F6.1,' S')
11820      GO TO 8
11830      7 CONTINUE
11840      WRITE(5,17)LMBDAE
11850      17 FORMAT(' ',//,' LMBDAE =',F8.3,' SECONDS-1')
11860      TH=1/LMBDAE
11870      WRITE(5,18)TH
11880      18 FORMAT(' ',/, ' HOLDUP TIME = 1/LMBDAE =',F8.1,' S')
11890      8 CONTINUE
11900      WRITE(5,10)SLOPE
11910      10 FORMAT(' ',//,' C = SLOPE =',F7.2)
11920      WRITE(5,11)STDC
11930      11 FORMAT(' STANDARD DEVIATION OF SLOPE =',F7.3)
11940      WRITE(5,12)GAMMA
11950      12 FORMAT(' ',//,' GAMMA = Y INTERCEPT =',F7.1,' COUNTS/S')
11960      WRITE(5,13)STD
11970      13 FORMAT(' STANDARD DEVIATION OF GAMMA =',F7.1,' COUNTS/S')
11980      WRITE(5,14)XFIT
11990      14 FORMAT(' ',//,' COEFFICIENT OF CORRELATION, XFIT =',F9.5)
12000      WRITE(5,25)CASE
12010      WRITE(5,16)
12020      25 FORMAT(' ',//,1H ,6A5)
12030      WRITE(5,24)
12040      24 FORMAT(' ',7(/))
12050      STOP
12060      END
%      - End of file

```

APPENDIX C

FORTRAN Flowchart for Subroutine TRANSIT

```

      ENTRANCE
      U
      U
*****
* SUBROUTINE TRANSIT(IOUT,RES,RESP,TF,T,F,AP,A,NDIM,NSTEP)
* THIS SUBROUTINE COMPUTES THE NET TRANSIT TIME FROM THE
* CORE TO THE INLET OF THE FERO LOOP
*
*
* RES = OUTPUT VECTOR OF RESIDUALS, IN CPS
* RESP = OUTPUT VECTOR OF RESIDUALS, EXPRESSED AS A PERCENT
* OF MEASURED COUNTS
* RES AND RESP ARE COMPUTED IN SUBROUTINE REGRESS
*
*
* TF = INPUT VECTOR OF FERO-LOOP TRANSIT TIMES
* F = INPUT VECTOR OF FLOW RATES, GPM
* AP = OUTPUT VECTOR OF PREDICTED COUNT-RATES
* A = INPUT VECTOR OF CORRECTED COUNT-RATES (MEASURED-TRAMP)
* NDIM = INTEGER DIMENSION VARIABLE, NOT LESS THAN NSTEP
* T = LINEAR WORK ARRAY OF DIMENSION NDIM. ON OUTPUT T
* CONTAINS THE TOTAL TRANSIT TIME FROM THE CORE TO THE
* DETECTORS AS A FUNCTION OF FERO FLOW.
* DT = INTERVAL WIDTH FOR PARTITIONING OF REGRESSION DOMAIN
*
*
* DIMENSION RES(NDIM),RESP(NDIM),TF(NDIM),COR(50),CON2(50)
* DIMENSION TT(50),T(NDIM),F(NDIM),AP(NDIM),A(NDIM)
* REAL LE
*
* PRINCIPAL COMPUTED PARAMETERS ARE PASSED TO MAIN PROGRAM
* VIA COMMON AREA2
*
* COMMON/AREA2/TRANS,XFIT,SLOPE,GAMMA,LE
*
* STATISTICAL PARAMETERS FROM SUBROUTINE REGRESS ARE STORED
* IN LABELED COMMON AREA3
*
* COMMON/AREA3/R0,R1,STD,STDC
* WRITE(5,15)
*15 FORMAT(' ENTER VALUE OF EFFECTIVE ESCAPE-RATE COEFFICIENT
* & ,//, ' LAMDAE, IN SECONDS-1'//')
*****
      U
      U .....
      U
*****
*21 READ(5,16)LE
*16 FORMAT(F)
*****
      U
      U
      U
*****
* IF(LE)17,17,18
*****

```

