GRABGAM Analysis of Ultra-Low-Level HPGe Gamma Spectra

by

W. G. Winn

Westinghouse Savannah River Company

Savannah River Site

Aiken, South Carolina 29808

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HPGe Gamma Spectra

W.G. Winn

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I. INTRODUCTION

The GRABGAM code has been used successfully for ultra-low level HPGe gamma spectrometry analysis since its development in 1985 at Savannah River Technology Center (SRTC). Although numerous gamma analysis codes existed at that time, reviews of institutional¹ and commercial codes² indicated that none addressed all features that were desired by SRTC. Furthermore, it was recognized that development of an in-house code would better facilitate future evolution of the code to address SRTC needs based on experience with low-level spectra. GRABGAM derives its name from Gamma Ray Analysis BASIC Generated At MCA/PC.

Initially the code was developed for the five HPGe detectors of the SRTC Ultra-Low-Level Counting Facility (ULLCF).³⁻⁴ Typical samples were counted overnight, but their spectra included very few peaks; thus, the initial version of the code addressed singlet peaks only. A major concern during initial development was to incorporate earlier HPGe efficiency calibration data that included three vial sizes as a function of height⁵, an air filter geometry, and a well geometry. No commercial code was found to address a suitable interpolation for generating efficiencies as a function of vial height. Such a feature allows counting of all of a limited size sample rather than reducing or diluting it to match a fixed geometry, so that the sample counting efficiency is optimized for low-level counting.

The above initial version of the code was adequate until the ULLCF needed to analyze local fallout from the Chernobyl accident in the spring of 1986.⁶⁻⁷ Unlike the earlier samples, those from Chernobyl yielded numerous spectral peaks so that multiplet analyses were required. GRABGAM was upgraded to include a multiplet analysis, whereby three different size filters were introduced. The smallest filter finds peaks within a multiplet, while largest retains the ability to distinguish low-level singlets from the background. This version of the code was also applied to the HPGe detectors of the SRTC Underground Counting Facility, which began sample analysis at this time.⁸⁻⁹ More recent improvements in the multiplet analysis have refined the background model for the multiplet region and improved the method for partitioning the peak areas.

Further refinements also provided the user with different options for analyzing the minimum detectable activity (MDA), including a determination level⁹⁻¹⁰ and the traditional 95% detection level recommended by Currie.¹⁰ The former is a precision level below which peak detection is assumed questionable. The latter corresponds to an activity level that would be detected with 95% probability, as based on a threshold level that permits only 5% probability of false positives from background.

Throughout the evolution of GRABGAM, attention has been given to ease of use and helpful diagnostics. The code is operable from an IBM PC, and it provides a logical sequence of input frames for the user. The peak analysis printout provides typical peak data as well as isotope activity, measured and expected peak full width at half maximum (FWHM), and any non-sample peak backgrounds. A supplementary program allows the user to select weighted averages of isotope activities based on those of the individual peaks. Other support programs were also developed, and these address detector efficiency calibrations, backgrounds, isotope libraries, and diagnostics.

When GRABGAM was developed, other existing gamma analysis codes¹⁻² relied on Gaussian or modified Gaussian peak fitting algorithms. A recent review of the literature revealed that many subsequent developments¹¹⁻²¹ also use this approach. Because such fittings require adequate counting statistics for deducing peak parameters, their ability to address low-level peak analyses is limited. By contrast, GRABGAM deduces the integral peak probability function to analyze properties of the peak. Others have also developed non-Gaussian approaches for analyzing low-level spectral peaks.²²⁻²⁴

II. OVERVIEW OF PROGRAMS AND FILES

This section provides an overview of the programs and files used to set up, execute, and append the GRABGAM analysis. Table 1 correlates these programs and files, which are summarized below. More detailed information is given in Section IV, which discusses the user operation of GRABGAM.

Setup operations are typically performed before analyzing samples on a routine basis. A group of auxiliary programs may be used to create the necessary files for a GRABGAM spectral analysis, as noted below:

ISOLIBAS - creates isotope library file ISOLIBRY.LIB which includes user-assigned isotopes, their gamma energies with decay intensities, half-lives, and a MDA analysis flag.

DETLIBAS - creates vial efficiency parameters library DETLIBRY.LIB for up to three vial sizes and five detectors, providing efficiency as a function of vial fill height.

MERGBACK - creates a backgnd.BKG file that includes the peak count rates of gammas detected in the background of a detector, where backgnd is a user-assigned file label.

MERGCALB - creates a detreff.DCF efficiency file for a specific detector geometry, based on user input data. The program also inputs the DETLIBRY.LIB efficiency parameters to allow reference comparisons as appropriate.

Routine execution of the GRABGAM spectral analysis uses the files of the setup programs as given in Table 1, where it is noted that chained programs GRABDKR1 and GRABDKR2 are run. Specifically, these programs operate as follows:

GRABDKR1 - accepts keyboard inputs for spectral analysis and receives file data from DETLIBRY.LIB, backgnd.BKG, detreff.DCF, and counted gamma spectrum.CHN. It also conducts the peak search.

GRABDKR2 - continues with peak and multiplet analyses, including peak background corrections from backgnd.BKG, isotope correlations with ISOLIBRY.LIB, and flagged MDA analyses. It produces the peak printout table and also generates files DATACALB.DAT, DATASPEC.DAT, DATAISOS.DAT, DATAPEAK.DAT, and DATAMISC.DAT to allow operations with the supplementary analyses programs.

Appendage calculations for the GRABGAM spectral analysis may be performed with the supplementary programs. Each of these programs input the data.DAT files created by GRABDKR2. (The names of the data.DAT files are representative of the type of data contained). These programs are described as follows:

GRABISOS - groups and orders all peaks with regard to isotopic identification, allowing the user to select a weighted average of each isotopic activity for a more comprehensive analysis.

GRABBACK - produces peak background file backgnd.BKG based on the preceding GRABGAM spectral analysis for a detector background, as appropriate. It also has option to average with results from earlier peak background file results.

GRABCALB - produces detector efficiency file detreff.DCF based on preceding GRABGAM spectral analysis of calibration standard, as appropriate. It also provides for summing corrections using the spectrum peaks and continuum.

GRABDIAG - produces a diagnostic table to study presence of artifact peaks including Compton edges, backscatter, and escape peaks.

GRABPLOT - provides interactive peak analysis on monitor screen for user selected peaks.

PEAKPART - refines the multiplet analysis to better address overlapping peak areas.

III. GRABGAM ALGORITHMS

The primary data reduction algorithms are (1) the peak search, (2) singlet analysis, (3) multiplet analysis, (4) MDA analysis, and (5) library matching method. The algorithm discussion refers to two different FWHMs, denoted as FWHM and FWHM*. A FWHM is deduced from the spectral peak analysis, while a FWHM* is a user-input energy-dependent value.

III.A. Peak Search

The constructions for the peak search algorithms are summarized in Figure 1. Shown are three peak filters that are mathematically similar to second derivatives used in other search algorithms¹⁻² and initially developed by Mariscotti²⁵ for Gaussian peaks. Here the figure denotes that each filter "traps" or "ropes" an area A_f for peak spectral counts, viz.

$$A_f = g - b1 - b2 \pm (g + b1 + b2)^{1/2} \quad (1)$$

where g is the number of counts in the $2n$ middle channels spanned by the filter, and $b1$ and $b2$ are the counts in adjacent n channels sampled by the filter. The error is recognized as the $1-\sigma$ counting error. Each channel grouping is customarily denoted as a region of interest (ROI). In effect, as each filter moves across the spectrum, it calculates successive test peak areas A_f based on its ROIs. For each filter the adjacent background n -channel ROIs (with $b1$ and $b2$ counts) are each displaced n channels from the middle gross peak $2n$ -channel ROI (g counts) to help accentuate the peak/noise ratio.

In GRABGAM a peak is found when the test A_f exceeds its corresponding $1-\sigma$ counting error by a factor of 3. A peak location channel then approximates the centroid as the local maximum A_f from subsequent tests during passage of the filter over the peak. If two peaks are separated by $< 0.47 \text{ FWHM}^*$ they are combined as a single peak that is broadened by $< 21\%$. The peak location channels are stored monotonically in an array for later detailed peak analysis.

The three filters simultaneously trap their respective areas A_f relative to the same spectral region as shown in Figure 1. The smallest filter (2-pt rope) is first tested for the $A_f \geq 3\sigma$ criteria for peak presence; if satisfied, this smallest filter subsequently finds the peak location to allow better resolution definition should the peak be within a multiplet. Should the smallest filter not indicate a peak, the middle (4-pt rope) is tested, and should it fail, the largest (8-pt rope) is tested. These progressively larger filters are more sensitive for trapping a detectable A_f but provide less resolution for discriminating peaks within multiplets. As the candidate peaks are found during execution, they are displayed in a table on the monitor screen, as illustrated in Figure 2.

III.B. Singlet Analysis

The singlet analysis is activated when adjacent peaks are separated by at least 3.5 FWHM^* , so that adequate background ROIs exist on both sides of such peaks. The singlet analysis primarily seeks to use an integral peak analysis to accommodate low-level peaks more readily than the customary differential approach with peak fitting. In cases where the integral approach fails, other analysis options are applied as appropriate.

The peak-adjacent background ROIs are found first. Both background ROIs have an identical width of m channels corresponding to the FWHM^* associated with the peak location channel determined by the peak search algorithm; however, the code limits the minimum background ROI to three channels. The ROI backgrounds $B1$ and $B2$ are initially placed adjacent to the peak location channel as shown in Figure 3. Then first the $B1$ ROI and then the $B2$ ROI move down their respective sides of the peak while being tested for leveling out in appropriate background regions. As these ROIs move toward their destinations, their adequacy is tested against the criteria:

$$\begin{aligned} B1p - B1/m &< 2 (B1p + B1/m^2)^{1/2} \\ B2p - B2/m &< 2 (B2p + B2/m^2)^{1/2} \end{aligned} \quad (2)$$

where $B1p$ or $B2p$ denotes the counts in the channel just adjacent to the $B1$ ROI or $B2$ ROI, on the peak side.

The peak gross region is determined from its adjacent background regions. As indicated by Equation 2, the extreme end channels H1 and H2 of the peak gross region must have counts that are less than 2σ above the adjacent background regions. If by chance the resulting gross region is less than 2 FWHM^* , the average 3-point maximum channel Hmax of the gross peak is determined, and the gross region is defined by

$$\begin{aligned} H1 &= H_{\max} - \text{FWHM}^* - 1 \\ H2 &= H_{\max} + \text{FWHM}^* \end{aligned} \quad (3)$$

