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ICEDT:
AN EXPONENTIAL DATA ANALYSIS CODE

April, 1965

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ICEDT:
AN EXPONENTIAL DATA ANALYSIS CODE

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April, 1965

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

ABSTRACT

ICEDT is a comprehensive program for the reduction and analysis of exponential pile data. Geometrical buckling, horizontal or vertical extrapolation, or any combination are available under option. Standard output includes an analysis of the validity of data and aids to the location of possible input errors. Pile dimensions and counter data from horizontal and/or vertical traverses are required for input. Sample data forms and a complete description of input, output, and operation are given in the descriptive document. The symbolic deck consists of about 3000 Fortran and FAP cards. A 32k computer is required.

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INTRODUCTION

The uses, methods of analysis, and input requirements of ICEDT are described by this document. It is primarily intended for the use of those individuals involved in the taking and analysis of exponential pile data. A familiarity with exponential theory⁽¹⁾ and measurement practices at Hanford⁽²⁾ is assumed. ICEDT (Improved, Combined Exponential Data Treatment) is an alliance of three existing exponential data codes: (1) VT0CL computes relaxation length and geometrical buckling from vertical traverse data. (2) C0FIT2 determines horizontal extrapolation length from horizontal traverse data. (3) EVT0C0 uses VT0CL and C0FIT2 to determine vertical extrapolation by an iterative procedure. In combination, the three codes form a comprehensive program for the reduction and analysis of exponential pile data. ICEDT processes intermixed cases of all three kinds, making obsolete the existing programs and their descriptive documents.^(3,4)

The three codes are now individually described.

VTCL

Purpose

The principal use of VTCL is the computation of relaxation length and material buckling by means of a least squares fit on vertical traverse data taken in an exponential pile. The program may also be used to produce only end and/or harmonic corrections. Portions of VTCL are also used by BVTCL. When used by BVTCL, the description of VTCL Options and Formulation apply, but the VTCL Procedure is inapplicable.

Options

Two general types of VTCL cases, as outlined above, may be processed by the program. All other options serve only to define the conditions of the specific case.

Input data for a buckling calculation may be in the form of raw counter data or externally-computed thermal activities (A_{gt} 's). When raw data are submitted, A_{gt} 's may be computed by the standard method (Equation 4) or by the cadmium shutter method (Equation 6). When using the standard method, pile background may be entered as raw counts or as A_{bg} . If the raw data have been previously processed, the computed A_{gt} 's may be entered instead of raw data and all further options are still available.

If the user has available a set of corrections which may be close to those required, these may be entered as data, eliminating the computation of a trial set of corrections. If no corrections are available but a B_{11} is estimated, the trial set is computed using this B_{11} . If no B_{11} is entered, the code makes an adequate estimate from pile data.

One- or two-region standard harmonic corrections, and one- or two-region fast source theory harmonic corrections may be used in any combination with one- or two-region standard end corrections. End corrections are available without

VTECL

Options - cont'd.

harmonics, also. All options on corrections are operable whether a buckling is being computed or corrections are computed alone.

It is possible to exclude any slot or slots from all least-squares fits. The back-fit is printed for these excluded slots, but they are not considered in making the fit.

Intermediate values which are normally of no interest may be printed as an option. This option is used principally when the results of a given run seem questionable, and it is desirable to rerun to obtain more information. At this date, the only values given are intermediate results saved during the calculation of harmonic and end corrections of all types. It is possible to expand this option whenever required.

Procedure

Data are read and checked to assure that all input required for the requested options has been submitted. If necessary input values are missing or patently unreasonable, the error is defined in a message and the program proceeds to the next case. Counting data are processed as read, so that a case may be partially completed before being terminated because of an error.

If no data errors are discovered, the program determines to which of the two possible types the case belongs. If only corrections are required, these are computed and the program proceeds to the next case. If a buckling is required, the following procedure applies (see Figure 3).

If corrections are not entered as input, they are computed from a program-estimated B_{11} unless the user has entered a B_{11} guess. These corrections are

VT0CLProcedure - cont'd.

applied to the A_{th} 's which were either entered as data or computed from raw data, and a least squares fit is made to the corrected A_{th} 's producing a buckling and an output B_{11} . If the ΔB_{11} (/fit input B_{11} - fit output B_{11} /) is not within the limit specified by the input, the fit output B_{11} is used to compute a new set of corrections. These are applied to the A_{th} 's and a new fit is made. This process continues until $\Delta B_{11} \leq \Delta B_{11}$ limit from input data. This situation is referred to as a converged fit.

At this point a converged fit has been made using data from all slots (measurement positions). Throughout this procedure, slots excluded by input option are not considered. "All slots" means all those to be considered. Three more converged fits are now made: with the first (lowest) slot omitted, with the last slot omitted, and with both first and last slots omitted. If any one of these four converged fits is a satisfactory fit, the program continues to the next case. A satisfactory fit is defined as a converged fit in which no residual is greater than the ΔL limit specified by the input.

If none of the four is satisfactory, two more converged fits are made; one with the worst slot omitted, and one with the two worst omitted. The worst slot is defined as that slot with the largest relative residual (Equation 12) in the first fit (all slots included). If either of the preceding fits is satisfactory, the program continues to the next case.

If neither of the preceding fits is satisfactory, seven more converged fits are made, omitting slots in these combinations: (1) first and worst; (2) first and second worst; (3) last and worst; (4) last and second worst; (5) first, last, and worst; (6) first, last, and second worst; and (7) first,

VT00L

Procedure - cont'd.

last, worst, and second worst. Less than seven fits will result from this step if one or more would be a repeat of one of the first four, or if omission of the specified slots would not leave three points, the minimum number necessary to make a fit.

After completion of these seven converged fits, the program proceeds to the next case whether or not a satisfactory fit has been found.

VTSCG - cont'd.

Formulation - Data Reduction

In order to obtain a measurement of the thermal flux in the pile, measurements are taken with a bare detector, with a cadmium-covered detector, and with a bare detector while sources are removed from the pile (pile background measurement). Corrected counting rates for bare (A_{bare}), cadmium-covered (A_{cad}), and background (A_{bg}) conditions are computed at each measurement position by

$$A = \frac{\sum(cts + CL - BG)CF}{\sum time} \quad (1)$$

where CL is coincidence loss, CF is a counter standardization factor, and BG = time x (counter background/minute).

$$cts + CL = \frac{\text{counts}}{1 - \mu \left(\frac{\text{counts}}{\text{time}} \right)} \quad (2)$$

where μ = counter dead time = 7.6×10^{-6} sec. = 1.27×10^{-7} minutes.

The quantities

$$D_{bare} = \left(\frac{\sqrt{n}}{n} \right)_{bare}, D_{cad} = \left(\frac{\sqrt{n}}{n} \right)_{cad}, D_{bg} = \left(\frac{\sqrt{n}}{n} \right)_{bg} \quad (3)$$

are computed, where n is the total number of bare, cadmium-covered, or background counts at the measurement position.

Thermal flux in a standard experiment is computed by

$$A_{th} = (A_{bare} - A_{bg}) \left(\frac{CR - 1.0}{CR} \right) \quad (4)$$

where CR is the average cadmium ratio, that is, the average $\frac{A_{bare}}{A_{cad}}$.

A measure of the counting error may then be given by

$$B = \ln(A_{th}) - \ln[A_{th} + \sqrt{D_{bare}A_{bare} + D_{cad}A_{cad} + D_{bg}A_{bg}}] \quad (5)$$

VINCE

Formulation - Data Reduction - cont'd.

When using the cadmium shutter technique to make the measurement, data are taken with and without a cadmium shutter which shields the detector from the sources. Corrected counting rates for both conditions in a cadmium shutter experiment are computed by Equation 1, and thermal flux by

$$A_{th} = (A_{bare, no shutter} - A_{bare, with shutter}). \quad (6)$$

The measure of counting error is then

$$E = \ln(A_{th}) - \ln[A_{th} + \sqrt{D_{bare}A_{bare} + D_{shutter}A_{shutter}}] \quad (7)$$

VISCO - cont'd.

Formulation - Least Squares Method

To obtain the buckling of a pile, corrected values of A_{th} are assumed to fit a line of the form $\ln y = a_0 + \beta X$. In making the least squares fit, n = number of points, X = distance from source plane to detector (z in Figures 1 and 2), and $Y = \ln (A_{th} C_e C_h)$. In finding the intercept a_0 and slope β , $\sum$ indicates $\sum_{i=1}^n$.

$$a_0 = \frac{\sum Y \sum X^2 - \sum XY \sum X}{n \sum X^2 - (\sum X)^2} \quad (8)$$

$$\beta = \frac{n \sum XY - \sum X \sum Y}{n \sum X^2 - (\sum X)^2} \quad (9)$$

The values of the fitted equation are given by

$$\tilde{Y}_i = a_0 + \beta X_i \quad (10)$$

and residuals between data values and the fitted equation by

$$\delta Y_i = Y_i - \tilde{Y}_i \quad (11)$$

For the purpose of later determining which points are to be dropped in order to make a better fit, a "relative residual," $R\delta$, is computed for interior slots:

$$R\delta = |\delta Y_i - \delta Y_{i-1}| + |\delta Y_{i+1} - \delta Y_i| \quad (12)$$

The output B_{11} (relaxation length) is computed by

$$B_{11} = 1/\beta \quad (13)$$

and the buckling by

$$B = \frac{E^2}{a^2} + \frac{E^2}{b^2} - \frac{1}{B_{11}^2} \quad (14)$$

The standard deviations of the inverse relaxation length, $S_{B_{11}}$, and of the buckling, δB^2 , are then computed.