```

      U
      U
      U
*****
*17  WRITE(5,19)
*19  FORMAT(' VALUE OF LAMDAE MUST BE A POSITIVE REAL CONSTANT
*      WRITE(5,20)
*20  FORMAT(' RE-ENTER LAMDAE',//)
*****
      U
      U
      U
*****
*      GO TO 21
*****
      U
*****
*18  CONTINUE
*      WRITE(5,95)
*95  FORMAT(' ENTER STARTING VALUE FOR INDEPENDENT VARIABLE T',//)
*      READ(5,16)ISTART
*      WRITE(5,96)
*96  FORMAT(' ENTER INCREMENT DT',//)
*      READ(5,16)DT
*      WRITE(5,97)
*97  FORMAT(' ENTER THE TOTAL NUMBER OF ITERATIONS, NREP',//)
*****
      U
      U .....0
      U
*****
*45  READ(5,98) NREP
*98  FORMAT(I)
*****
      U
      U
      U
*****
*      IF(NREP.GT.4)GO TO 42 .....0
*****
      U
      U
      U
*****
*      WRITE(5,43)
*43  FORMAT(' NREP MUST BE AN INTEGER GREATER THAN FOUR')
*      WRITE(5,44)
*44  FORMAT(' RE-ENTER NREP',//)
*****
      U
      U
      U
*****
*      GO TO 45 .....0
*****
      U
      U .....0
*****
*42  CONTINUE
*****
      U
      U
      U

```

```

*****
*      IF(IOUT.EQ.2) GO TO 31
*****
      U
      U
      U
*****
*      WRITE(5,30)
*30    FORMAT(' ',//,15('*'),' ITERATION LOG FROM SUBROUTINE TRANSIT .
*      $ 14('*')//)
*      WRITE(5,25)
*25    FORMAT(' ITERATION INDEPENDENT FLOW PREDICTED MEASURED
*      $ ' CORRELATION')
*      WRITE(5,26)
*26    FORMAT(' NUMBER    VARIABLE    STEP 1,2,3 ACTIVITY 1,
*      $ ' COEFFICIENT')
*****
      U
      U
      U
*****
*31    CONTINUE
*****
      U
      U
      U
*****
*      DO 7 KEN=1,NREF
*****
      U
      U
      U
*****
*C     INCREMENT INDEPENDENT VARIABLE TT
*C
*      TT(KEN)=TSTART+(KEN-1)*DT
*****
      U
      U
      U
*****
*      DO 8 KEND=1,NSTEP
*****
      U
      U
      U
*****
*      TT(KEND)=TT(KEN)+TF(KEND)
*****
      U
      U
*****
*8     CONTINUE
*****

*****
*C
*U    SUBROUTINE FERR IS CALLED TO COMPUTE PREDICTED FERR
*U
*U    CALL FERRCLE(NSTEP,TT,OF,NDIM
*U
*U    SUBROUTINE REGRESS COMPUTES AN APPROX CORRELATION

```

```

*C COEFFICIENTS COR2.
*C NOTE THAT ALL OTHER OUTPUT PARAMETERS FROM REGRESS
*C ARE NOT USED AT THIS POINT AND ARE OVERWRITTEN AT
*C EACH SUBSEQUENT CALL IN CURRENT LOOP.
*C
*      CALL REGRESS(A,A,NSTEP,KES,RESF,COR(KEN),NDIM)
*****
      V
      V
      V
*****
*      IF (IOUT.EQ.2) GO TO 7
*****
      V
      V
      V
*****
*C
*C IF LONG FORM OUTPUT REQUESTED, PRINT ITERATION LOG DATA
*C PLACING INTERMEDIATE VALUES OF KEY PARAMETERS.
*C
*      WRITE(5,27) NEN, TT(NEN), 1, AF(1), A(1), COR(NEN)
*27  FORMAT('0',I5,F13.3,I7,2F10.1,F11.5)
*****
      V
      V
      V
*****
*      DO 29 J=2,NSTEP
*****
      V
      V
      V
*****
*      WRITE(5,28) J, AF(J), A(J)
*28  FORMAT(' ',22X,I3,2F10.1)
*****
      V
      V
      V
*****
*29  CONTINUE
*****
      V
      V
      V
*****
*7  CONTINUE
*****
      V
      V
      V
*****
*C
*C COMPUTE THE DERIVATIVE OF THE COR ARRAY WITH RESPECT TO
*C THE INDEPENDENT VARIABLE TT AND STORE IN THE FIRST NREF
*C ELEMENTS OF ARRAY COR2
*C
*      CALL DER(COR,COR2,DT,NREF)
*****
      V
      V
      V
*****
*      IF (IOUT.EQ.2) GOTO 32
*****

```