Should the gross region be an uneven number of channels, it is forced to be even by adding a channel to the low side of the gross region, effectively lowering H1 by 1. Then the B1 and B2 region are made adjacent to the final gross peak region. In every singlet peak analysis, the size of each background region is modified on its peak-remote side so that it has half the number of channels as the gross region. Using the ROI counts for gross counts G and adjacent backgrounds B1 and B2, the peak acceptance must satisfy

$$G - B1 - B2 \geq 3 (G + B1 + B2)^{1/2} \quad (4)$$

Having accepted a peak and its ROIs, the code proceeds with the integral calculations. The area calculation is trivial and given by

$$A = G - B1 - B2 \pm (G + B1 + B2)^{1/2} \quad (5)$$

The centroid, FWHM, and tail are determined by performing the peak integral, subject to the following assumption. Typically HPGe spectral peaks exhibit a flat background (B1) on the lower-energy side of the peak that is noticeably higher than a similar one (B2) on the high-energy side of the peak. The additional background on the lower-energy side of the peak is due to the escape of gamma-induced electrons from the sensitive detector volume¹ and forward Compton scattering within the sample, which are assumed to have distributions as shown in Figure 4. The theoretical distribution (perfect resolution) shows the peak as a spike and the escape electrons plus forward Compton as a step function. The detected distribution illustrates the resolution effect. The figure denotes the parallels of the two distributions. In effect, if we view the peak with centroid E_g as a differential probability function $f(E-E_g)$, the step background will be related to its integral

probability $F(E-E_g)$, and we may write the differential gross gamma response $g(E)$ in the peak region as

$$g(E) = A f(E-E_g) + b (1 - F(E-E_g)) + c + v(E) \quad (6)$$

where A is the peak area, b is the step background per keV, and $c+v(E)=z(E)$ is the background per keV upon which the peak distribution is superposed. For later convenience, $z(E)$ is divided into its constant c and energy-dependent $v(E)$ components. The uppercase (A, F) correspond to integral values, and the lowercase (g, f, b, c , and v) correspond to differential values. Integrating the above expression over a single channel j yields

$$g_j = A (F_{j+1/2} - F_{j-1/2}) + b_c - b_c (F_{j+1/2} + F_{j-1/2})/2 + c_c + v_j \quad (7)$$

where g_j denotes the counts in channel j , $F_{j+1/2}$ is the integral of $f(E-E_g)$ up to channel j upper limit of $j+1/2$, b_c and c_c are the constant background components per channel, and v_j is $v(E)$ in channel units. The expression $(F_{j+1/2} + F_{j-1/2})/2$ is taken as the average $F(E-E_g)$ over channel j . The above equation may be rearranged as a recursion relation to solve $F_{j+1/2}$ as

$$F_{j+1/2} = [g_j - v_j + (A+b_c/2)F_{j-1/2} - (b_c+c_c)] / [A - b_c/2] \quad (8)$$

which has an initial value $F_{i-1/2} = 0$ associated with the lowest channel i of the gross peak region. Actually GRABGAM uses a different but equivalent formalism for $F_{j+1/2}$, as developed by summing Equation 7 from $j=i$ to k , viz

$$\sum_{j=i}^k (g_j - v_j) = A (F_{k+1/2} - F_{i-1/2}) + (k-i+1)(b_c+c_c) - b_c \sum_{j=i}^k (F_{j+1/2} + F_{j-1/2})/2 \quad (9)$$

We note that the sum in the last term may be written as

$$\sum_{j=i}^k (F_{j+1/2} + F_{j-1/2})/2 = (F_{k+1/2} + F_{i-1/2})/2 + \sum_{j=i}^{k-1} F_{j+1/2} \quad (10)$$

where it is noted that $F_{j-1/2}$ for $j=p+1$ equals $F_{j+1/2}$ for $j=p$.

Recalling that $F_{i-1/2} = 0$ and substituting Equation 10 into Equation 9 and rearranging yields

$$F_{k+1/2} = \left[\sum_{j=i}^k (g_j - v_j) + b_c \sum_{j=i}^{k-1} F_{j+1/2} - (k-i+1)(b_c + c_c) \right] / [A - b_c/2] \quad (11)$$

With $F(E-E_g)$ solved per $F_{k+1/2}$, the following definitions result from the inverse function $E(F)$ for energy:

$$\begin{aligned} \text{Cent} &\equiv E(0.50) \\ \text{SigA} &\equiv E(0.16) \\ \text{SigB} &\equiv E(0.84) \\ \text{FWHM} &\equiv (2.355/2)(\text{SigA} - \text{SigB}) \\ \text{Tail} &\equiv (\text{Cent} - \text{SigA})/(\text{SigB} - \text{Cent}) \end{aligned} \quad (12)$$

Effectively, this analysis provides operational definitions of the centroid, FWHM, and tail with analogy to a Gaussian peak. The FWHM definition is consistent with other methods for calculating Gaussian peak FWHMs, which show better than 10% agreement.²⁶

The current GRABGAM singlet analysis assumes $v_j=0$ for Equation 11, and thus singlet peaks on non-constant $z(E)$ backgrounds are not directly addressed. However, for a singlet such backgrounds have essentially no impact on the peak area calculation and only a minor impact on the peak centroid. On the other hand, multiplet peaks can be significantly impacted, and a more realistic v_j is modeled for this case, as discussed in the next section along with a detailed development in Appendix A.

There are cases where the F-integral analysis is not used, and these are flagged by negative values of the tail, as denoted in Figure 4. For these cases the centroid is set as the middle channel of the gross region $(H1+H2)/2$ and the FWHM is the gross width $(H2-H1+1)$, where again $H1$ and $H2$ are the end channels of the gross region. The negative tail and the abnormally large FWHM alert the user that the analysis may require further scrutiny.

III.C. Multiplet Analysis

A multiplet analysis is used for consecutive peaks that have their locations separated by less than 3.5 FWHM*. The FWHM* is assumed constant over the multiplet region and calculated based on the middle channel between the first and last peak of the multiplet.

Initially background regions B1 and B2 above and below the multiplet are found similarly to that of a singlet peak, except that the B1 region "ropes" down to a region on the low-energy side of the first multiplet peak and the B2 region "ropes" down to a region on the high-energy side of the last multiplet peak. The B1 and B2 regions are required to be displaced at least a FWHM* from their adjacent multiplet peaks. To give better representation against fluctuations, any points in the final "constant" B1 or B2 regions that exceed their respective averages by 3σ are removed from the average background per channel calculations.

The minima between adjacent peaks of the multiplet are found next, as illustrated in Figure 5. Three options are examined for calculating these minima. First, the gross minimum is sought, whereby it is assumed that effects from the underlying continuum background are negligible. If the resulting minimum is not displaced at least one channel from both adjacent peak locations, a relative minimum is sought as the maximum difference between channel counts and the line connecting the adjacent peak maxima. Again, if this minimum is not displaced from both adjacent peak locations by at least one channel, then the minimum is taken as the inverse center of gravity of the adjacent peak maxima. This minimum is forced to be displaced at least one channel from its adjacent peaks. The latter two minima analyses provide better capability for defining a boundary between closely spaced multiplet peaks that display shoulders as opposed to true minima, as illustrated in Figure 6.

The total area A_M of the multiplet is then calculated using the gross counts G between the adjacent background regions, in analogy to the method used for singlet peaks, or

$$A_M = G - (N_M/2N_1)B1 - (N_M/2N_2)B2 \pm \sigma(A_M)$$

$$\sigma(A_M) = [G + (N_M/2N_1)^2 B1 + (N_M/2N_2)^2 B2]^{1/2} \quad (13)$$

where N_M , N_1 , and N_2 are the number of channels in the multiplet and background regions.

The integral F-function is generated in the same manner as that for the singlet analysis, as the sum of individual peak integrals within the multiplet yields the F-function for the

multiplet. This is seen by noting how the individual peaks in the multiplet contribute as individual components of Equation 6. In particular,

$$g(E) = \sum A_m f(E-E_m) + \sum b_m (1 - F(E-E_m)) + c + v(E) \quad (14)$$

where the summation is over the multiplet peaks, each denoted by subscript m . Because the ratio of the step background b_m and peak area A_m should be essentially the same for each peak in the multiplet, we may substitute $b_m = \beta A_m$ in Equation 14 yielding

$$g(E) = \sum A_m f(E-E_m) + \beta \sum A_m (1 - F(E-E_m)) + c + v(E) \quad (15)$$

which may also be expressed as

$$g(E) = \sum A_m \frac{\sum A_m f(E-E_m)}{\sum A_m} + \beta \sum A_m \frac{\sum A_m (1 - F(E-E_m))}{\sum A_m} + c + v(E) \quad (16)$$

where it is recognized that $f_M(E) \equiv \sum A_m f(E-E_m) / \sum A_m$ is a differential probability function composed of peak-weighted probability functions of the multiplet, corresponding to integral probability $F_M(E) \equiv \sum A_m F(E-E_m) / \sum A_m$. Noting that $A_M = \sum A_m$ is the total of peak areas of the multiplet and also noting that $b_M = \beta \sum A_m = \sum b_m$ is the total of the step background components of the peaks, we may write

$$g(E) = A_M f_M(E) + b_M (1 - F_M(E)) + c + v(E) \quad (17)$$

which is identical in form to Equation 6 for a singlet peak. Thus, the peak multiplet integral $F_M(E)$ may be determined using the same algorithms developed for the singlet peak analysis of $F(E-E_g)$ developed in Section III.B.

For the most recent multiplet analysis, $z(E)=c+v(E)$ is modeled as a cubic polynomial in E , so that the background under the multiplet is smoothly matched to its adjacent background regions. The model also incorporates the step background, improves the peak centroid estimates, and refines the total multiplet area A_M to be consistent with its modeled background. The details for the modeling are discussed in Appendix A. Unlike the singlet analysis, the individual peak areas A_m can be strongly impacted by the underlying background. At the same time, prior GRABGAM analyses did

not reveal frequent impacts from such variable backgrounds as the statistical counting errors tended to dominate.

As the F-function is generated, the fraction $F_{m/M}$ for each multiplet peak is determined by denoting the portion of F between successive minima, whereby the end channels H1 and H2 of the gross multiplet region are also treated as minima. The area A_m of an individual multiplet peak is then given by

$$A_m = F_{m/M} A_M \pm (F_{m/M})^{1/2} \sigma(A_M) \quad (18)$$

The counting error for A_m is approximated assuming that the $F_{m/M}$ fraction exactly represents the peak area. Although useful as a guide to the counting statistics, the true error will be larger due to the analysis error. In particular, the analysis assumes that multiplet minima bound representative areas for individual peaks, and this is obviously an approximation due to peak overlap errors. These errors may be reduced by executing PEAKPART for the peaks of a multiplet, as described in Appendix A. For multiplets with very low statistics, the method encounters difficulties, and warning flags are issued to alert the user, as indicated the Figure 5.

III.D. MDA Analyses

MDA analysis is performed for two types of peaks. In one case a statistically significant peak has been detected in the spectrum, but it has a background file peak that cancels the spectral peak. In the other case, the MDA flag of a gamma energy in the isotope library causes an analysis although no corresponding spectral peak was found. Specifically, the peak channel for the gamma energy is determined, and gross peak and background channels are assigned based on the input FWHM, whereby the results output are a centroid at channel $(H1+H2)/2$, a "false" FWHM equal to the gross width of $(H2-H1+1)$, and a "false" tail assigned as -1 to flag the MDA analysis.

Both cases are calculated similarly. Each calculates a peak area A and an error $\sigma(A)$, which essentially derives from an expression,

$$A \pm \sigma(A) = [(A + B) - B] \pm (A + 2B)^{1/2} \quad (19)$$

where B is the effective background above which true signal A must be detected. Accordingly, from A and $\sigma(A)$ the value of the background can be determined as

$$B = (\sigma(A)^2 - A)/2. \quad (20)$$

Two types of MDAs are utilized in GRABGAM. One MDA is a determination level,¹⁰ which GRABGAM has modified so that results are presented as⁹

$$\begin{aligned} A \pm \sigma(A) & \quad \text{for} \quad A \geq 3 \sigma(A) \\ < 3 \sigma(A) & \quad \text{for} \quad A < 3 \sigma(A) \end{aligned} \quad (21)$$

The MDA format of the peak printout is " **$< 3 \sigma(A) = 3\sigma / A/\sigma(A)$** " where the bold entries are the calculated numbers; this format preserves the information for converting to $A \pm \sigma(A)$ if desired. The other MDA result uses the Currie definition of detection limit¹⁰, which is given as

$$< 2.71 + 4.65 B^{1/2} \quad (22)$$

which by itself is insufficient for conversion to $A \pm \sigma(A)$. In this case the peak printout is " **$< 2.71 + 4.65 B^{1/2}$** MDA = c+b". Overall, the calculation of both MDAs provides the user more options for interpretation.

III.E. Library Matching Method

The peak data are merged with matching library data as the code executes. Each peak that is found is analyzed in monotonically increasing order with energy. After each peak centroid and energy is determined, the monotonically ordered energies of the isotope library are stepped up to the region of the centroid energy to seek a match. If a match is found, the isotope data associated with the energy is transferred as part of the peak data for later calculations. If no match is found, the peak is labeled as "no-lib" and a set of default parameters (100% branching, zero decay time, etc) is assigned. This essentially one-dimensional matching approach speeds the search relative to a two-dimensional lookup technique.

For library-flagged MDAs that do not correspond to the found peaks, the code calculates these cases and simultaneously merges them within the above sequence in order of gamma energy. In this process the energies/MDA flags of the entire isotope library are stepped monotonically between the peak energies found earlier so that the new MDA analyses can be placed in the correct energy order within the peak list.