VTQCL

Formulation - Least Squares Method - cont'd.

$$S_b = \left[\frac{\sum y^2}{(n-2) \left(\sum X^2 - \frac{(\sum X)^2}{n} \right)} \right]^{1/2} \quad (15)$$

$$dB^2 = \frac{2S_b}{B_{11}} \quad (16)$$

VTAC1 - cont'd.

Formulation - Harmonic and End Corrections

Harmonic and end corrections are described by Equations 17-37. Pile dimensions used in these equations are (see Figures 1 and 2):

a = effective width

b = effective depth

Z = distance from source plane to effective top of pile

z = distance from source plane to measurement plane

z' = distance from effective bottom of pile to source plane

In addition, in a multi-region pile (see Figure 2):

s = distance from source plane to the boundary plane between regions one and two

C = distance from source plane to boundary plane between regions two and three

In either case, x' and y' denote detector position, while x_i and y_i define source positions, and S_i are fractional source strengths.

It should be noted that the assumptions made in the derivation of harmonic and end correction equations make them valid only when the sources are symmetrically placed with respect to both the x-axis and y-axis.

Harmonic and end corrections are based on an input B₁₁. If no B₁₁ is entered as input data, the program makes the estimate

$$B_{11} = \frac{Z_2 - Z_{n-1}}{\ln \frac{(A_{th})_{n-1} - (A_{th})_2}{(A_{th})_2 - (A_{th})_{n-1}}} \quad (17)$$

This B₁₁ enters the corrections in the form of the buckling (B) of the measurement region in Equation 22 or 24 by setting

$$B = \frac{\pi^2}{a^2} + \frac{\pi^2}{b^2} - \frac{1}{B_{11}^2} \quad (18)$$

VICCI

Formulation - Harmonic and End Corrections - cont'd.

Throughout Equations 19-37, n and m are odd integers from 1 to 9. The contribution of harmonics of order >9 is considered negligible and ignored.

One-region harmonic and end corrections are given in Equations 19 to 20.

$$C_h = \frac{A_{11} B_{11} F_{11} e^{-z/B_{11}}}{\sum_{nm} A_{nm} B_{nm} F_{nm} e^{-z/B_{nm}}} \quad (19)$$

$$C_e = \left[1 - e^{-2(Z - z)/B_{11}} \right]^{-1} \quad (20)$$

where

$$A_{nm} = 2 \left[1 - \coth(z'/B_{nm}) \right]^{-1} \quad (21)$$

$$B_{nm} = \left[\pi^2 \left(\frac{n^2}{a^2} + \frac{m^2}{b^2} \right) - B \right]^{-1/2} \quad (22)$$

$$F_{nm} = \cos \frac{L\pi x'}{a} \cos \frac{m\pi y'}{b} \sum_i S_i \cos \frac{L\pi x_i}{a} \cos \frac{m\pi y_i}{b} \quad (23)$$

When two-region harmonic or end corrections⁽⁵⁾ are required, we introduce the notation

$$(\gamma_i)_{nm} = \left[\pi^2 \left(\frac{n^2}{a^2} + \frac{m^2}{b^2} \right) - B_{\text{region } i} \right]^{1/2} = \left(\frac{1}{\beta_{nm}} \right)_{\text{region } i} \quad (24)$$

where region 1 is the base region, region 2 is the measurement region, and region 3 is the top region.* Then

$$C_h = \frac{F_{11} P_{11} e^{-z(\gamma_2)_{11}}}{\sum_{nm} F_{nm} P_{nm} e^{-z(\gamma_2)_{nm}}} \quad (25)$$

where

$$P_{nm} = \frac{e^{s(\gamma_2 - \gamma_1)_{nm}}}{(\gamma_1 + \gamma_2)_{nm} \left[(1 - D_{nm}) + (1 + D_{nm}) \coth \left[z' (\gamma_1)_{nm} \right] \right]} \quad (26)$$

*Note that if region i is graphite, $B_i = -1/L_G^2$.

VTGCL

Formulation - Harmonic and End Corrections - cont'd.

$$D_{nm} = \left(\frac{R_{nm} - 1}{R_{nm} + 1} \right) e^{-2s (Y_1)_{nm}}, \text{ and} \quad (27)$$

$$R_{nm} = (Y_1)_{nm} / (Y_2)_{nm} \quad (28)$$

When two-region end corrections are used, C_n may be computed from one- or two-region corrections as required and

$$C_e = \left\{ 1 + \exp [-2 (Y_2)_{11} (C - z)] \frac{\frac{1 - Q}{1 + Q} \exp[2 (Y_3)_{11} (Z - C)] - 1}{\exp[2 (Y_3)_{11} (Z - C)] - \frac{1 - Q}{1 + Q}} \right\}^{-1} \quad (29)$$

where

$$Q = (Y_3)_{11} / (Y_2)_{11} \quad (30)$$

Fast source theory single region harmonics⁽⁶⁾ are given by

$$C_n = \frac{A_{11} B_{11} F_{11} e^{-z/B_{11}} J_{11} \omega}{\sum_{nm} A_{nm} B_{nm} F_{nm} J_{nm} e^{-z/B_{nm}}} \quad (31)$$

Two-region fast source theory harmonics are given by

$$C_n = \frac{F_{11} P_{11} e^{-z (Y_2)_{11}} J_{11} \omega}{\sum_{nm} F_{nm} P_{nm} J_{nm} e^{-z (Y_2)_{nm}}} \quad (32)$$

In either case,

$$J_{11\omega} = 2 \sum_{j=1}^3 f_j e^{-B_1 r_j^2 / 4} \quad (33)$$

where f 's are the fractions of source neutrons emitted for corresponding source ranges (r 's) and B_1 is the buckling of the graphite base region $(-1/L_G^2)$.

The formulation of J_{nm} for fast source theory corrections depends upon whether or not the cadmium shutter method is used. If a cadmium shutter is present in the pile,

VT9CL

Formulation - Harmonic and End Corrections - cont'd.

$$J_{nm} = \sum_{j=1}^3 f_j e^{-B_1 r_j^2/4} \left\{ \left[1 + \operatorname{erf} \left(\frac{s}{r_j} - \frac{r_j}{2BF_{nm}} \right) \right] + e^{2s/BF_{nm}} \left[1 - \operatorname{erf} \left(\frac{s}{r_j} + \frac{r_j}{2BF_{nm}} \right) \right] \right\} \quad (34)$$

If a cadmium shutter is not used, J_{nm} is computed by

$$J_{nm} = \sum_{j=1}^3 f_j e^{-B_1 r_j^2/4} \left\{ \frac{1}{N} \sum_{i=1}^N \left[1 + \operatorname{erf} \left(\frac{d_i}{r_j} - \frac{r_j}{2BF_{nm}} \right) \right] + e^{2d_i/BF_{nm}} \left[1 - \operatorname{erf} \left(\frac{d_i}{r_j} + \frac{r_j}{2BF_{nm}} \right) \right] \right\} \quad (35)$$

where N is the number of sources and d_i is the distance from the source (at $x_i, y_i, 0$) to the measurement position (x', y', z).

$$d_i = [(x' - x_i)^2 + (y' - y_i)^2 + z^2]^{1/2} \quad (36)$$

In both Equations 34 and 35,

$$BF_{nm} = \left[\pi^2 \left(\frac{\omega_a^2}{a^2} + \frac{\omega_b^2}{b^2} \right) - B_1 \right]^{-1/2} \quad (37)$$

The ω_a^2 and ω_b^2 of Equation 37 provide a streaming correction based upon ratios of diffusion lengths perpendicular and parallel to streaming channels.*

*This can be more fully explained by referring to Richey and Block,⁽⁷⁾ page 14, where for case (a), $\omega_a = 1.0$ and $\omega_b = \frac{1}{-1}$, but for case (b), $\omega_a = \omega_b = \frac{1}{-1}$.

VTACL - cont'd.

Description of Output - Input Data Report

On the first page or pages of each case is an Input Data Report, listing input parameters with sufficient explanatory material to form a valuable addition to the permanent output record. This report also provides assistance in tracing possible input errors. Included are all identification cards, pile dimensions, source positions and strengths, detector positions, and an interpretation of all options which were selected.