```

V
V
V
*****
*      WRITE(5,41)
*41     FORMAT(' ', '/')
*      WRITE(5,41)
*      WRITE(5,40)
*40     FORMAT(' ', 65(' '))
*      WRITE(5,33)
*33     FORMAT(' ', 'CORRELATION COEFFICIENTS AND FIRST
*      $ DERIVATIVES FROM SUBROUTINE DER')
*      WRITE(5,40)
*      WRITE(5,41)
*      WRITE(5,34)
*34     FORMAT(' ITERATION CORRELATION FIRST')
*      WRITE(5,35)
*35     FORMAT(' NUMBER COEFFICIENT DERIVATIVE')
*****
V
V
V
*****
*      DO 36 I=1,NREP
*****
V
V
V
*****
*      WRITE(5,37) I, COR(I), COR2(I)
*37     FORMAT('0', I4, F15.5, E13.3)
*****
V
V
V
*****
*36     CONTINUE
*****
V
V
*****
*32     CONTINUE
*C
*C A CALL IS MADE TO SUBROUTINE ROOTS TO COMPUTE
*C THE VALUE OF TT AT WHICH THE DERIVATIVE VECTOR
*C COR2 VANISHES. THE ROOT IS RETURNED AS THE SINGLE
*C PRECISION SCALAR TRANS.
*C
*C CALL ROOTS(NROOT, COR2, TT, NREP, TRANS)
*C
*C INTEGER NROOT CONTAINS NUMBER OF ROOTS (ZERO OR ONE)
*C
*****
V
V
V
*****
*      IF(NROOT) 14, 14, 3
*****
V
V
V
*****
*C
*C NO ROOT WAS FOUND WITHIN SPECIFIED TIME INTERVAL

```

```

#C OUTPUT DIAGNOSTIC INFORMATION AND TERMINATE EXECUTION
#C
*****
      V
      V
*****
#14 WRITE(5,4)
#4  FORMAT(' NO ROOTS WERE FOUND WITHIN SPECIFIED TIME INTERVAL
#  WRITE(5,5)
#5  FORMAT(' , VALUES OF TIME AND CORRESPONDING VECTOR
#  & OF DERIVATIVES' , ARE AS FOLLOWS:
#6  FORMAT(' , ARE AS FOLLOWS: )
*****
      V
      V
      V
*****
# DO 10 I=1,NREF
*****
      V
      V
      V
*****
# WRITE(5,11)I,TT(I),COR(I)
*****
      V
      V
      V
*****
#10 CONTINUE
*****
      V
      V
      V
*****
#11 FORMAT(' ,13,F10.2,F10.4)
#  WRITE(5,12)
#12 FORMAT(' , ADJUST INPUT VARIABLES NREF, TSTART, AND TEND
#  WRITE(5,13)
#13 FORMAT(' , FOR A WIDER REGRESSION DOMAIN AND RE RUN
#  WRITE(5,94)
#94 FORMAT(' EXECUTION TERMINATING IN SUBROUTINE TRANSIT
*****
      V
      V
      V
*****
# STOP
*****
      V
      V
*****
#3 CONTINUE
# IF(IOUT,10,1) WRITE(5,93) TRANS
#93 FORMAT(' ,,,, DERIVATIVE VECTOR VANISHES AT LIMB
#  & F10.2, SECONDS )
#  WRITE(5,41)
#C
#C TOTAL TRANSIT TIME FROM CORE TO DETECTOR IS SUM OF
#C TRANS AND THE FEED LOOP TRANSIT TIME TEL
#C
*****
      V
      V

```


APPENDIX D

FORTRAN Flowchart for Subroutine LMBDA