IV. USER OPERATION OF GRABGAM

This section describes the user operations for GRABGAM, while Appendix B provides code listings. Discussed below are inputs, code execution, basic output, supplementary analyses, and auxiliary programs. The GRABGAM sequence diagram of Figure 7 assists the discussion, as well as the earlier Table 1 overview.

IV.A. GRABGAM Inputs

The inputs are both manual via keyboard and automatic from files. For the present we will assume that the input files are available; their creation will be discussed along with the supplementary analyses of Section IV.D and auxiliary programs of Section IV.E.

Upon execution of a batch code, an isotope library file ISOLIBRY.LIB and a detector library file DETLIBRY.LIB will be automatically input. ISOLIBRY.LIB provides a monotonic user-selected list of gamma-ray energies, along with their isotope symbols, halflives, intensities, and flags for MDA analyses. DETLIBRY.LIB provides sets of detector calibration curve parameters for three vial sizes as function of fill height. However, the user is not limited to these choices and can for example select a calibration file detreff.DCF developed for a specific geometry. For each detector a corresponding peak background file backgnd.BKG will also normally have been prepared prior to running the code although one may select a "no background subtraction" option if desired.

Following the above preliminaries, two informational frames (#1 and #2) are presented. Then the user is prompted to begin the input from the keyboard. The first analysis input frame (#3) queries whether background subtraction is to be used and the type of countrate units (e.g. cph for low-level samples, cps for calibration standards). At the bottom of each frame an option is given to edit the input per re-entering. Subsequent frames (#4 and #5) query information in the following order:

- o Two points for energy vs channel calibration
- o Two points for FWHM vs energy calibration
- o Detector for analysis
- o Detector efficiency for sample geometry

The energy (E) vs channel (C) calibration is linear ($E = aC + b$), but the FWHM vs energy calibration assumes the Fano effect,²⁷ which is related to the square root ($FWHM^* = [cE + d]^{1/2}$). The detector may be selected from the list or designated as "other" if not listed.

Listed detectors have queries for some or all of the following calibration geometry options - vials (up to three sizes) vs sample height, well, air filter. Selection for efficiency = 1 or parameter inputs for log-polynomial and/or log-hyperbola efficiencies are manual options for both listed and other detectors. Normally the "other" detector choice will use a calibration file detreff.DCF prepared for a specific geometry. A corresponding backgnd.BKG file is also queried for input, if the background subtract option has been selected. The user has the option of displaying an energy vs efficiency table on the screen before proceeding.

The final input frame (#6) queries the user for the spectral file to be analyzed and other aspects of the analysis. The spectral file is assumed to have the format of an EG&G ORTEC ADCAM file denoted as spectrum.CHN. Other analysis queries are the title, sample age, activity units (e.g. Bq/kg), numerator factor (e.g. conversion to Bq), denominator factor (e.g. number of kg), start/end channels for analysis, and the $\pm$ keV range for isotope identification. For this final screen, individual inputs may be changed by menu operations at the bottom of the frame. Following completion of any such changes, the code begins to execute.

IV.B. GRABGAM Execution

GRABGAM execution initially prints out a summary of the input parameters. Then the screen displays a listing of the peaks as they are found by the filters. These peaks are further analyzed and then printed out in the basic analysis table. Finally, the user is queried if supplementary analyses are desired; if so, appropriate files are created before the program terminates.

First, the input parameters are printed out as in the example given in Figure 8. This printout has proved useful as a QA check for the analyses. At the top of the printout is the user-input title for the analysis, which is followed by three main sections. These sections are Sample Counting Information, Sample Analysis Information, and Detector Status Information. A detailed discussion of this printout is given in Section IV.C.

Next, the screen displays the peaks as they are found by the filters, as shown in Figure 2. A screenprint hardcopy of this may also be obtained if desired. The table gives the channel number, energy, peak area trapped by filter, $1-\sigma$ percent error of this area, and the filter size or "rope". The rope filter sizes are designated "2-pt", "4-pt", and "8-pt" as defined in Figure 1. The number of forced MDA cases is also displayed immediately after this table.

After this a hardcopy summary of the multiplet parameters is printed to allow later refinement with PEAKPART as appropriate. For each multiplet peak, the table includes its maximum, bounding

minima, area, energy, and isotope identification. The minima codes (1,2,3) denote whether a minimum was determined as (1) a gross minimum, (2) relative minimum, or (3) inverse center of gravity between adjacent peaks. Further details are given in Appendix A.

Then, the basic peak analysis table is printed after the peaks have undergone further analysis and have been appended with background corrections and MDA cases. An example of the peak analysis table is shown in Figure 9, where the peak channel, energy, FWHM, tail, counts, peak rate, peak background rate, isotope identification, activity, and 1- σ errors are given. A more detailed description of the table is given in Section IV.C. Note that the basic peak analysis table is actually entitled "Detailed Sample Analysis" because final sample isotopic activities are also included.

Finally, the user is queried whether supplementary analyses are desired. These analyses can use the spectral data for developing background files, calibration files, or simply for examining the analysis in more detail. Operation of the supplementary analysis programs is discussed in Section IV.D. After the supplementary analysis query is answered, the GRABGAM execution is completed.

IV.C. GRABGAM User Output

After execution of GRABGAM, the user will have hardcopy tables of the input parameters and the peak analysis, as already introduced. The present section discusses these tables in more detail as a guide to their utilization.

The printout of the input parameters is examined in reference to the example in Figure 8. The Sample Counting Information at the top of the printout gives the sample spectral file and its associated ADCAM information, including MCA components (MCB/segment), start count (time/date), and count times (live/real). The Sample Analysis Information at the middle of the printout provides the channels analyzed (start/end), a peak search parameter (now defaulted), the $\pm$ keV limits for isotope identification, and the activity units along with associated numerator and denominator factors. The Detector Status Information at the bottom of the printout denotes the detector along with its background and efficiency calibration files, as well as the analysis configuration geometry and the calibration equations used for energy (EN), FWHM*, and efficiency (EFF). A quick review of this printout assures that the input data are appropriate for the intended analysis.

The Detailed Sample Analysis printout table is illustrated in Figure 9. (Just before this, a multiplet parameter table is printed, as discussed in Section IV.B and Appendix A). It has both

a heading and a footing for each column, which correlate with the top and bottom column entry of each peak data set. For example, the "top" peak energy corresponds to the centroid calculated by the code, while the "bottom" energy corresponds to the library value of the associated isotope. Similarly, for peak widths, the top value is the spectral analysis FWHM and the bottom is the guide FWHM* input by the user. Such information provides the user with a QA check on the adequacy of the calibrations used, as well as providing guidelines for recalculation with other calibration choices when necessary. For multiplet peaks, the top FWHM becomes the number of peaks in the multiplet and the tail denotes the number of the peak within the multiplet. Other infrequent peak flags have been summarized in Figures 4 and 5.

The Detailed Sample Analysis often indicates "less-than" values in the Activity column. For this situation, the top number corresponds to the GRABGAM determination limit⁹ and the bottom number corresponds to the customary 95%-confidence minimal detection limit (MDA) developed by Currie.¹⁰ Adjacent to the determination limit is the entry " $3\sigma/x\sigma$ ", which denotes that the code requires that a positive peak area had to exceed its determination limit of 3σ but the actual peak only had a smaller area of $x\sigma$. This allows the user to transform the determination limit to a measured activity with an error. Such a transformation is not possible with the single number provided by the conventional MDA, which is denoted in the table by the notation "MDA = c+b". Overall, the 3σ determination limit is comparable to the conventional MDA.

IV.D. Supplementary Analysis Programs

Six supplementary analyses programs may be run following GRABGAM execution, provided that the query for such analyses (except for the PEAKPART analysis) was affirmed to create appropriate data files. The supplementary programs are listed in Table 1.

GRABISOS is generally executed on a routine basis following GRABGAM sample analysis. Upon execution, GRABISOS bubble sorts all the peaks of the Detailed Sample Analysis table in the following ascending alphanumeric order: isotope mass number (A), isotope symbol (Z-A), and peak energy (Eg). This being done, the screen displays the first isotope (lowest A,Z) and its list of peak energy activities. From the list of peak activities, the user may flag those useful for a weighted average of the isotope activity. Then the analysis and result are recorded by the printer, as illustrated in Figure 10. The sequence is then repeated for the second isotope (lowest remaining A,Z) and subsequent isotopes until all have been addressed. The final peak grouping is for an artificial isotope that includes all peaks that were not identified with an isotope, such as x-rays, annihilation peak, escape peaks, and peaks that had

no counterpart in the isotope library. These peaks, ordered monotonically in energy, are assigned activities assuming 100% branching intensity and zero decay time, as this helps facilitate manual identifications of the residual peaks.

GRABBACK produces a peak background file from the background spectrum of a detector. GRABBACK can use a single spectral file for developing a background file backgnd.BKG or merge it with data of an earlier background file to improve statistics. Upon execution GRABBACK leads the user to these options. The merged file is an even weighted average of the new peak backgrounds with the peaks of the existing background file, so that the values are more representative of recent peak backgrounds. Two other options for making background files also exist. One option uses a text editor file creation, whereby line inputs for energy, countrate, and error are entered in monotonic order with energy using peak data from an appropriate background spectrum analysis. The other option uses the MERGBACK code, which is discussed in Section IV.E.

GRABCALB produces an efficiency calibration file for a specific detector and geometry. (Calibrations with vial height interpolations are performed externally and parameters are input to the DETLIBRY.LIB file using the DETLIBAS code described in section IV.E). Upon execution, GRABCALB retrieves data saved by the GRABGAM analysis of the calibration standard, and then queries information for the decay time from the standard calibration date, which is entered from the keyboard. The code then sequentially displays the peaks in the spectrum, giving their isotope identification, energy, and countrate, whereby the user can select those to be used in the calibration along with their gamma rates at the certified standard date. After completing these selections, a screen table is presented for acceptance or editing. Then, a log-log efficiency vs energy plot of the raw data appears on the screen with a query for correcting coincidence summing. For summing corrections, a representative detector thickness is entered along with summing gammas and their coincident fractions. The log-log efficiency plot of the refined data points is then redrawn for acceptance.

GRABCALB curve fitting proceeds following the corresponding data entry and refinement. With the data points displayed on the screen, the user moves three cursors that are sufficient for "artistically" constructing a log-log hyperbola to fit the data points. A comparison of the fit is given for each point, and then the comparison is improved by auto-renormalization that makes the average of the deviations zero. One may then opt to improve the fit further by applying a least-squares fitting to the hyperbola. A final option is to improve the fit by analyzing the perturbations from the hyperbola with a cubic least-squares fit. After the fitting options have been exhausted, the calibration parameter file detreff.DCF is created. Another option for making the detreff.DCF file is to use the MERGCALB code discussed in section IV.E.

GRABDIAG is a diagnostic program that explores whether a detected peak may be an artifact such as a Compton scatter or an escape peak. Upon running the code, each gamma peak of energy $E(\text{keV})$ from the preceding GRABGAM execution has the following calculations tabulated:

- o Compton Edge = $E / (1 + 511/2E)$
- o Compton Backscatter = $E / (1 + 2E/511)$
- o Single Escape Peak Parent = $E + 511$
- o Double Escape Peak Parent = $E + 1022$

Usage of GRABDIAG has revealed no Compton artifacts, affirming that the GRABGAM filters are favorable for finding peaks alone. Escape peaks of concern for SRTC low-level gamma spectrometry have been identified and placed in the isotope library to assist the user. Thus, GRABDIAG is not generally needed for routine analysis. Yet it remains a tool for helping diagnose the spectra of unusual samples.

GRABPLOT is used to plot peak regions to allow appraisal and possible reanalysis. This tool was primarily used in the early development of GRABGAM, but still remains available for peak studies. The peak to be plotted is selected by number from the preceding GRABGAM spectral analysis. The plot is displayed on the screen with colored regions to identify the ROIs used in the analysis. The ROIs may be varied by the user for an alternative analysis as appropriate.