Description of Output - Corrections Only

Unless VTACL is instructed by input option to compute only corrections, the program proceeds to the Data Reduction Report. If only corrections are to be computed, the Input Data Report is followed by a listing of computed corrections, after which the program goes on to the next case. The report of corrections only consists of one page for each input B_{11} . Each page gives the following information for every measurement position:

SLOT	Pile layer number
S	Source-to-measurement-position distance
CE	C_e , end correction (Equation 20 or 29)
CH	C_h , harmonic correction (Equation 19, 25, 31, or 32)
CECH	$C_e C_h$

Description of Output - Data Reduction Report

Following the Input Data Report is a summary of counter data reduction results. It lists the following quantities at each measurement position for bare, cadmium (or shutter), and background (if any) conditions:

SLOT	Pile layer number
COUNTS	From counter data input sheet (sample, p. 61)
TIME	

TABLE

Description of Output - Data Reduction Report - cont'd.

CTR BG/MIN	}	From counter data input sheet
CTR FACTOR		
A		Corrected counting rate (Equation 1)
1/SR N		D (Equation 3)

This is followed by a summary of the A_{th} calculation. In standard experiment, the A_{th} summary lists the following quantities at each measurement position:

SLOT	File layer number
A-BARE	}
A-CAD	
A-BC	
A-THERMAL	Equation 4
LN A-THERMAL	First term of Equation 5
LN CTNG ERROR	Second term of Equation 5
DIFF	E (Equation 5)

For cadmium-shutter experiment, the A_{th} summary gives

SLOT	File layer number
A-BARE NO SHTR	Equation 1
A-BARE WITHSHTR	Equation 1
A-THERMAL	Equation 6
LN A-THERMAL	First term of Equation 7
LN CTNG ERROR	Second term of Equation 7
DIFF	E (Equation 7)

VTSCOL - cont'd.

Description of Output - Least Squares Fits

During the search for a satisfactory fit, only converged fits are printed (see Procedure). For each converged fit, there is one set of output listing the following quantities for each measurement position:

SLOT	Pile layer number
A-THERMAL	A_{th} (Equation 4 or 6)
HAR _e CORR.	$C_e C_h$ (Product of end and harmonic corrections)
CORR. A-TH	$A_{th} C_e C_h$
LN	$\ln(A_{th} C_e C_h) = Y$ of Equations 8 and 9.
BACK FIT	$\tilde{Y}$ (Equation 10)
DIFFERENCE	δY (Equation 11)

Below the individual position information are two lines giving

INPUT B ₁₁	B_{11} with which corrections were computed
OUTPUT B ₁₁	Output B_{11} (Equation 13)
BUCKLING	Output buckling (Equation 14)
S-SUB-B	Standard deviation of $1/B_{11}$ (Equation 15)
D B-SQ	Standard deviation of buckling (Equation 16)

If any measurement positions were omitted from the fit, their deviations are computed. The information given above for fitted positions is then listed for these omitted measurements.

COFIT2

Purpose

Horizontal extrapolation length of an exponential pile is computed by means of a least squares cosine fit to horizontal traverse data.⁽³⁾ The program may also be used to produce only end and/or harmonic corrections. Portions of COFIT2 are also used by BVT0C0.

Options

The usual case is the computation of extrapolation length from horizontal traverse data. It is also possible to compute only end and/or harmonic corrections.

When extrapolation length is being determined, A_{th} 's (normalized values of thermal flux) may be computed by the standard method (Equation 4) or by the cadmium shutter method (Equation 6).

One- or two- region standard harmonic corrections and one- or two-region fast source theory harmonic corrections may be used in any combination with one- or two-region standard end corrections. End corrections are available without harmonics, also. All above options on corrections are operable whether extrapolation length is being determined or corrections are computed alone. It is also possible to fit data without corrections (all corrections set equal to 1.0).

Results of the least squares analysis are normally printed only after convergence or after twenty iterations, if convergence does not occur. The program may be directed, however, to print every iteration during the fitting procedure.

The code can be directed to automatically omit five sets of end points (corresponding measurement positions farthest from the pile center), computing a new value of extrapolation length after dropping each set of points.

CONFIT2

Options - cont'd.

It is possible to exclude any position or positions from all cosine fits. The back-fit is computed for these positions, but they are not considered in making the fit.

Intermediate values which are normally of no interest may be printed as an option. This option is used principally when the results of a given run seem questionable and it is desirable to rerun to obtain more information. At this date, the only values given are intermediate results saved during the calculation of harmonic and end corrections of all types. It is possible to expand this option whenever required.

Procedure

Data are read and checked for validity. If necessary quantities are missing or if certain quantities or option combinations are unreasonable, the error is defined in a message and the program proceeds to the next case. Counting data are processed as read, so that a case may be partially completed before being terminated because of an error.

If no data errors are recognized, the program determines to which of the two general types the case belongs. If only corrections are required, these are computed and the program proceeds to the next case.

When extrapolation length is to be computed, corrections are computed using the specified B_{11} and applied to the A_{th} 's computed from counter data. A cosine fit is then made to the corrected A_{th} 's, using the estimated A_0 , B_0 , and C_0 ; thus obtaining an output A , B , and C . If all three parameters meet convergence criteria (i.e., $|A - A_0| \leq \epsilon_1$, $|B - B_0| \leq \epsilon_2$, and $|C - C_0| \leq \epsilon_3$),

CGFIT2

Procedure - cont'd.

the results are printed. If any of the three parameters has not converged, A_0 , B_0 , and C_0 are replaced by A , B , and C , and a new cosine fit is made. This procedure is repeated until all criteria are met, with a limit of 20 iterations. If the input option does not specify dropping end points, the program then continues to the next case.

If end points are to be dropped, a converged fit is made omitting the point farthest from the source on either end of the traverse. Converged fits are then made with successive pairs of end points dropped until only $n-10$ (or 3, if $n < 13$) points remain. The case is then terminated.

In selecting end points to be dropped, positions excluded by input option from the original cosine fit are considered. For example: Counter data were entered for ten positions, and input option specified the dropping of end points and the exclusion of one of the outside points only. The first converged fit is made with nine points (all except the excluded point). Converged fits then are made with 8, 6, and 4 points.

CGFIT2 - cont'd.

Formulation - Data Reduction

Corrected counting rates, A_{ch} 's, and counting error are computed for each measurement position by methods identical to those used in VTCL. Equations 1-7 apply.

The utilization of the described data in a least squared cosine fitting method also requires computation of the quantity

$$\Delta Y = C_e C_h \sqrt{[A_{bare} D_{bare}]^2 + [A_{cad} D_{cad}]^2 + [A_{bg} D_{bg}]^2} \quad (38)$$

For a cadmium shutter experiment,

$$\Delta Y = C_e C_h \sqrt{[A_{bare} D_{bare}]^2 + [A_{cad} D_{cad}]^2} \quad (39)$$

Formulation - Harmonic and End Corrections

Harmonic and end corrections are computed for each measurement position by methods identical to those used by VTCL. Equations 17-37 apply.

Formulation - Parameter Estimates

Since A is the value of the flux at the effective center of the pile, the code will use $C_e C_h A_{th}$ of the center point (slot 01) as A_0 . If no measurement is taken in the center position, an estimate for A_0 must be entered on the data sheet. For a side-to-side traverse, the program computes

$$B_0 = \frac{\pi}{\text{physical } a + 2 (\text{estimated } \lambda)} \quad (40)$$

For a front-to-rear traverse, physical b replaces physical a in the above equation. C_0 is assumed to be zero unless an estimate is entered.

CGFIT2 - cont'd.

Formulation - Least Squares Method

The CGFIT method is from Anderson and Lawton.⁽⁹⁾ Since the following discussion of method is taken from their presentation, some unavoidable confusion of notation arises. It should be noted that the symbols a , b , C (pile dimensions), and B (buckling) are duplicated and must be re-defined when considering the least squares method.

In order to determine extrapolation length, the thermal flux across the pile is assumed to fit a cosine function of the form $Y = A \cos[B(X - C)]$ where Y = corrected thermal flux and X = signed distance from pile centerline to measurement position.

It is desired to determine the parameters A , B , and C that best fit the data, as well as the standard deviations S_A , S_B , and S_C due to uncertainties in the measured data. A is the corrected value of thermal flux at the effective center of the pile. C is the displacement of the effective pile center from the physical pile center. The effective pile width, H , may be determined from B by $H = \pi/B$.

A standard least squares analysis in an iterative scheme is used to determine A , B , and C from the set of N measurements Y_i and errors ΔY_i ($i = 1, 2, \dots, N$) where $3 \leq N \leq 50$. The functional form may be expressed as

$$\begin{aligned} \hat{f}_i &= A \cos B (X_i - C) \\ &= (A_0 + a) \cos \left[(B_0 + b)(X_i - (C_0 + c)) \right] \end{aligned}$$

where a , b , and c are small increments on A_0 , B_0 , and C_0 , the initial estimates of the parameters.

CCFIT2

Formulation - Least Squares Method - cont'd.