```

      ENTRANCE
      V
      V
*****
*   SUBROUTINE LMBDA(IOUT,RES,RESP,TF,F,AF,A2,NDIM,T,NSTEP)
*   DIMENSION RES(NDIM),RESP(NDIM),TF(NDIM),COR(50),COR2(50)
*   DIMENSION LMD(50),T(NDIM),F(NDIM),AF(NDIM),A2(NDIM)
*C
*C   THIS SUBROUTINE COMPUTES THE ISOTOPIC ESCAPE RATE
*C   COEFFICIENT FOR SN PRECURSORS EMITTED FROM THE FUEL
*C   TO THE COOLANT.
*C
*C   RES = OUTPUT VECTOR OF RESIDUALS, IN CPS
*C   RESP = OUTPUT VECTOR OF RESIDUALS, EXPRESSED AS A PERCENTAGE
*C   OF MEASURED COUNTS
*C   RES AND RESP ARE COMPUTED IN SUBROUTINE REGRESS
*C
*C   TF = INPUT VECTOR OF FERRI-LOOP TRANSIT TIMES
*C   F = INPUT VECTOR OF FLOW RATES, GPM
*C   AF = OUTPUT VECTOR OF PREDICTED COUNT RATES
*C   A2 = INPUT VECTOR OF CORRECTED COUNT RATES (MEASURED-TRAMF)
*C   NDIM = INTEGER DIMENSION VARIABLE, NOT LESS THAN NSTEP
*C   T = AUXILIARY WORK ARRAY OF DIMENSION NDIM, ON OUTPUT T
*C   CONTAINS THE TOTAL TRANSIT TIME FROM THE CORE TO THE
*C   DETECTORS AS A FUNCTION OF FERRI FLOW.
*C
*   REAL LMBDAE,LMD,LE1
*   COMMON /AREA2/TRANS, XFIT,SLOPE,GAMMA,LMBDAE
*C
*C   STATISTICAL PARAMETERS FROM SUBROUTINE REGRESS STORED IN
*C   LABELED COMMON AREA3
*   COMMON/AREA3/BO,B1,STD,STDC
*   WRITE(5,7)
*7   FORMAT(' ENTER CORE-SODIUM TRANSPORT TIME IN SECONDS'//)
*****
      V
      D .....0
      V
*****
*9   READ(5,8)TRANS
*8   FORMAT(F)
*****
      V
      V
      V
*****
*   IF(TRANS)20,20,21
*****
      V
      V
      V
*****

```

```

*20  WRITE(5,22)
*22  FORMAT(' VALUE OF TRANS MUST BE A POSITIVE REAL CONSTANT
*      WRITE(5,23)
*23  FORMAT(' RE-ENTER TRANS'//)
*****
      U
      U
      U
*****
*      GO TO 9
*****
      D .....
      U

*****
*21  CONTINUE
*      WRITE(5,15)
*15  FORMAT(' ENTER STARTING VALUE FOR INDEPENDENT VARIABLE
*      & LAMDAE'//)
*****
      U
      D .....
      U

*****
*46  READ(5,8)LE1
*****
      U
      U
      U

*****
*      IF(LE1)42,42,43
*****
      U
      U
      U

*****
*42  WRITE(5,44)
*44  FORMAT(' VALUE MUST BE GREATER THAN ZERO /)
*      WRITE(5,45)
*45  FORMAT(' RE-ENTER STARTING VALUE IN SECONDS-1 /)
*****
      U
      U
      U

*****
*      GO TO 46
*****
      D .....
      U

*****
*43  CONTINUE
*      WRITE(5,16)
*16  FORMAT(' ENTER INCREMENT DLE'//)
*****
      U
      D .....
      U

*****
*49  READ(5,8)DLE
*****
      U
      U
      U

*****
*      IF(DLE)47,47,50

```

```

*****
      V
      V
      V
*****
*47  WRITE(5,44)
*   WRITE(5,48)
*48  FORMAT(' RE-ENTER INCREMENT DLE IN SECONDS-1'//)
*****
      V
      V
      V
*****
*   GOTO 49
*****
      V
      V
*****
*50  CONTINUE
*   WRITE(5,17)
*17  FORMAT(' ENTER THE TOTAL NUMBER OF ITERATIONS, NREP ,
*****
      V
      V
      V
*****
*54  READ(5,18) NREP
*18  FORMAT(I)
*****
      V
      V
      V
*****
*   IF(NREP.GE.5)GOTO 51
*****
      V
      V
      V
*****
*   WRITE(5,52)
*52  FORMAT(' NREP MUST BE AN INTEGER GREATER THAN FOUR
*   WRITE(5,53)
*53  FORMAT(' RE-ENTER NREP'//)
*****
      V
      V
      V
*****
*   GO TO 54
*****
      V
      V
      V
*****
*51  CONTINUE
*****
      V
      V
      V
*****
*   IF(IOUT.EQ.2) GO TO 31
*****
      V
      V
      V

```