PEAKPART refines the multiplet peak areas to better account for peak overlap. For a given multiplet the user inputs the GRABGAM peak centroids, areas, and their bounding minima. Then, the code calculates the Gaussian peak fractions that contribute to these minima-bounded areas. In turn these peak fractions act as coefficients of the refined areas, which are solved within a set of M linear equations, where M is the number of peaks in the multiplet. Further details are given in Appendix A.

IV.E. Auxiliary Programs

Four auxiliary programs also create files for GRABGAM. These stand-alone programs do not require prior execution of GRABGAM. The programs are given in Table 1, and each program is explained in the following discussion.

ISOLIBAS contains the isotope library information that the user selects as appropriate. This BASICA program is configured so that lines from 20,000 to 23,000 contain a DATA line for each isotopic gamma ray. The gamma energies are monotonically sequenced

by using DATA lines corresponding to the energies. For example the data for the 834.8 keV gamma of Mn-54 is entered in line 20835 as:

```
20835 DATA "Mn-54", 312.7, 834.8, 99.98, 0
```

where 312.7 is the half-life in days, 834.8 is the gamma energy in keV, and 99.98 is its intensity per decay in percent. Finally, the 0 indicates that an MDA analysis is not forced. By contrast, if the 0 were replaced by a 1, an MDA would be forced when the peak is not detected. Upon execution of ISOLIBAS, the information of all such DATA lines is written to the file ISOLIBRY.LIB.

DETLIBAS contains the detector library information for up to five detectors for three different vial sizes as a function of fill height. The fitted efficiency function is the product of a hyperbola and a third order polynomial in h and $\ln(E)$, where h is the vial fill height and E is the gamma energy.⁵ The parameters for these efficiency functions are determined by a special least-squares program and then entered into DATA lines within the DETLIBAS program. Upon execution of DETLIBAS, the information of these data lines is written to the file DETLIBRY.LIB.

MERGBACK is a stand-alone analog of GRABBACK, which was discussed earlier in Section IV.D. MERGBACK requires the user to have tabulated the peak background rates for keyboard entry. Overall, GRABBACK effectively streamlines the text editor approach for making the backgnd.BKG file by providing better ease for input and editing.

MERGCALB is the stand-alone analog of GRABCALB, which was discussed earlier in Section IV.D. Unlike GRABCALB, MERGCALB requires the user to have tabulated the appropriate energy-efficiency pairs for manual entry. Also any summing corrections will need to have been already applied since the spectral information for this is not provided by MERGCALB. With the data entered and ready for analysis, the subsequent execution of MERGCALB is identical to GRABCALB, yielding the file detreff.DCF, which includes parameters of the fitted efficiency curve.

V. DISCUSSION/CONCLUSIONS

V.A. Philosophy of Low-Level HPGe Spectral Analysis

Spectral analyses of low-level gamma peaks are always subject to statistical limitations with regard to peak fitting. Accordingly GRABGAM pursues an integral approach to peak analysis as opposed to a differential fitting. Theoretically, the GRABGAM integral function F is automatically corrected for its background, regardless of the actual peak shape. This is also true for the F -function of a multiplet. Overall, the F -function defines a consistent centroid (as median), FWHM (integral limits), and tail (integral asymmetry) for each singlet peak, with no requirement on the detector performance for producing ideal peaks. Of course, even the integral approach has its statistical limitations, but even if the F -analysis fails to give acceptable results, a basic ROI analysis is flagged to yield an estimate so that the peak can be considered.

Singlets are anticipated to be predominant in low-level gamma spectrometry. Due to concerns for statistical and resolution limitations, the GRABGAM peak search routine does not distinguish peaks that are separated by less than 0.47 FWHM^* ; however, the F -analysis for the FWHM and tail measured for the resulting singlet peak alerts the user that the observed peak may be a composite of peaks. Concern for the statistics similarly restricts the multiplet analysis, as a given peak within a multiplet may also be a composite. Overall, GRABGAM experience in counting low-level samples has not been hampered by such hidden composite peaks, as the probability of such occurrences is generally low. Furthermore, typical unresolved composite peaks often may be identified from other gammas within the spectra, as is the case for a composite of the 185.7 keV gamma of ^{235}U and the 186.2 keV gamma of ^{226}Ra since ^{235}U frequently exhibits other gammas in the spectrum.

GRABGAM calculates both a determination limit and a detection limit. The GRABGAM determination limit⁹ of $A \geq 3\sigma$ is comparable to that of the Currie detection limit¹⁰ (95% probability detection), but both are always higher than the Currie critical level¹⁰ (5% false positive) for being detected above background. These three values can be derived as a function of background counts B and are plotted in Figure 11. GRABGAM assures that its minimum detection has a $1\text{-}\sigma$ statistical error no worse than 33%, while recorded detection at the Currie critical level has errors in excess of 60%. Instead of directly accepting peaks with such high errors, the GRABGAM philosophy is to flag MDA analyses for potentially useful peaks, and utilize the " $3\sigma/x\sigma$ " formalism to extract the $x\sigma \pm \sigma$ activity as appropriate. Consequently GRABGAM has a low false positive acceptance in general, while providing an inspection option for reconsidering the acceptance of flagged MDA peaks.

Although the GRABGAM determination level and the Currie detection limit are comparable in magnitude, their associated MDAs have different interpretations. The Currie MDA is the level for which 95% of the time an actual peak at this level would exceed the Currie critical level for 5% false positives. As such, the Currie MDA is based on a priori reasoning. The GRABGAM MDA indicates that the detected peak was less than this amount, and thus uses a posteriori reasoning. Overall, the Currie MDA may be stated as the "minimum detectable amount" and the GRABGAM MDA be stated as the "minimum detected amount". An attractive feature of the GRABGAM MDA is that the detected values always exceed the MDA, whereas the Currie MDA can contradict this situation. One may prefer to use a determination limit $n\sigma$ with $n < 3$ to provide more sensitivity at the expense of more false positives, and GRABGAM effectively provides this option within its " $3\sigma/x\sigma$ " formalism for flagged MDA peaks. Other approaches to detection limits have also been offered, such as the use of direct Poisson statistics²⁸ and individual peak channel evaluations for peak areas.²¹

V.B. Algorithm Features and Limitations

The peak search algorithm uses filters that trap the area above displaced adjacent background regions, as illustrated earlier in Figure 1. As GRABGAM was originally developed for 2000 keV spectra spanning 4000 channels, a filter with a 4.0 keV (8 channel) gross region was selected to contain essentially all of the area of a 1332 keV gamma peak with FWHM of 2.0 keV, which is fairly representative of HPGe performance. Adjacent background regions of 2.0 keV (4 channels) displaced from the peak region by 2.0 keV (4 channels) then assured a good signal-to-background selection, even for a significantly larger FWHM. Upon developing the multiplet analysis, similar smaller filters with gross regions of 1.0 keV (2 channels) and 2.0 keV (4 channels) were added to help resolve peaks. These filters also have the potential to accentuate the signal to background. However, the 1.0 keV filter could miss evidence of a peak (or shoulder) indicated by two high count channels relative to the two directly (as opposed to displaced) adjacent channels. On the other hand, two high channels provides little peak definition to assure its existence as opposed to a fluctuation, and thus their missed detection by GRABGAM is not considered a serious loss. Filter fluctuations occasionally identify two peaks that are displaced by less than 0.47 FWHM^* , which would not render two peaks for even identical gaussian peaks separated by this amount. In these cases the two peaks are combined as a single peak. Overall, the GRABGAM filters find peaks that can be comparable or broader than those of the user input FWHM^* for the analysis. The subsequent detailed peak analysis provides information concerning whether the peak is a true singlet or a broader composite of peaks.

The singlet peak algorithms do not depend on fitting parameters for a particular model, which is customary for differential peak fitting.¹⁻² Instead, the adjacent background ROIs are selected by searching for the flat regions on either side of the peak, as illustrated in Figure 3. Thus, even if the peak is a pure Gaussian, smeared by amplifier drift, or degraded by a tail, the calculated peak area corresponds to the full-energy gamma response within the gross peak region. Additionally, the integral F-analysis provides adequate values for median, FWHM, and tail. A peak found by the search algorithm will be rejected if the peak analysis indicates $A < 3\sigma$. This possibility exists since the signal-to-noise enhancement of the filters may cause peak identification for statistical fluctuations. However, experience has shown that the combination of search and singlet algorithms effectively eliminate these false positive cases. Also, GRABGAM does not detect other spectral artifices such as Compton edges or backscatter.

In the F-analysis for both singlets and multiplets, it had been assumed until recently that constant adjacent background regions existed. This is generally true in low-level gamma spectrometry, as such background regions are normally determined within statistical requirements. On the contrary, a significantly variable background does have an impact on an F-analysis which assumes $v(E)=0$, as illustrated in Figure 12. In this example, the F-analysis is in error because the average background on the lower-energy side of the peak is higher than nearby points of the peak region and the average background on the higher-energy side is lower. Thus, for the singlet F developed in Section III.B, the F values will be negative on the low-energy side of the peak and also modified on the high-energy side. Yet, the singlet peak area is essentially unaffected and the centroid, FWHM, and tail experience only minor inconsequential impacts. For multiplets the effects can be more detrimental, and Appendix A describes the recently upgraded F algorithm that addresses such variable backgrounds; however, even the earlier analysis flagged the user when the F algorithm was not appropriate. Overall, numerous GRABGAM analyses over 14 years have encountered minimal impact from variable backgrounds.

The multiplet algorithms produce an analysis like the example in Figure 5. The F-function approach uses an individual background subtraction for each gross channel count within the multiplet. The total area A_m of all peaks in the multiplet is generally determined with accuracy comparable to that of a singlet peak. However, a calculational error exists for partitioning A_m among the individual peaks of the multiplet, as the area A_m of an individual peak is the area between its adjacent minima. The analysis assumes that the peak areas that extend beyond the minimum between the two peaks are equal; however, the accuracy of this approximation deteriorates for smaller peak spacing and larger differences in peak magnitude. As described in Appendix A, the supplementary program PEAKPART may be applied to correct such errors.

Further improvement on the current multiplet analysis will require more detailed information on the peak shapes. Ideally, peak shapes could be extracted using the larger peaks of the sample spectrum, so that the intrinsic generality of the GRABGAM analysis for a spectrum is preserved; however, the prospect of a sufficient set of peaks is not likely for low-level samples. Thus, spectral shapes from calibration standards and/or modelling will be required for each detector as well as geometry in some cases, so that the intrinsic generality of the analysis would be compromised. A standard addition method in which identical spiked and unspiked samples are counted would essentially retain intrinsic generality and provide the peak shapes; however, quality spiking of samples with gamma standards can be expensive and labor intensive.

Multiplets with low-level counting statistics can cause additional concerns, and if F is not well-behaved, warning flags are printed with the output. This approach follows the overall GRABGAM philosophy of presenting the user with the option of reevaluating marginal cases rather than automatically removing them from consideration. In practice, with these guidelines and those mentioned above, the GRABGAM multiplet analysis has generally provided a useful tool for appraising closely spaced peaks.

V.C. Performance History

The GRABGAM code has successfully supported low-level HPGe gamma spectrometry at SRS for over 14 years, involving analyses of over 10,000 samples. Various projects supported during this period include studies of Chernobyl fallout,⁶⁻⁷ appraisal of LDEF satellite samples for NASA,²⁹ monitoring radioactive levels in the Savannah River,³⁰⁻³¹ evaluation of sediment levels in SRS cooling ponds,³¹⁻³⁴ environmental analyses of high volume air samples near SRS,³⁵ and studies of the Arctic Ocean.³⁶ In addition to these, numerous customer service samples have been conducted for SRS and offsite patrons.