The function f_i may be expanded in a Taylor series about the point (A_0, B_0, C_0) .

$$f_i(A, B, C) = f_i(A_0, B_0, C_0) + \left. \frac{\partial f_i}{\partial A} \right|_0 a + \left. \frac{\partial f_i}{\partial B} \right|_0 b + \left. \frac{\partial f_i}{\partial C} \right|_0 c + \dots$$

Define

$$\left. \frac{\partial f_i}{\partial A} \right|_0 = u_i, \quad \left. \frac{\partial f_i}{\partial B} \right|_0 = v_i, \quad \left. \frac{\partial f_i}{\partial C} \right|_0 = w_i,$$

then

$$\begin{aligned} u_i &= \cos B_0 (X_i - C_0), \\ v_i &= - (X_i - C_0) A_0 \sin B_0 (X_i - C_0), \\ w_i &= A_0 B_0 \sin B_0 (X_i - C_0). \end{aligned}$$

The deviations, d_i , of the experimental points Y_i from the curve f_i are given by

$$d_i = Y_i - f_i(A_0, B_0, C_0) - u_i a - v_i b - w_i c, \quad (41)$$

$$F_i = Y_i - u_i a - v_i b - w_i c,$$

where

$$F_i = Y_i - f_i(A_0, B_0, C_0).$$

The least squares principle now asserts that the quantity

$$s^2 = \sum_{i=1}^N \left(\frac{d_i}{\Delta Y_i} \right)^2 \quad (42)$$

is to be minimized with respect to the constants, i.e., $\frac{\partial s^2}{\partial A} = \frac{\partial s^2}{\partial B} = \frac{\partial s^2}{\partial C} = 0$ are the defining equations for a, b, c .

CONTINUED

Formulation - Least Squares Method - cont'd.

Performing these differentiations leads to the equations

$$\sum_{i=1}^N \left(\frac{1}{\Delta Y_i} \right)^2 (F_i - u_i a - v_i b - w_i c) u_i = 0 ,$$

$$\sum_{i=1}^N \left(\frac{1}{\Delta Y_i} \right)^2 (F_i - u_i a - v_i b - w_i c) v_i = 0 ,$$

$$\sum_{i=1}^N \left(\frac{1}{\Delta Y_i} \right)^2 (F_i - u_i a - v_i b - w_i c) w_i = 0 .$$

Setting

$$\mu_i = \frac{u_i}{\Delta Y_i} , \quad v_i = \frac{v_i}{\Delta Y_i} , \quad \omega_i = \frac{w_i}{\Delta Y_i} , \quad \rho_i = \frac{F_i}{\Delta Y_i}$$

gives the following solutions for a, b, c.

$$a = \frac{\begin{vmatrix} (\rho_i \mu_i) & (\mu_i v_i) & (\mu_i \omega_i) \\ (\rho_i v_i) & (v_i v_i) & (v_i \omega_i) \\ (\rho_i \omega_i) & (\omega_i v_i) & (\omega_i \omega_i) \end{vmatrix}}{D} ,$$

$$b = \frac{\begin{vmatrix} (\mu_i \mu_i) & (\rho_i \mu_i) & (\mu_i \omega_i) \\ (\mu_i v_i) & (\rho_i v_i) & (v_i \omega_i) \\ (\mu_i \omega_i) & (\rho_i \omega_i) & (\omega_i \omega_i) \end{vmatrix}}{D} ,$$

$$c = \frac{\begin{vmatrix} (\mu_i \mu_i) & (\mu_i v_i) & (\rho_i \mu_i) \\ (\mu_i v_i) & (v_i v_i) & (\rho_i v_i) \\ (\mu_i \omega_i) & (v_i \omega_i) & (\rho_i \omega_i) \end{vmatrix}}{D} ,$$

where

$$D = \begin{vmatrix} (\mu_i \mu_i) & (\mu_i v_i) & (\mu_i \omega_i) \\ (\mu_i v_i) & (v_i v_i) & (v_i \omega_i) \\ (\mu_i \omega_i) & (v_i \omega_i) & (\omega_i \omega_i) \end{vmatrix}$$

CEFIT2

Formulation - Least Squares Method - cont'd.

and parentheses indicate summation, i.e.,

$$(\mu_i \mu_i) = \sum_{i=1}^N \mu_i \mu_i.$$

By defining the following minors

$$D_{11} = (\nu_i \nu_i) (\omega_i \omega_i) - (\nu_i \omega_i)^2,$$

$$D_{22} = (\mu_i \mu_i) (\omega_i \omega_i) - (\mu_i \omega_i)^2,$$

$$D_{33} = (\mu_i \mu_i) (\nu_i \nu_i) - (\nu_i \mu_i)^2,$$

$$D_{12} = D_{21} = (\omega_i \nu_i) (\mu_i \omega_i) - (\mu_i \nu_i) (\omega_i \omega_i),$$

$$D_{13} = D_{31} = (\mu_i \nu_i) (\nu_i \omega_i) - (\mu_i \omega_i) (\nu_i \nu_i),$$

$$D_{23} = D_{32} = (\nu_i \mu_i) (\mu_i \omega_i) - (\mu_i \mu_i) (\nu_i \omega_i),$$

a, b, c, may be expressed as

$$a = \frac{(\rho_i \mu_i) D_{11} + (\rho_i \nu_i) D_{12} + (\rho_i \omega_i) D_{13}}{D},$$

$$b = \frac{(\rho_i \mu_i) D_{12} + (\rho_i \nu_i) D_{22} + (\rho_i \omega_i) D_{23}}{D},$$

$$c = \frac{(\rho_i \mu_i) D_{13} + (\rho_i \nu_i) D_{23} + (\rho_i \omega_i) D_{33}}{D},$$

where

$$D = (\mu_i \mu_i) D_{11} + (\mu_i \nu_i) D_{12} + (\mu_i \omega_i) D_{13}.$$

The above solutions for a, b, c are the first corrections to A_0 , B_0 , C_0 .

Since the method described depends upon the use of only the first order terms of the Taylor expansion, it is necessary to repeat the calculation with

A_1 , B_1 , C_1 substituted for A_0 , B_0 , C_0 , where

$$A_1 = A_0 + a, \quad B_1 = B_0 + b, \quad C_1 = C_0 + c.$$

33.072

Formulation - Least Squares Method - cont'd.

This procedure is repeated until the convergence criteria are satisfied:

$$\left| \frac{A_n - A_{n-1}}{A_{n-1}} \right| < \epsilon_1 \quad \left| \frac{B_n - B_{n-1}}{B_{n-1}} \right| < \epsilon_2 \quad \left| \frac{C_n - C_{n-1}}{C_{n-1}} \right| < \epsilon_3$$

Measures of the error in A, B, and C due to inaccuracy in the values of Y_i are given by the quantities

$$\Delta A = \sqrt{\frac{D_{11}}{D}}, \quad \Delta B = \sqrt{\frac{D_{22}}{D}}, \quad \Delta C = \sqrt{\frac{D_{33}}{D}} \quad (43, 44, 45)$$

The standard deviations of the estimates for A, B, C are calculated by

$$S_A = \Delta A \sqrt{\frac{\delta^2}{N-3}}, \quad S_B = \Delta B \sqrt{\frac{\delta^2}{N-3}}, \quad S_C = \Delta C \sqrt{\frac{\delta^2}{N-3}} \quad (46, 47, 48)$$

It may be shown that if ΔY_i are the standard deviations of the Y_i , $\delta^2 = N-3$, and $S_A = \Delta A$, $S_B = \Delta B$, $S_C = \Delta C$.

The effective pile width, H, and its standard deviation, S_H , are computed by

$$H = \frac{A}{B}, \quad \Delta H = \frac{A}{B^2} \Delta B, \quad S_H = \Delta H \sqrt{\frac{\delta^2}{N-3}} \quad (49, 50, 51)$$

The average extrapolation, $\bar{\lambda}$, is computed from H by

$$\bar{\lambda}_a = \frac{H - \text{physical } a}{2} \quad \text{or} \quad \bar{\lambda}_b = \frac{H - \text{physical } b}{2} \quad (52, 53)$$

Equation 52 is used to compute $\bar{\lambda}_a$ if the fit was made with side-to-side traverse data. If the traverse was taken front-to-rear, $\bar{\lambda}_b$ is computed by equation 53. The centerline displacement, C, is now used to compute the extrapolation on either side of the pile

$$\lambda_{av} = \bar{\lambda}_a + C \quad \text{or} \quad \lambda_{b+} = \bar{\lambda}_b + C \quad (54)$$

and

$$\lambda_{a-} = \bar{\lambda}_a - C \quad \lambda_{b-} = \bar{\lambda}_b - C \quad (55)$$

CQFIT2 - cont'd.

Description of Output - Input Data Report

On the first page or pages of each case is an Input Data Report, listing input parameters with sufficient explanatory material to form a valuable addition to the permanent output record. This report also provides assistance in tracing possible input errors. Included are all identification cards, pile dimensions, source positions and strengths, detector positions, initial estimates of the parameters A, B, C, and an interpretation of all options which were selected.

Description of Output - Corrections Only

Unless CQFIT2 is instructed by input option to compute only corrections, the program proceeds to the Data Reduction Report. If only corrections are to be computed, the Input Data Report is followed by a listing of computed corrections, after which the program goes on to the next case. The report of corrections only consists of one page for each input B_{11} . Each page gives the following information for every measurement position:

POS	Measurement position number
X-PRIME	} (x', y'), detector position
Y-PRIME	
CE	C_e , end correction (Equation 20 or 29)
CH	C_h , harmonic correction (Equation 19, 25, 31, or 32)
CECH	C_e, C_h

Description of Output - Data Reduction Report

Following the Input Data Report is a summary of counter data reduction results including an A-thermal report. The quantities listed here correspond to those of the VTOOL Data Reduction Report, and the cited equations apply. One

CONFIT2

Description of Output - Data Reduction Report - cont'd.

additional column of information is given, headed X-PRIME or Y-PRIME. This is the variable coordinate of detector position.