```

*****
*C
*C IF LONG FORM OUTPUT REQUESTED, PRINT ITERATION NO.
*C DISPLAYING INTERMEDIATE VALUES OF KEY PARAMETERS
*C
*   WRITE(5,30)
*30  FORMAT('1000.15% * V, ITERATION LOSS FROM BEATING MEAS. ')
*   I 14(100.0/20)
*   WRITE(5,25)
*25  FORMAT(' ITERATION INDEPENDENT FLOW ASSOCIATED MEAS. NO. ')
*   I 10 'CORRELATION')
*   WRITE(5,26)
*26  FORMAT(' NUMBER    VARIABLE    STEP    COEFFICIENT ')
*   I 10 'COEFFICIENT ')
*****
      V
      V
      V
*****
*31  CONTINUE
*C
*C INCREMENT INDEPENDENT VARIABLE LMI
*C
*****
      V
      V
      V
*****
*   DO 1 I=1,NREF
*****
      V
      V
      V
*****
*   LMD(I)=LEI+(I-1)*DLE
*****
      V
      V
      V
*****
*1  CONTINUE
*****
      V
      V
      V
*****
*C
*C TOTAL TRANSIT TIME FROM CORE TO DETECTOR * 106 = T
*C TRANS AND THE FEED LOOP TRANSIT TIME TF.
*C
*****
      V
      V
      V
*****
*   DO 2 I=1,NSTEP
*****
      V
      V
      V
*****
*   T(I)=TRANS+TF(I)
*****
      V
      V
      V

```



```

*****
*2    CONTINUE
*****
      U
      U
*****
*      DO 3 I=1,NREP
*****
      U
      U
*****
*      LMBDAE=LMD(I)
*
*C
*C    SUBROUTINE FERD IS CALLED TO COMPUTE PREDICTED ACTIVITIES
*C    USING CURRENT VALUE OF LMBDAE
*C
*      CALL FERD(LMBDAE,NSTEF,T,AF,NDIM)
*C
*C    SUBROUTINE REGRESS COMPUTES AN ARRAY OF CORRELATION
*C    COEFFICIENTS COR.
*C    NOTE THAT ALL OTHER OUTPUT PARAMETERS FROM REGRESS
*C    ARE NOT USED AT THIS POINT AND ARE OVER-WRITTEN AT
*C    EACH SUBSEQUENT CALL IN CURRENT LOOP.
*C
*      CALL REGRESS(AF,A2,NSTEF,RES,RESP,COR,I,NDIM)
*****
      U
      U
*****
*      IF(IOUT.EQ.2)GO TO 3
*****
      U
      U
*****
*      WRITE(5,27)I,LMBDAE,I,AF(I),A2(I),COR(I)
*27    FORMAT('01,I5,F13.4,I7,2F10.1,F11.5')
*****
      U
      U
*****
*      DO 29 J=2,NSTEF
*****
*      WRITE(5,28)J,AF(J),A2(J)
*28    FORMAT('01,I7,22X,I3,2F10.1')
*****
      U
      U
*****
*29    CONTINUE
*****
      U
*****
*3    CONTINUE
*****

```

```

      V
      V
      V
*****
*C
*C  COMPUTE THE DERIVATIVE OF THE COR ARRAY WITH RESPECT TO
*C  THE INDEPENDENT VARIABLE TT AND STORE IN THE FIRST NREF
*C  ELEMENTS OF ARRAY COR2
*C
*      CALL DER(COR,COR2,DLE,NREF)
*C
*****

```

```

      V
      V
      V
*****
*      IF(IOUT.EQ.2)GOTO 32
*****

```

```

      V
      V
      V
*****
*      WRITE(5,41)
*41      FORMAT(' ',//)
*      WRITE(5,40)
*40      FORMAT(' ',65(' '))
*      WRITE(5,33)
*33      FORMAT(' ', 'CORRELATION COEFFICIENTS AND FIRST'
*      % DERIVATIVES FROM SUBROUTINE DER')
*      WRITE(5,40)
*      WRITE(5,41)
*      WRITE(5,34)
*34      FORMAT(' ITERATION CORRELATION   FIRST ')
*      WRITE(5,35)
*35      FORMAT(' NUMBER    COEFFICIENT DERIVATIVE')
*****

```