GRABGAM analyses have been applied to both laboratory and in-the-field detectors. Laboratory applications include 13 HPGe detectors with efficiency range of 10-160%, which have been used in the Ultra-Low-Level Counting Facility³⁻⁴ and the Underground Counting Facility.⁸⁻⁹ The two HPGe detectors on the SRS TRAC mobile laboratory³⁷ also used GRABGAM for a number of years. One early TRAC applications was the collection and analysis of air samples following the Chernobyl accident, where the TRAC vehicle analyzed regional samples during transits within Georgia and South Carolina.⁷ Although microphonics associated with the vehicle motion degraded the quality of the spectral peaks, the general nature of the peak analysis with the F -function properly analyzed these peaks, giving good agreement for similar samples analyzed at the ULLCF laboratory.⁶ Similar performance is exhibited in the quality

chart of Figure 13, which illustrates how the peak areas remained constant for a detector that gradually degraded in resolution over the years. In-the-field spectra obtained with a HPGe sonde³⁸ and an HPGe underwater detector³¹⁻³⁴ have also been successfully analyzed with GRABGAM.

The output hardcopies of GRABGAM have provided useful guidance and documentation of the sample analyses. The initial input summary sheet lists information on all user inputs as a quality check. The peak listing prints both the peak energy determined by the analysis and the energy matched by the isotope library, guiding the user on any need for reanalysis with a refined energy calibration. Also the analysis-determined FWHM and the user-input FWHM* are printed, allowing a quality check on detector performance and advising the user on whether the input FWHM* is adequate in selecting ROI-dependent analyses such as flagged MDAs. Examination of FWHM and tail provide either singlet quality information or flags concerning MDAs, ROI analyses, and multiplet features.

The GRABGAM printouts have also provided consistency checks for the adequacy of detector backgrounds and efficiencies. The spectral peak counts and statistical errors are printed adjacent to those from background spectra, for direct consistency checks. Subsequent GRABISOS calculations frequently provide the user with consistency checks on the stability of the detector efficiency curve by comparing the different peak activities deduced for an individual isotope. For example, soil samples often contain radium daughters B-214 and Pb-214 that are in equilibrium, whereby several nicely spaced gammas are detected over a range of 200-1800 keV. Agreement for the isotope activities for these peaks shows that the efficiency curve is consistent in a relative sense. This information, coupled with monthly check source tests, affirms the absolute efficiency calibration as well. In summary, the above routine information from GRABGAM analyses provides the user with excellent guidelines for affirming the quality of the results.

V.D. Conclusions

GRABGAM has performed well in its role for analyzing low-level environmental samples by HPGe analysis. Overall, the analysis has attempted to provide user options for evaluating the presence of marginal but potentially real peaks, while automatically processing peaks with $1-\sigma$ detection statistics that are better than 33%. Evaluation of marginal peaks is possible by conversion of the GRABGAM-formatted MDA data and/or by direct inspection of the spectrum. However, the best option is to continue counting for a time based on the statistics of the marginal peak. None of these options would be available if GRABGAM discarded the marginal peaks.

The general nature of the GRABGAM peak search and analysis does not depend on specific peak shape parameters. Accordingly, other types of spectroscopy are expected to be amenable to the GRABGAM algorithms. Indeed, a NaI version GRABNAI was developed for an underwater NaI detector in the Savannah River to monitor effluent activities from SRS and the Plant Vogtle power reactors.³⁰ While not an advanced NaI peak stripping code, GRABNAI has provided useful gamma peak analyses for time profiles of the effluent discharges, which have correlated well with recorded discharges at the source. Another spinoff is GRABTRIT, which was developed to analyze SRS low-level tritium samples counted within gas proportional counters.³⁻⁴ In this case a spectrum results for the detector signals following their pulse-shape discrimination, which separates cosmic-ray background components from a narrow tritium peak. A code GRABALFA for surface barrier alpha spectrometry has also been written, as features of alpha tailing due to sample thickness should be handled well by the singlet algorithm. However, an algorithm for handling alpha multiplets still needs to be developed. Finally, the peak search algorithm was utilized in a gas chromatography spectral analysis code at SRS.

Improvements in GRABGAM have continued to be sought. Although the multiplet algorithm has provided adequate information for SRS applications in the past, an improved algorithm could provide a more complete deconvolution of the peaks. Due to recent improvements for addressing variable backgrounds, the F-function now provides a better estimate for the background profile beneath the multiplet peaks. The resulting peak areas are refined additionally with the partitioning code PEAKPART. For further refinements, peak shape information will be required, but this can only be marginally applied due to statistical limitations for low-level spectra.

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Table 1. Overview of Programs and Files

OPERATIONS	PROGRAMS	FILES	
Setup	Auxiliary	Creation	Usage
Isotope library	ISOLIBAS	ISOLIBRY.LIB	
Vial efficiencies	DETLIBAS	DETLIBRY.LIB	
Peak backgrounds	MERGBACK	<u>backgnd</u> .BKG	
Other efficiency	MERGCALB	<u>detreff</u> .DCF	DETLIBRY.LIB
Execution	GRABGAM	Creation	Usage
Analysis setup	GRABDKR1		DETLIBRY.LIB
Peak search			<u>backgnd</u> .BKG <u>detreff</u> .DCF <u>spectrum</u> .CHN
Peak analysis	GRABDKR2	DATAALB.DAT	ISOLIBRY.LIB
Multiplet analysis		DATASPEC.DAT	<u>backgnd</u> .BKG
Background correct		DATAISOS.DAT	
MDA analysis		DATAPEAK.DAT	
Peak results table		DATAMISC.DAT	
Appendage	Supplementary	Creation	Usage
Wtd Isotopics	GRABISOS		All GRABname Programs
Peak backgrounds	GRABBACK	<u>backgnd</u> .BKG	
Other efficiency	GRABCALB	<u>detreff</u> .DCF	DATAALB.DAT
Artifact peaks	GRABDIAG		DATASPEC.DAT
Peak plot analysis	GRABPLOT		DATAISOS.DAT
Multiplet peaks	PEAKPART	<printout>	DATAPEAK.DAT
			DATAMISC.DAT
			<printout>

Fig. 1. Spectrum examined by three different size filters. Each filter sums spectral counts g in the middle channels and counts $b1$ and $b2$ in adjacent channels, as indicated. The counts A_f trapped by filter is $g - b1 - b2$ with counting $\sigma = (g + b1 + b2)^{1/2}$. If $A_f \geq 3\sigma$, a candidate peak is retained for further analysis.

peak	channel	KeV	Area	%-error	Rope
1	146	72.89731	176	12.44824	2-pt
2	151	75.37191	449	6.271772	2-pt
3	156	77.84651	88	21.50101	2-pt
4	171	85.2703	235	9.842581	2-pt
5	176	87.74489	140	13.55262	2-pt
6	187	93.18901	91	17.13017	2-pt
7	264	131.2978	111	26.06392	8-pt
8	370	183.7593	93	32.52577	8-pt
9	376	186.7288	60	27.98809	2-pt
10	481	238.6954	312	7.489309	2-pt
11	488	242.1598	94	19.08974	2-pt
12	596	295.6111	133	13.88435	2-pt
13	625	309.9638	53	32.29669	4-pt
14	683	338.6691	62	22.92366	2-pt
15	710	352.0319	287	7.593901	2-pt
16	735	364.4049	71	19.86864	2-pt
17	825	408.9476	79	26.15693	8-pt
18	935	463.3888	30	32.65986	2-pt
19	967	479.2262	62	30.85666	8-pt
20	1031	510.9011	139	16.79513	2-pt
21	1078	534.1623	34	32.21897	4-pt
22	1177	583.1593	76	16.00727	2-pt
23	1230	609.39	190	9.930507	2-pt
24	1249	618.7935	21	32.64597	2-pt
25	1336	661.8515	71	17.87124	2-pt
26	1363	675.2144	21	31.2259	2-pt
27	1469	727.6758	33	24.8041	2-pt
28	1551	768.2591	23	31.04969	2-pt
29	1721	852.3955	21	31.2259	2-pt
30	1811	896.9382	18	31.42697	2-pt
31	1840	911.2909	59	17.36771	2-pt
32	1897	939.5013	15	29.05933	2-pt
33	1957	969.1966	33	27.60738	2-pt
34	2149	1064.221	22	32.77774	4-pt
35	2262	1120.147	38	23.82996	2-pt
36	2340	1158.751	19	32.86841	4-pt
37	2497	1236.453	31	32.41895	8-pt
38	2501	1238.433	38	21.70056	4-pt
39	2589	1281.986	38	24.40426	8-pt
40	2635	1304.752	24	32.27486	8-pt
41	2783	1378	32	21.65064	4-pt
42	2950	1460.652	180	11.41258	2-pt
43	2972	1471.54	12	31.18048	2-pt
44	3493	1729.393	34	21.20913	8-pt
45	3562	1763.542	55	16.16036	4-pt
46	3771	1866.98	13	27.73501	4-pt

Fig. 2. Example of candidate peaks table displayed on monitor.

Fig. 3. Singlet analysis for ROIs of gross (G) and background (B1, B2) counts. The two background ROIs are found such their corresponding adjacent gross channels have counts that do not exceed their respective background channel averages by more than 2σ .

Fig. 4. Detected gamma response function for (a) perfect solution and (b) actual solution, along with (c) flags indicating nature of analysis. It can be shown that convoluting $\delta(E'-E_g)$ and $H(E'-E_g)$ with $f(E-E')$ yields the $f(E-E_g)$ and $F(E-E_g)$ above.

Fig. 5. Multiplet analysis: (a) calculation of total multiplet area A_M , similar to that for singlet; (b) individual peak areas $A_{m/M}$ calculated from A_M and $F_{m/M}$; (c) flagged multiplet analyses for reconsideration.

Fig. 6. Multiplet minimum for "shoulder doublet".

Fig. 7. GRABGAM operational sequence per input/outs as keyboard (KB), printer (PR), video monitor (CRT) and disk files (xxxxx.xxx).

***** Vegetation A10 (6/3/98) counted 6/28/98

----- Sample Counting Information -----

Sample disk file 6431vegs.chn

MCB number 2

Segment 2

Start time 1413

Date 10JUL02

Live time 63599.8 sec

Real time 63931.9 sec

----- Sample Analysis Information -----

Start channel 50

End channel 3950

Peak search channels 8

Isotope ID (+/- keV) 2

Decay corrected to 25 days earlier

Activity units (pCi modified per factors below) pCi/g

Numerator factor = 3.83

Denominator factor = 43.9

----- Detector Status Information -----

Det4 with p4back.BKG and pdet4cal.dcf

Configuration = 1(1) SPECIAL (2) DIAPER (3) WELL (4) VIAL

Energy(keV) calibration: $EN = .6390686 + .4949195 * CHAN$

FWHM(channel) calibration: $FWHM = \text{SQRT}(8.019283 + 5.772945E-03 * CHAN)$

Efficiency calibration: $EFF = G * \text{EXP}(HYPERBOLA * \text{POLYNOMIAL}) * (1 + \text{PERTURBATION})$

$G = \text{global calibration factor} = .20397$ $D = \text{LN}(G) = -1.589783$

$HYPERBOLA = A * \text{SQRT}(B^2 + (\text{LN}(EN) - C)^2)$ with values below:

($A = -.5424688$ $B = -.1952242$ $C = 5.166513$)

$\text{POLYNOMIAL} = C0 + C1 * \text{LN}(EN) + C2 * \text{LN}(EN)^2 + C3 * \text{LN}(EN)^3$ with values below:

($C0 = 2.791449$ $C1 = -.670216$ $C2 = 8.085154E-02$ $C3 = -3.105141E-03$)

5000 keV = crossover between low EN (above) and high EN (below) cases

($C0 = 0$ $C1 = 0$ $C2 = 0$ $C3 = 0$)

$\text{PERTURBATION} = P0 + P1 * \text{LN}(EN) + P2 * \text{LN}(EN)^2 + P3 * \text{LN}(EN)^3$ with values below:

($P0 = 0$ $P1 = 0$ $P2 = 0$ $P3 = 0$)

Fig. 8. Printout of input parameters (8.5 in. x 11.0 in. sheet)

***** Vegetation A10 (6/3/98) counted 6/28/98

----- Detailed Sample Analysis -----

Peak #	Channel #	Energy keV	FWHM keV	Tail #	Counts #	Rate cph	Bkgnd cph	Isotope Z-A	Activity pCi/g	Error N-stats
1	92.7	46.5	2.97	-1.00	34	1.9	0.0	Pb-210	<0.83E+00	3 σ /1.4 σ
		46.5	1.45		± 25	± 1.4	± 0.0		<0.91E+00	MDA=c+b