Description of Output - Least Squares Fits

The results of the least squares analysis are printed when a converged fit has been obtained. The following are listed for each measurement position:

POS	Measurement position number
X-PRIME (or Y-PRIME)	X used in the cosine fit (variable coordinate of detector position)
CORR A-THERMAL	Y used in the cosine fit ($=A_{th} C_e C_h$)
DELTA Y	ΔY used in the cosine fit (Equation 38 or 39)
Y/A	Y/(Final value of the parameter A as determined by least squares analysis)
COS B(X - C)	Cos B(X - C) computed from final values of the parameter B and C
DIFFERENCE	$Y/A - \cos B(X - C)$
D/DELTA Y	(Deviation of Y)/ ΔY (Deviation = d of Equation 41)

Below this are listed

AO	Initial estimate of the parameter A
A	Final value of A as determined by the least squares analysis
S-SUB-A	S_A (Equation 46)
BO	Initial estimate of the parameter B
B	Final value of B
S-SUB-B	S_B (Equation 47)
CO	Initial estimate of the parameter C
C	Final value of C
S-SUB-C	S_C (Equation 48)

COFITE

Description of Output - Least Squares Fits - cont'd.

DELTA-SQ	δ^2 (Equation 42)
H	H (Equation 49)
S-SUB-H	S_H (Equation 51)
LAMBDA-1	λ_{a+} or λ_{b+} (Equation 54)
LAMBDA-2	λ_{a-} or λ_{b-} (Equation 55)

The iteration count is given. If any measurement positions were omitted from the fit, a back fit is computed for these points and the information given above for fitted positions is then listed for these omitted measurements.

If printing of every iteration is requested, one page of the format outlined above is printed at the completion of each iteration, giving current values of the described quantities.

If input option requires that further cosine fits are made with pairs of end points dropped, each of these fits is represented by an additional page of the form given above.

BVTECE

Purpose

The code determines vertical extrapolation length, either alone or in combination with the determination of one or both horizontal extrapolations. Because BVTECE (Both VTCE and CEFIT) utilizes the functional portions of both the other codes, traverses in all three directions may be processed in one pass. The code is designed to accept complete packets of VTCE or CEFIT2 cards so that these cases may be kept intact for future reference.

BVT000 - cont'd.

Options

BVT000 determines vertical extrapolation and may also determine horizontal extrapolation in either or both directions. This multiple option is implied by the program from the presence or absence of horizontal traverse data.

Vertical and horizontal options, such as the omission of certain data points, the type of harmonic and end corrections used, or the printing of intermediate information, are applicable to each traverse on the basis of information entered on the required cards applicable to that traverse. Refer to Options of both VT0CL and CCFIT2.

One VT0CL and two CCFIT2 options are invalid for a BVT000 case: BVT000 will not compute corrections only in either the horizontal or vertical direction, and successive sets of end points cannot be dropped from a horizontal traverse of a BVT000 case.

Procedure - Phase I

In Phase I the program makes a preliminary determination of λ_z , the vertical extrapolation using the input estimates of λ_z and λ_D . Control is passed to VT0CL, which reads and checks vertical traverse data, and reduces these data to A_{th} 's by the method of Equations 1-7. Harmonic and end corrections are computed and applied to the A_{th} 's, a least squares fit is made, and control returned to BVT000. BVT000 then computes the λ_z for which dB^2 (Equation 18) is a minimum by passing a quadratic through three points encompassing the minimum. The dB^2 for each trial λ_z is obtained from a fit made by VT0CL using the previously computed A_{th} C_n 's (harmonic correction - A_{th} product) to which now end corrections have been applied.

In every least squares fit made for BVT000 all data points are used except those specifically excluded by input option.

BVTQCO - cont'd.

Procedure - Phase II

In Phase II, the horizontal extrapolations, λ_a and λ_b are determined using the λ_z determined by Phase I. Phase II is omitted if no horizontal traverses are included in the case. Similarly, if only one horizontal traverse is included, only the extrapolation measured by that traverse is computed.

Each horizontal traverse is processed by relinquishing control to CQFIT2, which reads, checks, and fits the data by the standard CQFIT2 procedure, omitting from the least squares cosine fit those points specified by input option. After traverse is completely processed, control is returned to BVTQCO, which determines by examining following input whether to go on to Phase III or to call CQFIT2 back to process another horizontal case.

Procedure - Phase III

The final determination of λ_z is made in Phase III. If the case includes no horizontal traverse, Phase III is omitted since the preliminary determination of λ_z made in Phase I is also the final one. Phase III uses the best known values of λ_a and λ_b ; that is, the input estimate of either is used only if none was computed from horizontal traverse data.

The procedure for final determination of λ_z is identical to that of the preliminary determination in Phase I, except that the vertical traverse data are already reduced to A_{th} 's.

Formulation

All equations for data reduction, harmonic and end corrections, and methods of least squares are as given under VTQCL and CQFIT2 formulation.

BVTQCO - cont'd.

Description of Output - Phase I

Aside from additional heading information, Phase I output is substantially the same as standard VTQCL output through the Input Data Report and the Data Reduction Report. Following are reports of each least squares fit computed during the search for a minimum dB^2 . Each of these gives the values of λ_a , λ_b , and λ_z with which it was computed. A summary of these fits is then given listing for each fit:

EFFECTIVE Z	Z (effective pile height) used in this fit
B11 (IN)	Input and output B ₁₁ 's
(OUT)	
BUCKLING	Output B (Equation 14)
LAMBDA Z (CM.)	λ_z (in cm. and inches), vertical extrapolation used in this fit
(IN.)	
D B-SQ	dB^2 (Equation 16)

The last report of Phase I is the results of the fit made with the λ_z which is predicted to produce a minimum dB^2 .

Description of Output - Phase II

The output of Phase II consists of one set of CQFIT2 output for each horizontal traverse of BVTQCO case.

Description of Output - Phase III

Phase III output is identical in form to that of Phase I. It consists of a series of fits to the vertical data, using the values of λ_a and λ_b computed in Phase II. The last two pages of Phase III are a summary of fits and the final fit made with the best values of λ_a , λ_b , and λ_z .

INPUT INSTRUCTIONS

Case Numbering System

The ICEDT case numbering system bears a degree of complexity arising from the necessity of retaining compatibility with data already run on the older codes VTECL and OCFIT2. An ICEDT case may be composed of as few as one or as many as three traverses. Each horizontal and each vertical traverse has its own case number. In addition, an ICEDT case number is assigned. This system permits the same horizontal or vertical traverse data cards to be processed in different ways while retaining a unique identifying number. Example: ICEDT case 001 is a VTECL run on vertical case 671; ICEDT case 030 may be a EVTECL run on vertical case 671 and horizontal case 332. Output from both runs identify the vertical traverse as 671.

In addition to the three-digit numeric case number, an alphabetic suffix may be associated with any case number. This six-digit suffix may be used to denote re-runs, corrections, etc.

The importance of a unique case number for each set of data cannot be over-emphasized. Endless confusion caused by duplicate card decks and similar output sheets can be avoided by application of the philosophy that case numbers are free. This practice should be extended to the use of unique suffixes when the data is rerun with even minor changes.

INPUT INSTRUCTIONS - cont'd.

Input Data Summary Sheet

Each batch of data submitted for processing must be accompanied by an Input Data Summary Sheet (sample, page 57). It contains the information required for preparation of data by Systems Control Operation. No keypunching is done from this sheet.

One line is entered for each ICEDT case, giving the ICEDT case number and case numbers of all vertical or horizontal cases included in that ICEDT case. By each case number, either "CARDS" or "DATA SHEETS" is checked, indicating whether submitted material is in the form of cards or data sheets. A combination of cards and data sheets for the same case number is not permitted.

The lower part of the sheet contains instructions to Systems Control Operation.

The attention of the user is directed to these items:

- Item 1: Data will be returned without processing if this sheet is incorrectly completed or if the ICEDT, Scientific Applications, and GBT cards are missing.
- Item 2: When previously keypunched cards are submitted, each case is separately banded, with "Vertical Case XXX" or Horizontal Case XXX" clearly penciled on the first card. All cards within the case must be in order; they will not be sorted.
- Item 4 and
Footnote: If two cases of the same number (whether or not both are on cards) are submitted at the same time, place an asterisk after the case number each time it appears on the form at the top of the page. Thus, conceivably, ICEDT case 777 could be run at the same time as vertical case 777 and horizontal case 777, if all three 777 entries on the form were starred.

TEST INSTRUCTIONS - cont'd.