```

      V
      V
      V
*****
*      DO 36 I=1,NREF
*****

```

```

      V
      V
      V
*****
*      WRITE(5,37)I,COR(I),COR2(I)
*37      FORMAT('0',I4,F15.5,E13.3)
*****

```

```

      V
      V
      V
*****
*36      CONTINUE
*****

```

```

      V
      V
      V
*****
*32      CONTINUE
*C
*C  A CALL IS MADE TO SUBROUTINE ROOTS TO COMPUTE
*C  THE VALUE OF TT AT WHICH THE DERIVATIVE VECTOR
*C  COR2 VANISHES. THE ROOT IS RETURNED AS THE SINGLE
*C  PRECISION SCALAR LMBDAE.
*C

```

```

*      CALL ROOTS(NROOT,COR2,LMD,NREF,LMBDAE)
*****
      V
      V
      V
*****
*      IF(NROOT)24,24,19
*****
      V
      V
      V
*****
*C
*C NO ROOT WAS FOUND WITHIN SPECIFIED TIME INTERVAL
*C OUTPUT DIAGNOSTIC INFORMATION AND TERMINATE EXECUTION
*C
*****
      V
      V
      V
*****
*24  WRITE(5,4)
*4   FORMAT(' //NO ROOTS FOUND WITHIN SPECIFIED REGRESSION
*       DOMAIN')
*   WRITE(5,5)
*5   FORMAT(' //VALUES OF LMBDAE AND CORRESPONDING VECTOR
*       OF DERIVATIVES// ARE AS FOLLOWS: ')
*6   FORMAT(' //ARE AS FOLLOWS: ')
*****
      V
      V
      V
*****
*      DO 10 I=1,NREF
*****
      V
      V
      V
*****
*      WRITE(5,11)I,LMD(I),COR(I)
*****
      V
      V
      V
*****
*10  CONTINUE
*****
      V
      V
      V
*****
*11  FORMAT(' //I3,F10.2,F10.4)
*   WRITE(5,12)
*12  FORMAT(' //ADJUST INPUT VARIABLES NREF, LMD, AND COR
*   WRITE(5,13)
*13  FORMAT(' //FOR A WIDER REGRESSION DOMAIN AND REFIN
*   WRITE(5,39)
*39  FORMAT(' //EXECUTION TERMINATING IN SUBROUTINE LMBDA
*****
      V
      V
      V
*****
*      STOP
*****

```

```

J .....
V
*****
*19  CONTINUE
*   IF(IOUT.EQ.1)WRITE(5,38)LMBDAE
*38  FORMAT(' ',//, ' DERIVATIVE VECTOR VANISHES AT LMBDAE = E14.4
*       ' , ' SECONDS-1')
*C
*C  A FINAL CALL TO FERD COMPUTES THE PREDICTED ACTIVITY AF
*C  AT THE OPTIMUM VALUE OF LMBDAE
*C
*   CALL FERD(LMBDAE,NSTEP,T,AF,NDIM)
*C
*C  REGRESS IS NOW CALLED TO COMPUTE OVERALL REGRESSION
*C  COEFFICIENT XFIT, RESIDUALS, AND LINEAR FIT PARAMETERS
*C  B0 AND B1.
*C
*   CALL REGRESS(AF,A2,NSTEP,RES,RESF,XFIT,NDIM)
*C
*C  B0 AND B1 PASSED BY LABELED COMMON
*C
*   GAMMA=B0
*   SLOPE=B1
*****
V
V
V
*****
*   RETURN
*****
*   END
*****

```

LIST OF STATEMENT NUMBERS USED IN THE ABOVE ROUTINE.

1	2	3	4	5	6	7	8	9	10	11		13	17	18		19	29		
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
42	43	44	45	46	47	48	49	50	51	52	53	54							

END OF JOB

ACKNOWLEDGMENTS

I express appreciation to Bob Strain of the EBR-II Project. Without his interaction and comments, development of the earliest version of GIRAFFE would not have been possible. Feedback from his experience running GIRAFFE during code checkout and verification led to many improvements in the current version of the code.

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