23	1335.6	661.6	1.59	1.22	156	8.8	3.4	Cs-137	4.30E-02	21.8 %
		661.6	1.96		± 20	± 1.1	± 0.3		± 0.93	
24	1468.5	727.4	4.95	-3.00	61	3.5	0.0	Bi-212	3.37E-01	24.5 %
		727.2	2.01		± 15	± 0.8	± 0.0		± 0.82	
25	1606.7	795.8	4.95	-1.00	5	0.3	0.0	Cs-134	<0.20E-01	3 σ /0.4 σ
		795.8	2.06		± 13	± 0.7	± 0.0		<0.23E-01	MDA=c+b
26	1636.9	810.8	4.95	-1.00	-3	-0.2	0.0	Co-58	<0.18E-01	3 σ /0.0 σ
		810.8	2.07		± 11	± 0.6	± 0.0		<0.22E-01	MDA=c+b
27	1840.1	911.4	1.61	1.08	126	7.1	0.0	Ac-228	2.13E-01	13.3 %
		911.1	2.14		± 17	± 0.9	± 0.0		± 0.28	
28	1956.5	968.9	4.95	-3.00	46	2.6	0.0	Ac-228	1.35E-01	32.1 %
		969.1	2.18		± 15	± 0.8	± 0.0		± 0.43	
29	2262.4	1120.3	1.82	1.17	116	6.6	0.0	Bi-214	3.68E-01	14.0 %
		1120.3	2.27		± 16	± 0.9	± 0.0		± 0.52	
30	2262.4	1120.3	1.82	1.17	116	6.6	0.0	Sc-46	7.11E-02	14.0 %
		1120.5	2.27		± 16	± 0.9	± 0.0		± 1.00	
31	2369.2	1173.2	4.95	-1.00	-4	-0.2	0.0	Co-60	<0.16E-01	3 σ /0.0 σ
		1173.2	2.31		± 10	± 0.6	± 0.0		<0.19E-01	MDA=c+b
32	2497.5	1236.7	2.02	1.02	23	1.3	0.0	Bi-214	<0.23E+00	3 σ /2.7 σ
		1238.1	2.34		± 9	± 0.5	± 0.0		<0.23E+00	MDA=c+b
33	2501.5	1238.7	2.02	2.02	5	0.3	0.0	Bi-214	<0.10E+00	3 σ /1.2 σ
		1238.1	2.35		± 4	± 0.2	± 0.0		<0.12E+00	MDA=c+b
34	2691.2	1332.6	4.95	-1.00	14	0.8	0.0	Co-60	<0.15E-01	3 σ /1.5 σ
		1332.6	2.40		± 9	± 0.5	± 0.0		<0.17E-01	MDA=c+b
35	2950.3	1460.8	2.14	1.06	701	39.7	1.1	K-40	3.67E+00	4.1 %
		1460.8	2.48		± 28	± 1.6	± 0.2		± 0.15	
36	3494.4	1730.1	2.65	1.24	29	1.6	0.0	Bi-214	6.18E-01	29.1 %
		1729.6	2.63		± 8	± 0.5	± 0.0		± 1.80	
37	3562.9	1764.0	2.62	1.04	98	5.5	0.0	Bi-214	3.69E-01	12.5 %
		1764.5	2.65		± 12	± 0.7	± 0.0		± 0.46	

Key: spect spect spect spect spect spect file lib to-left to-left
- - lib calc - +/- +/- +/- - - +/- -

Fig. 9. Peak analysis printout table (8.5 in. x 11.0 in. sheets)

***** AVERAGED RESULTS PER ISOTOPE *****

Source	Gamma #	Energy keV	Activity pCi/g	Average y/n
Be-7	1	477.6	<0.25E+00=3 σ /0.0 0.28E+00=MDA	n

Source	Gamma #	Energy keV	Activity pCi/g	Average y/n
K-40	1	1460.8	[3.67 +/- 0.15] x E 0	n

Source	Gamma #	Energy keV	Activity pCi/g	Average y/n
Cs-137	1	661.6	[4.30 +/- 0.93] x E-2	n

Source	Gamma #	Energy keV	Activity pCi/g	Average y/n
Bi-214	1	609.3	[3.81 +/- 0.21] x E-1	y
Bi-214	2	1120.3	[3.68 +/- 0.52] x E-1	y
Bi-214	3	1238.1	<0.23E+00=3 σ /2.7 0.23E+00=MDA	n
Bi-214	4	1238.1	<0.10E+00=3 σ /1.2 0.12E+00=MDA	n
Bi-214	5	1729.6	[6.18 +/- 1.80] x E-1	n
Bi-214	6	1764.5	[3.69 +/- 0.46] x E-1	y

Average = [3.78 +/- 0.18] x E-1

Source	Gamma #	Energy keV	Activity pCi/g	Average y/n
PbBiKX	1	74.9	<0.40E-01=3 σ /1.6 0.44E-01=MDA	n
PbBiKX	2	74.9	[8.65 +/- 2.10] x E-2	n
No-Lib	3	78.1	[4.42 +/- 0.67] x E-2	n
PbBiKX	4	86.0	<0.16E+00=3 σ /0.8 0.18E+00=MDA	n
Annihl	5	511.0	<0.19E-01=3 σ /2.9 0.20E-01=MDA	n

Fig. 10. GRABISOS isotope printout (8.5 in. x 11.0 in. sheets)

Fig. 11. Comparison of detection level scenarios.

Fig. 12. Effect of sloping background on F-analysis for $v(E) \equiv 0$, per comparison of Gaussian peak (centroid $\equiv 0.00$, FWHM $\equiv 3.00$, tail $\equiv 1.00$) on flat and sloping backgrounds.

Fig. 13. Peak area count rate constancy per GRABGAM analysis, during resolution degradation.

APPENDIX A

RECENT MULTIPLY REFINEMENTS

Two recent refinements for the multiplet analysis have been developed. The first addresses variable backgrounds in the GRABGAM code. The second is a new auxiliary program PEAKPART, which provides the user the option of refining the area partitioning for the multiplet peaks. Details of both are discussed below, and code listings are given in Appendix B.

VARIABLE BACKGROUNDS

A GRABGAM algorithm was developed to address variable backgrounds so that a more precise integral probability F is utilized. As pointed out in the main text, the math for deducing the F distribution over the gross region of a singlet or multiplet is equivalent; thus, the somewhat simpler notation for the singlet will be used in this discussion.

General Nature of Algorithm

The algorithm defines $z(E) = c + v(E)$ of Equation 6 as a third order polynomial in gamma energy, viz

$$z(E) = c + v(E) = c_0 + c_1(E-E_L) + c_2(E-E_L)^2 + c_3(E-E_L)^3 \quad (A-1)$$

where E_L is conveniently chosen to correspond to the background adjacent to the peak on its lower energy side, as shown in Figure A-1. With this substitution Equation 6 becomes

$$g(E) = A f(E-E_g) + b (1-F(E-E_g)) + c_0 + c_1(E-E_L) + c_2(E-E_L)^2 + c_3(E-E_L)^3 \quad (A-2)$$

Integrating this equation over one channel yields

$$g_j = A (F_{j+1/2} - F_{j-1/2}) + b_c - b_c (F_{j+1/2} + F_{j-1/2})/2 + c_{c0} + c_{c1}(j-j_L) + c_{c2}(j-j_L)^2 + c_{c3}(j-j_L)^3 \quad (A-3)$$

where c_{c0} , c_{c1} , c_{c2} , c_{c3} , j and j_L are the equivalent coefficients and

energies for $z(E)$ in channel units. Thus, the resulting F-function expression of Equation 11 becomes

$$F_{k+1/2} = \frac{\sum_{j=1}^k \{g_j - c_{c1}(j-j_L) - c_{c2}(j-j_L)^2 - c_{c3}(j-j_L)^3\} + b_c \sum_{j=1}^{k-1} F_{j+1/2} - (k-i+1)(b_c + c_{c0})}{A - b_c/2} \quad (A-4)$$

Selection of Algorithm Parameters

The background regions adjacent to the multiplet are fitted with straight lines given by

$$z_L = a_{L0} + a_{L1}(j-j_L) \quad \text{and} \quad z_R = a_{R0} + a_{R1}(j-j_L) \quad (A-5)$$

where the subscripts L and R refer to the background regions to the left and right of the gross peak region. The code normally uses 8 points in each background region for the fits, but if a nearby peak exists it will use fewer points but at least 3. Also, if the magnitude of the slope ($|a_{L1}|$ or $|a_{R1}|$) is less than its uncertainty (1.5σ), then the slope is set to zero and the constant term (a_{L0} or a_{R0}) is the average of the points; this helps eliminate non-representative erratic slopes that are based on poor counting statistics.

It is desired to fit the background under the multiplet as the third order polynomial of Equation A-1 in a consistent manner with the above linear adjacent background regions. In channel units, Equation A-1 becomes

$$z = c_{c0} + c_{c1}(j-j_L) + c_{c2}(j-j_L)^2 + c_{c3}(j-j_L)^3 \quad (A-6)$$

The notations j_L and j_R , which denote the background channels adjacent to the gross peak region on its left and right sides, are useful in the development. Initially Equation A-6 is selected for a quadratic dependence with $c_{c3} = 0$, subject the following conditions:

$$\begin{aligned} z &= z_R & j &= j_R \\ dz/dj &= dz_R/dj & j &= j_R \\ dz/dj &= dz_L/dj & j &= j_L \end{aligned} \quad (A-7)$$

These conditions result in defining the coefficients in Equation A-6 as

$$\begin{aligned}
 c_{c0} &= a_{R0} + (a_{R1} - a_{L1})(j_R - j_L)/2 \\
 c_{c1} &= a_{L1} \\
 c_{c2} &= (a_{R1} - a_{L1})/2(j_R - j_L) \\
 c_{c3} &= 0
 \end{aligned}
 \tag{A-8}$$

which may be verified by substituting them into Equation A-6 and performing the calculations prompted by Equations A-7.

Selection of the step background b_c must also be made. The algorithm calculates

$$b_c = z_L - z \quad \text{for } j = j_L \tag{A-9}$$

which is tested for the condition

$$0 \leq b_c \leq b_{cmax}$$

where the range defines realistic values for b_c . (An estimate for b_{cmax} will be discussed later in this appendix). If b_c lies between these limits, then the quadratic z is used to model the variable background. For other cases the cubic representation of z is deduced subject to the following conditions:

$$\begin{aligned}
 z &= z_R & j &= j_R \\
 dz/dj &= dz_R/dj & j &= j_R \\
 z &= z_L - b_k & j &= j_L \\
 dz/dj &= dz_L/dj & j &= j_L
 \end{aligned}
 \tag{A-10}$$

where b_k replaces b_c as

$$\begin{aligned}
 b_c &\text{ ---> } b_k = 0 & \text{for } b_c < 0 \\
 b_k &= b_{cmax} & \text{for } b_c > b_{cmax}
 \end{aligned}
 \tag{A-11}$$

The conditions of Equation A-10 result in defining the coefficients in Equation A-6 as

$$\begin{aligned}
 c_{c0} &= a_{L0} - b_k \\
 c_{c1} &= a_{L1} \\
 c_{c2} &= 3(a_{R0} - a_{L0} + b_k)/(j_R - j_L)^2 + 2(a_{R1} - a_{L1})/(j_R - j_L) \\
 c_{c3} &= -2(a_{R0} - a_{L0} + b_k)/(j_R - j_L)^3 - (a_{R1} - a_{L1})/(j_R - j_L)^2
 \end{aligned}
 \tag{A-12}$$

which may be verified by substituting them into Equation A-6 and performing the calculations prompted by Equation A-10. In these limiting cases for b_c , the true nature of the step background may be obscured by a larger magnitude of the variable background component, whereby unrealistic values of b_c could result. By requiring $0 \leq b_c \leq b_{cmax}$, such values are eliminated.