Data Sheets - General

Reference to the following pages will aid the user in correct completion of the data sheets. Explanatory comments on each data entry are given, as well as the format required. Possible formats are:

In	Integer number. Enter n or less digits anywhere in the field. Do not use decimal point.
Dn	Floating number. Enter n or less digits anywhere in the field. Decimal point must be included. If the number cannot be expressed in n or less digits, including sign and decimal point, a signed power of ten must be included. Examples: the number 1×10^4 may be entered as 1000. in a field of format B5; the number 1×10^5 must be written 1.0+4 or 1.+4 or .1+5 or 0.1+5 in a field of the same format, since 10000. is more than 5 digits.
An	Descriptive information. Enter n or less characters of alphabetic or numeric information anywhere in the field. Characters may be the numbers 0 through 9, the letters A through Z, the eleven special characters + - = ~ () [\ * / . , and blank.
nX	Skip. The information entered in n spaces is disregarded by the program.

INPUT INSTRUCTIONS - cont'd.

ICEDT Data Sheet

One ICEDT Data Sheet (sample, page 55) is completed for each ICEDT case.

Complete application number (CUB???) and fill in ICEDT case number at top of page.

1. Physical a (E13) side-to-side physical dimension in cm.
2. Physical b (E13) front-to-rear physical dimension in cm.
3. Physical Z (E13) distance from source plane to physical top of pile, in cm.
4. Unused at present (E13).
5. Case type (A1) may be B for BWGCG case, V for VIGCL case, or C for CQFIE2 case. If other than B, V, or C is entered, the program will attempt to determine case type by scanning the data.
6. Machine run date (A6) of form month-day-year is entered here to aid in identifying decks and output. This date appears in the main heading at the top of each page output.
7. ICEDT case number suffix (A6) is used to aid in differentiating between output from similar cases, as reruns and corrected runs. May be blank. This suffix follows the ICEDT case number, printed at the top of every page of output.
8. Estimated a extrapolation (E13) on each side, in cm.
9. Estimated b extrapolation (E13) (front + rear)/2, in cm.
10. Estimated Z extrapolation (E13) at top, in cm.
11. Maximum run time this case (E13) maximum amount of machine time in minutes to be spent searching for λ_2 in a BWGCG case. If entered greater than 5.0, or if omitted, running time is set to 1 minute. Ignored on VIGCL and CQFIE2 cases.
12. Unused at present (E13).
13. (72) is adaptive information for main heading. These 72 characters appear at the top of each page of output.

INPUT INSTRUCTIONS - cont'd

INPUT Data Sheet

14.-22. (172) Descriptive information which will appear on the output only once, at the top of the first page of the Input Data Report. Any or all of Items 14-22 may be omitted.

INPUT INSTRUCTIONS - cont'd.

Vertical/Horizontal Data Sheets

One of each of the two Vertical/Horizontal data sheets (samples, pp. 59 and 60) must be completed for each vertical and each horizontal traverse. Many items on these sheets (designated by reference to footnotes) are not required for all types of cases. Complete application number (JUS???), cross out the in-applicable portion of VERTICAL/HORIZONTAL at top of page, and place vertical or horizontal case number in space following.

1. Experiment number* (A8) name given to the experiment as a whole; several cases may have the same experiment number. Example: 33-17A, 33-17AR.
2. Lattice* (A7) lattice spacing designation. Examples: 12-3/8, DOUBLE6
3. Size* (A5) shape or size. Examples: 2.2x2, STD.
4. Wet/dry* (A6) specifies whether or not there is coolant in the tubes. Examples: DRY, WET, MIPB, 7UP.
5. Program options are defined by answers to Questions 5.01 through 5.15 (0 = yes; 1 = no). All questions must be answered. Tables 1 and 2 outline restrictions placed on combinations of answers, but need be consulted only when the validity of certain combinations is in doubt. The format for each answer is 11.

5.01 Is counter data entered? This is always yes except when computing corrections only, or when previously-computed A_{thermal} 's are entered on the form at the bottom of the Vertical Data Sheet.

5.02 Are corrections entered as input data? (No for horizontal traverse). This is always no unless previously-computed $C_e C_h$'s are entered on the form at the bottom of the Vertical Data Sheet.

*This field is used only in output headings. Information entered here has no effect upon computed results.

INPUT INSTRUCTIONS

Vertical/Horizontal Data Sheets - cont'd.

- 5.03 Cadmium shutter method? The answer to this question determines whether J_{nm} is computed by Equation 34 or 35 in computation of fast source $C_e C_h$.
- 5.04 Is a trial B_{11} suggested? (Yes for C-cases). The program makes its own initial estimate if this is answered no for a vertical traverse.
- 5.05 Calculate corrections only? If yes, harmonic and end corrections are computed and printed using the B_{11} from Question 26, and according to instructions given by Questions 5.03, 5.06, 5.07, 5.11, and 5.12. The B_{11} is then increased by the B_{11} increment (Question 27), the number of B_{11} 's (Question 10) decreased by one, and another set of corrections computed with the incremented B_{11} if the number of B_{11} 's > 0 . This procedure is repeated until the number of B_{11} 's is reduced to zero. See example given for Question 27. Note: if Question 5.05 = 0 for a horizontal case, x' or y' must be entered on the Horizontal Data Sheet as explained on page 50.
- 5.06 Use 2-region harmonic corrections? This determines the method of computing C_h . Yes indicates that a base region is present under the measurement region.
- 5.07 Use 2-region end corrections? This determines the method of computing C_e . Yes indicates that another region is present above the measurement region.
- 5.08 All corrections = 1.0? (No for vertical traverse). Yes sets $C_e C_h = 1.0$ at all points of a horizontal traverse.
- 5.09 Print intermediate information? If yes, certain intermediate portions of the end and harmonic correction calculations are printed. It should never be necessary to use this as long as the program remains in its relatively stable state.

INPUT INSTRUCTIONS

Vertical/Horizontal Data Sheet - cont'd.

- 5.10 Drop and plumes? (No for vertical traverse and for all traverses of LVRCCO case). This option is fully explained under CONFIR Procedure, page 19.
- 5.11 Use and corrections only? (No for horizontal). If yes, thermal flux is corrected by C_0 only, rather than $C_0 C_{T1}$.
- 5.12 Use fast source corrections? If yes, corrections are computed by fast source theory, taking into account answers to Questions 5.03, 5.05, 5.06, 5.07, and 5.11.
- 5.13 Option inactive at present.
- 5.14 Must background counts/minute be calculated? Yes, unless estimated pile backgrounds (A_{bg}) and each measurement position are entered on the form at the bottom of the Vertical Data Sheet.
- 5.15 Print every iteration of cosine fit? (No for vertical traverses.) This option is explained in the description of CONFIR2 least squares output.
6. Number of sources (I1) present in the pile ($1 \leq n \leq 9$).
7. Initial slot* (I2) is the integer assigned to the lowest measurement position of a vertical traverse. See example given for Question 9.
8. Slot increment* (I2) is the difference between slot numbers assigned to different measurement positions of a vertical traverse, if constant. See example given for Question 9. If not constant, slot increment is variable and slot numbers are entered under Question 13.

*Initial measurement is not required for horizontal traverse, but may be present if desired.

GENERAL INFORMATION

Vertical Traverses: Slot 1 slot = slot 1.

9. Value of "Slots" (I2) is the number of measurement positions for a vertical traverse ($3 \leq n \leq 50$). Example: If measurements are taken in slots 2, 5, 8, and 11, initial slot = 2, slot increment = 3, and the number of slots = 4.
10. Value of $E_{1,1}$ (I2) is used only when Question 5.05 = 0, specifying corrections only. This is the value of input $E_{1,1}$'s for which corrections are to be computed. See example given for Question 27.
11. Value of cadmium slot# (I2) is the number of measurement position in which cadmium-covered counts are taken in a vertical traverse. If cadmium measurements are taken at all positions, Question 11 may be left blank. Example: If both bare and cadmium counts are taken in slots 2, 5, 8, and 11, the number of slots (Question 9) = 4, and the number of cadmium slots may be left blank or entered as 4. If bare counts are taken in 2, 5, 8, and 11, but cadmium counts are taken only in slots 2, 5, and 11, the number of slots = 4, and the number of cadmium slots = 3.
12. Case number suffix (I6) appears following the vertical case number or horizontal case number as it appears in the secondary heading of each page of output associated with that traverse. May be omitted.
13. Slot numbers (I2, I3, I2, I3, I2...) entered if slot increment is constant. If slot increment is not constant, Question 9 is left blank and slot numbers (including initial slot) of all vertical traverse measurement positions are entered here.

Other comments: is not required for horizontal traverses but may be present if slot blank.

Other comments: when present only for vertical traverses and must be omitted from horizontal ones.

GENERAL INFORMATION

Vertical/Horizontal Data Traverses - cont'd.

17. Omitted slots** (I2, I1, I2, I1, I2...) are slot numbers of those measurement positions to be omitted during computation of fits in a vertical traverse. No entry if all slots are to be used.
- 18-19. Heading cards (A65) are printed in secondary heading of every page of output associated with this traverse. At least one character must be entered on each of these lines.
20. Unused at present (E13).
21. Unused at present (E13).
22. z'*** (E13) is the distance in cm. from the floor to the source plane (see Figures 1 and 2).
23. Unused at present (E13).
24. Initial z* (E13) is the distance in cm. from the source plane to the first measurement position (initial slot).
25. z increment* (E13) is the distance in cm. between adjacent measurement positions of a vertical traverse, if constant. If not constant, the z increment is omitted, and z's are entered under Question 34.
26. B₁ (measurement region) (E13) is the calibration length of the measurement region, and must be entered for horizontal traverses. B₁ must be entered for vertical traverses if all of Question 5.04 or 5.05 is answered (yes).

*This information is not required for horizontal traverses but may be present if convenient.

**This information pertains only to vertical traverses and must be entered from original cards.

***This information is not required for horizontal traverses of a NUSSC type, but may be present if convenient.

INPUT INSTRUCTIONS

Number of Horizontal Data Points - cont'd.

27. B₁ increment (E13) is used only when Question 5.05 = 0, specifying that only corrections are to be computed for this case. See fuller explanation under Question 5.05. Example: if corrections are to be computed for B₁'s of 34.5, 34.6, and 34.7, number of B₁'s = 3, B₁ = 34.5, and B₁ increment = 0.1.
 28. AB₁ limit* (E13) specifies the maximum AB₁ $\left[\frac{\text{input } B_1 - \text{output } B_1}{\text{input } B_1} \right]$ acceptable for a converged fit to a vertical traverse. If AB₁ limit is left blank, the program sets it to 0.03.
 29. B₂*** (E13) is the buckling of region one (base region), and must be given if two-region harmonic corrections are specified.
 30. B₃*** (E13) is the buckling region three (top region), necessary if two-region end corrections are specified.
 31. G*** (E13) is the distance in cm. from the source plane to the boundary plane between regions two and three (see Figure 2) in a multi-region pile, necessary when two-region end corrections are specified.
 32. g*** (E13) is the distance in cm. from the source plane to the boundary plane between regions one and two (see Figure 2), necessary when two-region harmonic corrections are specified.
 33. AB limit* (E13) specifies the maximum absolute value of the residual (as defined by Equation 11) acceptable for a satisfactory fit to a vertical traverse. If omitted, AB limit is set to 0.03 by the program.
- *This information is not required for a horizontal traverse, but may be present if convenient.
- ***This information is not required for horizontal traverses of a TWO-REGION case, but may be present if convenient.

INPUT INSTRUCTIONS

Vertical/Horizontal Data Sheets - cont'd.

34. This form is used to enter z (distance in cm. from source plane to measurement position) of slots other than initial slot if z increment is not constant (Question 25 blank or zero). Enter five (E13) values per line, starting with z of the second slot. No entry is required if z increments is constant.

35,45. x' and y' (E13) are the coordinates in the horizontal plane of the detector position for a vertical traverse.

35-44,
46-54. x_i and y_i^{***} (E13) are the coordinates in the horizontal plane of the source positions. The number of source positions defined here must correspond to the number of sources given in Question 6.

55-63. S_i^{***} (E13) are the fractional source strengths $\left(\sum_{i=1}^n S_i = 1.0 \right)$, where n is the number of sources given in Question 6. If no strengths are entered, the program sets all $S_i = 1/n$.

64. Unused at present (E13).

65,66. u_1^2 and u_2^{***} (E13) are ratios of diffusion lengths perpendicular and parallel to streaming channels (see footnote to Equation 37), required only when fast source corrections are used (Question 5.12 = yes).

67-72. $\underline{f}_1$, $\underline{f}_2$, and $\underline{f}_2^{***}$ (E13) are the fractions of source neutrons emitted for corresponding source ranges $\underline{r}_1$, $\underline{r}_2$, and $\underline{r}_2^{***}$ (E13). Fractions and ranges are required only when fast source corrections are to be used.

This information is not required for a horizontal traverse, but may be present if convenient.

***This information is not required for horizontal traverses of a BV1960 type, but may be present if convenient.

INPUT TRANSMISSIONS

Vertical/Horizontal Data Sheets - cont'd.

- 36. Unused or present (E13).
- 37. Unused or present (E13).
- 38. Omitted positions**** (I2, I4, I2, I4, I2...) are numbers of those measurement positions to be omitted during computation of fits in a horizontal traverse. No entry if all positions are to be used.

****This information is required only for a horizontal traverse and must not be present for a vertical traverse.

INPUT INSTRUCTIONS - cont'd.

Vertical Data Sheet

One or more pages of the Vertical Data Sheet (sample, page 61) may be used as required to enter vertical traverse counter data. Complete application number (CUG???) and fill in vertical case number on upper right hand corner. Where a figure or figures are to be carried down the column for several lines, as for CARD TYPE, keypunching is simplified by writing the figure on the first line, then drawing a bracket below it, with an arrow from the bracket to the last repeated line.

On the upper form, complete one line for each item of counter data:

LINE (I2) is the number of measurements this slot; that is, the number of lines of this CARD TYPE data taken in this SLOT.

COUNTS (I13) are raw counter data.

TIME (I12) is total time during which COUNTS this line were accumulated.

COUNTING FACTOR (I13) is the counter standardization factor applicable at the time COUNTS this line were taken.

COUNTER NOISE (I13) is the counter background level (in counts/minute) applicable at the time COUNTS this line were taken. ..

CARD TYPE (I2) tells the program whether this line is bare, cadmium-covered, or pile background data. Fill in code from upper left corner of data sheet.

SLOT (I2) is the slot number assigned to the measurement position in which COUNTS this line were taken.

DATA INSTRUCTIONS

Vertical Data Sheet - cont'd.

The lower form on the data sheet is required only when certain options are exercised. One or two columns, as required, are completed for each measurement position:

Thermal₁ (E13) is thermal flux externally computed by Equation 4 or 6. If Thermal₁'s are entered, Question 5.01 = 1 and no counter data are entered on the upper form.

P_{bg} (E13) is pile background estimated or externally computed by Equation 1. If P_{bg}'s are entered, Question 5.14 = 1 and no pile background data are entered on the upper form.

E₂ (E13) are harmonic end end corrections externally computed. Question 5.02 = 0, Question 5.04 = 0, and the E_{21} from which the E_{20} 's were computed is entered in Question 25.

Horizontal Data Sheet

One or more pages of the Horizontal Data Sheet (sample, page 62) may be used as required to enter horizontal traverse counter. The application number (CUS???) should be completed and the horizontal case number filled in on upper right corner. One line for each item of counter data is then completed:

NAMP (I2) is the number of measurements this position; that is, the number of lines of this CARD TYPE data taken in this measurement position.

x' or y' (E11) is the distance in cm. from the centerline to this measurement position in the direction of the traverse. The constant coordinate of detector position is also entered as x' or y' with NAMP = 00, CARD TYPE = 15, PCs = 00,

INPUT INSTRUCTIONS

Horizontal Data Sheet - cont'd.

and all other fields blank. If no measurement is taken in the center position, A_0 must be estimated and entered as COUNTS on a line having 00 as NMTP, 15 as CARD TYPE, and 00 as POS. If both these conditions exist, one card will suffice for both entries.

COUNTS (E13) are raw counter data.

TIME (E13) is total time during which COUNTS this line were accumulated.

COUNTER FACTOR (E13) is the counter standardization factor applicable at the time COUNTS this line were taken.

COUNTER BGRND (E13) is the counter background level (in counts/minute) applicable at the time COUNTS this line were taken.

CARD TYPE tells the program whether this line is bare, cadmium-covered, or pile background data. Fill in code from upper left corner of data sheet.

POS (I2) is a unique number assigned to this measurement position. POSition numbers are two-digit integers, the first of which must be 01.

When only corrections are being computed (Question 5.05 = 0) for a horizontal case, detector positions must be entered on type 18 cards. The constant coordinate of detector position is entered as described above. One line must then be completed for each measurement position, with detector position as x' or y', 18 as CARD TYPE, as ascending integers as measurement POSitions.

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3. D. D. Matsumoto, VT0CL - A 709 Program for Reduction of Exponential Pile Data, HW-68806. April, 1961. HW-68806ADD, February, 1962.
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9. B. L. Anderson and T. J. Lawton, COFIT - A Least Squares Cosine Fitting Program for the IBM-704, WAPD-TM-26. October, 1956.

FIGURE 1

FIGURE 2

Simplified flow chart illustrating procedure for selecting files to be made:

* $|\Delta Y|$ = absolute value of residual (Equation 11.)