Optimization of F-Function and Net Area A

The final F-function is made self-consistent as an integral probability function by requiring that $F=1$ when calculated for the total gross region. The net peak-region area calculated using the B1, G, and B2 ROIs described in the main text is not strictly accurate for a multiplet, although singlets are estimated well with this approach. Thus, for a multiplet this area estimate is refined by iteratively finding the area A that causes Equation A-4 to yield $F=1$ for the total gross peak region. Typically, the resulting A is within a few percent of the B1/G/B2 initial estimate. However, it has been noted that it is possible (although rare) that the iteration can cause unrealistic negative A; these cases default to the originally calculated A and use the FlagB=2 analysis, but rerunning GRABGAM with a better choice of FWHM may eliminate the negative A possibility altogether.

Figure A-2 illustrates how the step background components of a multiplet can cause the B1/G/B2 estimate to be in error. In addition the shape of the background function $z(E)$ of Equation A-1 also impacts the peak areas of the multiplet. Thus, the F-function approach for determining the multiplet background is preferred.

Selection of b_{cmax}

The step background b_c beneath a peak is due to incomplete energy conversion within the active volume of the HPGe detector and forward Compton scattering. Thus, b_c depends both on the detector size and the sample geometry. When the code determines b_c

such that $0 \leq b_c \leq b_{cmax}$, the b_c is assumed to be adequate as it is physically reasonable. For cases where b_c is only a small component of the background, the code may initially estimate an artificial b_c that lies outside the physically reasonable range; subsequently b_c is fixed at either 0 or b_{cmax} as discussed earlier while the larger component of the background is fitted to the cubic polynomial of Equation A-6. It is clear that b_c cannot be less than zero, which is an easily defined limit. It is also clear that b_c must not exceed some b_{cmax} ; however, experimental measurements are needed to define b_{cmax} .

Ideally, b_{cmax} should be defined for each detector and sample geometry; however, such an effort is not practical. For GRABGAM, a study of b_{cmax} for various detectors and geometries yielded the empirical relation

$$b_{cmax} = 0.04 (100/E) (A/W) \quad (A-13)$$

where E is the gamma energy in keV, A is the area of the peak, and W is the effective channel width of the peak that reproduces the peak height as A/W. A reasonable approximation is $W = FWHM$, and GRABGAM uses the calculated value $FWHM^*$, which is discussed in the main text. Measurements of b_c for singlet peaks are given in Figure A-3, relative to the b_{cmax} defined in Equation A-13. For multiplets, the same equation is used, as b_{cmax} includes contributions from all peaks in the multiplet, where A is their summed areas yielding A/W as their summed composite height.

Multiplet Printout Table

With these recent improvements GRABGAM now prints a detailed multiplet table, as illustrated in Figure A-4. This table immediately precedes the peak analysis table, as described in Figure 9. The table gives the maximum, bounding minima, area, energy, and isotope identification for each peak of the all multiplets detected in the spectrum. The bounding minima, min1 and min2, have different formats, xxxx.x and xxxx.xy, whereby the xxxx.x denotes the channel number and y is a flag indicating how the minimum is determined, as denoted in Figure A-4.

The multiplet information provides the user with guidelines for any further evaluation of the multiplet, including application of the area partitioning program PEAKPART, which is discussed next.

REFINEMENT FOR PEAK AREA PARTITIONING

The auxiliary program PEAKPART was developed to provide the option of refining the peak partitioning of GRABGAM for multiplets. As discussed in Section III.C, GRABGAM calculates a peak area within a multiplet as the area A_m bounded by its adjacent minima. This is not the actual area X_m of peak, because A_m does not contain all of X_m and includes contributions from other peaks in the multiplet. Thus, the A_m estimate for peak area X_m is in error due to "cross talk" with other peaks of the multiplet.

The peak area X_m is distributed within the M peak regions of the multiplet, whereby a fraction F_{km} is included in the region k for an area $F_{km}X_m$. We note that the peak fractions sum to 1, viz

$$\sum_{k=1}^M F_{km} = 1 \quad (A-14)$$

From Figure A-5, it is recognized that the GRABGAM peak areas A_k may be expressed as a set of linear equations,

$$A_k = \sum_{m=1}^M F_{km} X_m \quad (A-15)$$

which for $M=3$ are given by

$$\begin{aligned} A_1 &= F_{11}X_1 + F_{12}X_2 + F_{13}X_3 \\ A_2 &= F_{21}X_1 + F_{22}X_2 + F_{23}X_3 \\ A_3 &= F_{31}X_1 + F_{32}X_2 + F_{33}X_3 \end{aligned} \quad (A-16)$$

Thus, if the F_{km} are known then the actual areas X_m may be determined from the A_k values.

The F_{km} can be defined by assuming that each multiplet peak m is Gaussian with known centroid μ_m and width parameter σ . For the X_m peak, its area fraction within the minima-bounded peak region k is given by

$$F_{km} = \int_{l_k}^{h_k} \frac{1}{(2\pi)^{1/2}} \exp[-(x-\mu_m)^2/2\sigma^2] dx \quad (A-17)$$

where the lower and upper integral limits l_k and h_k correspond to the minima that bound region k . For mathematical purposes, the

values of l_k and h_m are effectively treated as $-\infty$ and $+\infty$ to assure that all peak fractions add to 1 as provided in Equation (A-14). The μ_m are determined using the four contiguous channels that contain the highest net counts per the F-function background subtraction within region m ; however, if this estimate is not within ± 0.5 channel of the location determined by the peak find algorithm, the peak find average location is used. The σ is estimated from the measured FWHM of nearby singlet peaks within the spectrum or from prior calibrations.

It should be noted that the X_m solved from the linear equations, such as Equation A-16, satisfy the following condition

$$\sum_{m=1}^M X_m = \sum_{m=1}^M A_m \quad (\text{A-18})$$

so that the total multiplet area is not changed by the analysis. The preceding equation is proved by summing the A_k as given in Equation A-15, viz

$$\sum_{k=1}^M A_k = \sum_{k=1}^M \sum_{m=1}^M F_{km} X_m = \sum_{m=1}^M \left(\sum_{k=1}^M F_{km} \right) X_m = \sum_{m=1}^M X_m \quad (\text{A-19})$$

where Equation A-14 is substituted for the F_{km} summation. Thus, transformation from A_m to X_m does not alter the total area of the multiplet; it simply redistributes this area among the peaks.

The accuracy of the resulting X_m depends primarily on the accuracy of the μ_m and σ . By contrast, the minima channels l_k and h_k that bound the A_k are inconsequential because the corresponding F_{km} will correctly address whatever values are used for l_k and h_k , provided that the μ_m and σ are accurate. At the same time, when l_k and h_k correspond to accurate minima, the peak "cross talk" between the A_m regions tends to be minimized, so that the initial estimate for $A_m \approx X_m$ is better. This was the original GRABGAM basis for partitioning the peak areas of a multiplet. Now PEAKPART may be used to refine these estimates as appropriate.

PEAKPART analysis examples are given in Figure A-6, as based on data from Figure A-4. Here the $[F_{ij}]$ matrices are displayed to illustrate the peak overlap, which is greater when the off-diagonal elements are larger. Each case illustrates that the total multiplet area is not altered by the repartitioning, as predicted by Equation A-18. Also it is noted that the individual $X_m \approx A_m$ within the statistical error for these low-level multiplets, and the corresponding X_m/A_m must be significantly different than 1 to display a significant difference in the integer values of X_m and A_m , which are presented in the figure.

Fig. A-1. Features of Background Model

Fig. A-2. Actual Multiplet Background vs B1/B2 Estimate

Perfect resolution is used for clarity in the above examples. Note that the B1 and B2 backgrounds are the same in both cases, but the B1/B2 estimate is greater than the actual background for case (a) and smaller for case (b).

Fig. A-3. Empirical Relation for b_{cmax}

The plotted values of $b_c/(A/W)$ are for detectors with resolution of ~ 2 keV for the 1332 keV gamma. (Note that in the present work $W = \text{FWHM}$ in channels). The range of values for the 662, 1173, and 1332 keV gammas correspond to detectors with standard HPGe efficiencies of 20-160%. The general trend over the entire energy range is dominated by large Marinelli water standards counted by a 160% HPGe.

----- Multiplet Peak Details -----								
Peak #	----- min1	Channel max	----- min2	Area counts	+/- counts	Error counts	Energy keV	Isotope Z-A
1	147.5	152.5	154.51	68	+/-	26	75.1	PbBiKX
2	154.5	157.4	161.50	37	+/-	19	77.6	No-Lib
1	468.5	473.4	476.51	109	+/-	32	239.0	Pb-212
2	476.5	479.5	483.50	50	+/-	21	242.0	Pb-214
1	1112.5	1118.8	1119.53	5	+/-	4	568.4	Cs-134
2	1119.5	1122.5	1127.50	39	+/-	13	570.3	Cs-134
1	1422.5	1428.7	1429.53	10	+/-	5	726.7	Bi-212
2	1429.5	1430.3	1435.50	16	+/-	6	727.5	Bi-212
1	1570.5	1576.9	1578.53	10	+/-	6	802.4	Cs-134
2	1578.5	1579.5	1580.53	6	+/-	5	803.7	Cs-134
3	1580.5	1581.5	1586.50	7	+/-	5	804.7	Bi-214
1	2695.5	2702.7	2703.53	7	+/-	3	1377.2	Bi-214
2	2703.5	2706.6	2712.50	17	+/-	5	1379.2	Bi-214

Fig. A-4. GRABGAM Multiplet Printout

Note that MIN2 format xxxx.xy provides channel number as xxxx.x, while y equals 0 for end minimum, 1 for absolute minimum, 2 for relative minimum, and 3 for inverse weighted minimum.

GRABGAM
Multiplet

Peak 1

Peak 2

Peak 3

Fig. A-5. GRABGAM Multiplet Areas A_m and Actual Areas X_m

Note that summing the $F_{mj}X_j$ area components for each A_m yields the linear relations in Equation A-16.

Channel/ Max min	FWHM chns	[F_{ij}]	A_m	X_m	err	X_m/A_m
147.5/m 152.5/M 154.5/m 157.4/M 161.5/m	1.8	$\begin{bmatrix} 0.9955 & 0.0001 \\ 0.0045 & 0.9999 \end{bmatrix}$	68 37	68 37	± 26 ± 19	1.0044 0.9918
468.5/m 473.4/M 476.5/m 479.5/M 483.5/m	2.4	$\begin{bmatrix} 0.9989 & 0.0016 \\ 0.0011 & 0.9984 \end{bmatrix}$	109 50	109 50	± 32 ± 21	1.0004 0.9992
1112.5/m 1118.8/M 1119.5/m 1122.5/M 1127.5/m	3.0	$\begin{bmatrix} 0.7086 & 0.0093 \\ 0.2914 & 0.9907 \end{bmatrix}$	5 39	7 37	± 4 ± 13	1.3131 0.9599
1422.5/m 1428.7/M 1429.5/m 1430.3/M 1435.5/m	3.3	$\begin{bmatrix} 0.7159 & 0.2841 \\ 0.2841 & 0.7159 \end{bmatrix}$	10 16	6 20	± 5 ± 6	0.6053 1.2467
1570.5/m 1576.9/M 1578.5/m 1579.5/M 1580.5/m 1581.5/M 1586.5/m	3.3	$\begin{bmatrix} 0.8731 & 0.2378 & 0.0162 \\ 0.1217 & 0.5244 & 0.2216 \\ 0.0051 & 0.2378 & 0.7622 \end{bmatrix}$	10 6 7	10 6 7	± 6 ± 5 ± 5	0.9641 1.0271 1.0280
2695.5/m 2702.7/M 2703.5/m 2706.6/M 2712.5/m	4.2	$\begin{bmatrix} 0.6731 & 0.0412 \\ 0.3269 & 0.9588 \end{bmatrix}$	7 17	10 14	± 3 ± 5	1.3591 0.8521

Fig. A-6. Examples of PEAKPART results

Results are for multiplets given in Fig. A-4. Note that the $X_m \approx A_m$ within the statistical error for these low-level cases. Also note that $\sum X_m = \sum A_m$ for each multiplet.