APPENDIX B

TABLE 1 - VERTICAL TRAVERSE OPTION RESTRICTIONS

Question	Answer	Restrictions on Other Answers	Data Which Must Be Submitted	Data Which Must Not Be Submitted
5.01	0	5.05 = 1	Counter data on Vertical Data Sheet; see also 5.14.	A _{th} 's on 11-cards.
	1	5.14 = 1	**	Counter data on Vertical Data Sht.
5.02	0	5.05 = 1	C _e C _h for each slot on 11-cards, B ₁₁ on 04-card.	**
	1	None	**	C _e C _h on 11-cards.
5.03	0	5.14 = 1	**	Background counts on 10-cards.
	1	None	**	**
5.04	0	None	B ₁₁ on 04-card.	**
	1	5.05 = 1	**	B ₁₁ on 04-card.
5.05	0	5.01 = 1, 5.02 = 1 5.04 = 0, 5.14 = 1	No. of B ₁₁ 's on 01-card, B ₁₁ on 04-card, B ₁₁ increment on 04-card.	Counter data on Vertical Data Sheet.
	1	None	**	No. of B ₁₁ 's on 01-card, B ₁₁ increment on 04-card.
5.06	0	5.11 = 1	B ₁ on 05-card, s on 05-card.	**
	1	None	**	B ₁ on 05-card, s on 05-card.
5.07	0	None	B ₃ on 05-card, C on 05-card.	**
	1	None	**	B ₃ on 05-card, C on 05-card.
5.08	1	Option inactive for vertical traverses; code assumes 1.		
5.09	0/1	None	**	**
5.10	1	Option inactive for vertical traverses; code assumes 1.		
5.11	0	5.06 = 1, 5.12 = 1	**	**
	1	None	**	**
5.12	0	5.11 = 1	All data on 12- & 13-cards.	**
	1	None	**	12- and 13-cards.
5.13	1	Option inactive; code assumes 1.		
5.14	0	5.01 = 0, 5.05 = 1	Background counts on 10-cds.	A _{th} on 11-cards.
	1	5.01 = 1 <u>or</u> 5.03 = 0	**	Background counts on 10-cards.
		5.01 = 0 <u>and</u> 5.03 = 1	A _{th} on 11-cards.	Background counts on 10-cards.
5.15	1	Option inactive on vertical traverses; code assumes 1.		

**As dictated by other options.

APPENDIX B - cont'd.

Table 2- Horizontal Traverse Option Restrictions

Question	Answer	Restrictions on Other Answers	Data Which Must Be Submitted	Data Which Must Not Be Submitted
5.01	0	5.05 = 1	Counter data on Horizontal Data Sheet.	**
	1	5.05 = 0	**	Counter data on Horiz. Data Sheet.
5.02	1	Option inactive for horizontal traverse; code assumes 1		
5.03	0	None	Background data on 17-cards.	**
	1	None	**	Background data on 17-cards.
5.04	0	None	B ₁₁ on 04-card.	**
	1	5.05 = 1	**	B ₁₁ on 04-card.
5.05	0	5.04 = 0	No. of B ₁₁ 's on 01-card, B ₁₁ on 04-card, B ₁₁ increment on 04-card, detector positions on 18-cards.	Counter data on Horiz. Data Sheet.
	1	None	**	No. of B ₁₁ 's on 01-card, B ₁₁ increment on 04-cd, detector positions on 18-card.
5.06	0	5.11 = 1	B ₁ and s on 05-card.	**
	1	None	**	B ₁ and s on 05-cd.
5.07	0	None	B ₃ and C on 05-card.	**
	1	None	**	B ₃ and C on 05-cd.
5.08	0	5.04 = 1, 5.05 = 1	**	**
	1	None	**	**
5.09	0/1	None	**	**
5.10	0	5.05 = 1	**	**
	1	None	**	**
5.11	1	Option inactive for horizontal traverse; code assumes 1		
5.12	0	None	All data on 12- and 13-cds.	**
	1	None	**	12- and 13-cards.
5.13	1	Option inactive for horizontal traverse; code assumes 1		
5.14	0/1	Question inapplicable; code refers to Question 5.03 for answer.		
5.15	0/1	None	**	**

**As dictated by other options.

(Date)

[illegible]

1. Check submitted material. If it does not correspond to summary above, bundle up the whole mess and return to sender. IDENT Card and Scientific Applications Card should be included, also.
2. All submitted cards to Step 5. They are sorted, banded, and labeled.
3. Key punch and verify from all accompanying data sheets. ICEDT cards to Step 5; VERTICAL and HORIZONTAL cards to Step 4.
4. Sort* keypunched VERTICAL and HORIZONTAL cards on columns 66-72.
5. Make up data deck for each ICEDT case as follows:
 - a. ICEDT cards.
 - b. One or no VERTICAL cases, as indicated above.
 - c. One, two, or no HORIZONTAL cases, as indicated above.
6. Any number of cases may be run at one time, in order listed above.
7. Use SPL ICEDT deck on 7090.
8. One-part paper is sufficient for output. If multi-part paper is used, decollate.
9. Send report, along with input cards, data sheets, and this sheet, to:

*If any case numbers are starred, this indicates duplicate case numbers and each case of this number must be sorted by itself.

Page _____ of _____

ICEDT CASE _____

STARTING COLUMN				CARD TYPE
1	1.	Physical a	_____	
14	2.	Physical b	_____	
27	3.	Physical Z	_____	
40	4.		_____	
50	5.	Case type (B, V, or C)	_____	
52	6.	Machine run date	_____	
60	7.	ICEDT Case number suffix, if any	_____	0001
1	8.	Estimated a extrapolation	_____	
14	9.	Estimated b extrapolation	_____	
27	10.	Estimated Z extrapolation	_____	
40	11.	Maximum run time this case	_____	
52	12.		_____	0002
1	13.		_____	0010
1	14.		_____	0011
1	15.		_____	0012
1	16.		_____	0013
1	17.		_____	0014
1	18.		_____	0015
1	19.		_____	0016
1	20.		_____	0017
1	21.		_____	0018
1	22.		_____	0019

KEYPUNCH: Please punch case number in cols. 66-68 and card type in cols. 69-72, of each card. Omit cards having no data entered on them.

STARTING

CULAN

CARD TYPE

1	1.	Experiment number	
9	2.	Lattice	
16	3.	Slug	
21	4.	Wet/dry	
	5.	For questions 5.01-5.15, 0 = yes, 1 = no.	
21	5.01	Is counter data entered? (Yes for horizontal)	
28	5.02	Are corrections entered as input data? (No for horizontal)	
29	5.03	Cadmium shutter method?	
30	5.04	Is a trial B_{11} suggested?	
31	5.05	Calculate corrections only?	
32	5.06	Use 2-region harmonic corrections?	
33	5.07	Use 2-region end corrections?	
34	5.08	All corrections = 1.0 (No for vertical)	
35	5.09	Print intermediate information?	
36	5.10	Drop end points (No for vertical and for B-cases)	
37	5.11	Use end corrections only? (No for horizontal)	
38	5.12	Use fast source corrections?	
39	5.13	Option removed	1
40	5.14	Must background counts/minute be calculated?	
41	5.15	Print every iteration of cosine fit? (1 for vertical)	
42	6.	Number of sources	
43	7.	Initial slot	
44	8.	Slot increment	
45	9.	Number of slots	
46	10.	Number of B_{11} 's (if corrections only)	
51	11.	Number of cadmium slots	
52	12.	Case number suffix, if any	0100
1	13.		0101
1	14.		0102
1	15.		0200
1	16.		0201
1	17.		0202
1	18.		0203
1	19.		
11	20.		
27	21.		
40	22.	z'	
53	23.		
1	24.	Initial z	
14	25.	z increment	
27	26.	B_{11} (meas)	
40	27.	B_{11} inc	
53	28.	ΔB_{11}	
1	29.	B_{11}	
14	30.	B'	
27	31.	δ	
40	32.		
53	33.		

Page _____ of _____

VERTICAL/HORIZONTAL CASE _____

STARTING COLUMN			CARD TYPE
1	35.	x ₁	
11	36.	x ₁	
20	37.	x ₂	
40	38.	x ₃	
50	39.	x ₄	0600
1	40.	x ₅	
11	41.	x ₆	
20	42.	x ₇	
40	43.	x ₈	
50	44.	x ₉	0601
1	45.	y ₁	
11	46.	y ₁	
20	47.	y ₂	
40	48.	y ₃	
50	49.	y ₄	0700
1	50.	y ₅	
11	51.	y ₆	
20	52.	y ₇	
40	53.	y ₈	
50	54.	y ₉	0701
1	55.	s ₁	
11	56.	s ₂	
20	57.	s ₃	
40	58.	s ₄	
50	59.	s ₅	0650
1	60.	s ₆	
11	61.	s ₇	
20	62.	s ₈	
40	63.	s ₉	
50	64.		0651
1	65.	ω_a^2 (if fast source)	
11	66.	ω_b^2 (if fast source)	
20	67.	r ₁ (if fast source)	
40	68.	r ₂ (if fast source)	
50	69.	r ₃ (if fast source)	1200
1	70.	r ₁	
11	71.	r ₂	
20	72.	r ₃	
40	73.		
50	74.		
1	75.		
11	76.	z (heir)	
20	77.		
40	78.		
50	79.	c	
60	80.		
60	81.		
60	82.		
60	83.		
60	84.		
60	85.		
60	86.		
60	87.		
60	88.		
60	89.		
60	90.		

Page _____ of _____

VERTICAL CASE

CARD TYPE:

Page 03

Cadmium	09
---------	----

Background 10

[illegible][illegible]

NOTE: Please punch case number in columns 66-68 of each card.

Page 12

HORIZONTAL CASE

CARD TYPE:

Barre	25
Cadmium	26
Background	27

[illegible]

REMARKS: Please punch case number in columns 66-68 of each card.

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