APPENDIX B

GRABGAM CODE LISTINGS

INTRODUCTION

Listings of source codes associated with GRABGAM are provided in this appendix. The BASIC codes are operable as BASICA or GWBASIC versions. Modification to later BASIC versions or FORTRAN has not been necessary, although future efforts in these directions would be useful for further evolution of the code. The present BASIC codes have been compiled for faster execution. Typically a GRABGAM analysis may be completed within 30 seconds using a pentium computer. As some of the code operations refer to disk drive B, the user may wish to develop DOS batch files with ASSIGN or SUBST commands to conveniently address this drive.

The code listings provided are given in the order categorized below:

<u>Category</u>	<u>Code</u>	<u>Page</u>
Auxiliary/Setup	ISOLIBAS	B-4
	DETLIBAS	B-6
	MERGBACK	B-9
	MERGCALB	B-13
Execution/GRABGAM	GRABDKR1	B-27
	GRABDKR2	B-39
Appendage/Supplement	GRABISOS	B-54
	GRABBACK	B-60
	GRABCALB	B-67
	GRABDIAG	B-81
	GRABPLOT	B-85
	PEAKPART	B-92
Development/Analysis	BDATRANS	B-96
	GEFFCX1	B-99
	TEFFPERF	B-102

BACKGROUND INFORMATION

The codes of the first three categories are discussed in the main text and in Appendix A, while the three codes of the last category are discussed in this section.

BDATRANS is a skeleton code that was used to develop the first five Appendage/Supplement codes listed above. Primarily this code reads in the files generated by GRABGAM for supplementary analysis. Thus, BDATRANS is the basis on which the other supplementary codes were developed, and it can be used for development of any new supplementary codes in the future.

GEFFCX1 and TEFFPERF are codes used in fitting efficiency data to a function dependent on both gamma energy and vial height. Such efficiency options are discussed and referenced in the main text.³ Given a set of experimentally measured efficiencies as a function of energy (E) and vial height (h), it is desired to fit these data to some efficiency function $\epsilon(E,h)$. In actuality, it is more convenient to use $x = \ln(E)$ and fit a function $\epsilon(x,h)$.

For a given geometry, it has been noted that the energy- or x-dependent efficiency may be fitted to a hyperbola in a $\ln(\epsilon)$ vs $\ln(E)=x$ plot, viz

$$\ln(\epsilon) = A [B^2 + (x-C)^2]^{1/2} + D \quad (B-1)$$

Thus, such a relation should be reasonable for the efficiency of each vial height, as well as the average efficiency for the vial height cases. If we measure the efficiency of a particular energy as a function of vial height, it is similarly noted that the efficiency may be approximated as

$$\epsilon = \epsilon_0 / (h + h_0)^2 \quad (B-2)$$

Averaging Equation B-2 over the different energy cases also yields a similar approximation.

GEFFCX1 is a least-squares program for fitting the h-averaged efficiencies to Equation B-1. The E-averaged efficiencies can be fitted to Equation B-2 by plotting $\epsilon^{-1/2}$ vs h and extracting h_0 as the h-intercept and $(\epsilon_0)^{-1/2}$ as the slope; or a least-squares fit for a straight line may be used. Then, we may combine Equations B-1 and B-2 to yield an approximate efficiency of

$$\epsilon_A(x,h) = G \exp\{ A [B^2 + (x-C)^2]^{1/2} \} / (h + h_0)^2 \quad (B-3)$$

where G represents constants D and ϵ_0 of Equations B-1 and B-2.

TEFFPERF refines the approximate efficiency $\epsilon_A(x,h)$. First, all constants A, B, C, and h_0 are accepted from the preceding analysis, and then Equation B-3 is force fitted to all the experimental measurements $\epsilon_m(x,h)$ to obtain the best fitted value of G. Next, the relative perturbations $p(x,h)$ between $\epsilon_m(x,h)$ and $\epsilon_A(x,h)$ are calculated as

$$p(x,h) = \epsilon_m(x,h)/\epsilon_A(x,h) - 1 \quad (B-4)$$

Then, TEFFPERF performs a least-squares polynomial fit to $p(x,h)$ as $p_f(x,h)$ or explicitly

$$\begin{aligned} p_f(x,h) = & a_{00} + a_{10}x + a_{01}h + a_{20}x^2 + a_{11}xh + a_{02}h^2 \\ & + a_{30}x^3 + a_{21}x^2h + a_{12}xh^2 + a_{03}h^3 \end{aligned} \quad (B-5)$$

The final fitted efficiency $\epsilon(x,h)$ is then calculated as the product of Equations B-3 and B-5, viz

$$\epsilon(x,h) = \epsilon_A(x,h) [1 + p_f(x,h)] \quad (B-6)$$

LISTING INFORMATION

Each code listing is presented with lines grouped according to function. A sequential outline of the code precedes each listing, describing main program functions and subroutines with regard to line numbers. Some of the codes could be edited for bogus lines and nonessential printout; such lines are identified in the sequential outlines when appropriate. Also, some of the dimensioned variables (defined in DIM statements) may need to have their array sizes increased in the future.

ISOLIBAS: Program Structure Reference

Main<--- Subroutines and [files]

2-100/DIM Init

8005-8050/READ data <--- 20000-23000 DATA on gammas/isotopes
<--- Create B:ISOLIBRY.LIB

```

2 REM ISOLIBAS.BAS
50 CLS
70 PRINT "Isotope libraries being stored in b: (RAM disk)"
100 DIM ISO$(250), ISOTH(250), ISOEN(250), ISOGAM(250), MDA(250)

8005 OPEN "B:ISOLIBRY.LIB" FOR OUTPUT AS #3
8010 FOR ISO=1 TO 250
8015 READ ISO$(ISO), ISOTH(ISO), ISOEN(ISO), ISOGAM(ISO), MDA(ISO)
8020 WRITE #3, ISO$(ISO), ISOTH(ISO), ISOEN(ISO), ISOGAM(ISO), MDA(ISO)
8030 IF ISO$(ISO) = "limit " THEN ISO=250
8040 NEXT ISO
8050 CLOSE #3

20000 REM - library of isotope data by gamma enegry order - lines 20000-23000
20001 'isotope,half-life(d),energy,igamma,mda

20046 DATA "Pb-210",8145.1,46.5201,4.050,1
20059 DATA "Am-241",157861,59.3571,35.91,0
20063 DATA "Th-234",24.101,63.2901,4.471,0
20075 DATA "PbBiKX",1.00e6,74.9001,74.03,0
20086 DATA "PbBiKX",1.00e6,86.0001,21.49,0
20087 DATA "Eu-155",1741.1,86.5431,30.81,0
20088 DATA "Cd-109",464.01,88.0301,3.611,0
20093 DATA "Th-234",1632e9,92.5901,5.161,0
20105 DATA "Eu-155",1741.1,105.308,20.51,0
20121 DATA "Eu-152",4868.6,121.782,28.32,0
20122 DATA "Co-57 ",270.91,122.063,85.59,0
20123 DATA "Eu-154",3127.1,123.141,40.51,0
20129 DATA "Ac-228",511e10,129.201,2.929,0
20134 DATA "Ce-144",284.31,133.544,10.81,0
20136 DATA "Co-57 ",270.91,136.476,10.61,0
20144 DATA "U-235 ",2571e8,143.761,10.93,0
20145 DATA "Ce-141",32.501,145.441,48.44,0
20163 DATA "U-235 ",2571e8,163.401,5.001,0
20166 DATA "Ce-139",137.71,165.851,79.95,0
20185 DATA "U-235 ",2571e8,185.715,57.51,0
20186 DATA "Ra-226",5.84e5,186.211,3.281,0
20205 DATA "U-235 ",2571e8,205.301,5.031,0

| | | | | | | |
| | | | | | | |

21120 DATA "Bi-214",5.84e5,1120.29,15.71,0
21121 DATA "Sc-46 ",83.851,1120.52,99.99,0
21155 DATA "Bi-214",5.84e5,1155.19,1.701,0
21173 DATA "Co-60 ",1924.1,1173.21,99.91,1
21238 DATA "Bi-214",5.84e5,1238.11,5.941,0
21274 DATA "Eu-154",3127.1,1274.45,35.50,0
21275 DATA "Na-22 ",950.41,1274.51,99.95,0
21280 DATA "Bi-214",5.84e5,1280.96,1.481,0
21292 DATA "Fe-59 ",44.496,1291.60,43.21,0
21333 DATA "Co-60 ",1924.1,1332.56,99.98,1
21365 DATA "Cs-134",753.11,1365.01,3.401,0
21377 DATA "Bi-214",5.84e5,1377.82,5.061,0
21384 DATA "Ag110m",249.76,1384.31,24.28,0
21385 DATA "Bi-214",5.84e5,1385.21,0.776,0
21402 DATA "Bi-214",5.84e5,1401.51,1.386,0
21408 DATA "Eu-152",4868.6,1408.01,20.85,0
21409 DATA "Bi-214",5.84e5,1408.11,2.477,0
21461 DATA "K-40 ",467e12,1460.75,10.71,0
21496 DATA "Ac-228",511e10,1495.81,0.900,0
21509 DATA "Bi-214",5.84e5,1509.21,2.192,0
21583 DATA "Bi-214",5.84e5,1583.21,0.717,0
21588 DATA "Ac-228",511e10,1588.21,3.201,0
21593 DATA "DX2614",511e10,1593.21,100.1,0
21596 DATA "La-140",1.6758,1596.49,95.49,0
21620 DATA "Bi-212",511e10,1620.51,2.751,0
21630 DATA "Ac-228",511e10,1630.51,1.949,0
21661 DATA "Bi-214",5.84e5,1661.28,1.150,0
21691 DATA "Sb-124",60.201,1690.98,47.31,0
21729 DATA "Bi-214",5.84e5,1729.61,2.971,0
21765 DATA "Bi-214",5.84e5,1764.49,17.01,0
21836 DATA "Y-88 ",106.66,1836.01,99.35,0
21838 DATA "Bi-214",5.84e5,1838.36,0.385,0
21847 DATA "Bi-214",5.84e5,1847.42,2.091,0
21873 DATA "Bi-214",5.84e5,1873.16,0.227,0
23000 DATA "limit ",1.0000,5000.01,1.000,0

```

DETLIBAS: Program Structure Reference

Main<--- Subroutines and [files]

2-24/DIM Init

9000-9100/READ data <--- 50000-50538 DATA on det vial effs
 <--- Create B:DETLIBRY.LIB

```

2 REM DETLIBAS.BAS
5 PRINT
6 PRINT "Detector calibrations for vials being stored in b: (RAM disk)"
7 PRINT
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CE0H1(5,3),CE2H0(5,3),CE1H1(5,3),CE0H2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CE0H3(5,3)

```

```

9000 OPEN "B:DETLIBRY.LIB" FOR OUTPUT AS #3
9010 FOR I=1 TO 5
9020 FOR J=1 TO 3
9030 READ GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
9035 WRITE #3,GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
9040 READ CEOH0(I,J)
9045 WRITE #3,CEOH0(I,J)
9050 READ CE1H0(I,J),CE0H1(I,J)
9055 WRITE #3,CE1H0(I,J),CE0H1(I,J)
9060 READ CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
9065 WRITE #3,CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
9070 READ CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
9075 WRITE #3,CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
9080 NEXT J
9090 NEXT I
9100 CLOSE #3

```

50000 REM - library for vial efficiency parameters

```

50110 REM - old bottom - large vials
50111 REM G A B C HO
50112 DATA 4.4014,-1.0759,.23537,4.7811,7.521
50113 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50114 DATA -1.0715,-.66925,-.11622,-.13165,3.8465e-2,-8.1974e-3
50115 REM E3H0 E2H1 E1H2 EOH3
50116 DATA 8.1961e-3,-2.9106e-3,9.0012e-4,4.1102e-4
50118 REM
50120 REM - old bottom - medium vials
50121 REM G A B C HO
50122 DATA 4.2723,-1.1133,.20449,4.6917,5.39
50123 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50124 DATA -1.5687,-.90226,-.28041,-.16506,6.3938e-2,5.5751e-2
50125 REM E3H0 E2H1 E1H2 EOH3
50126 DATA 9.6486e-3,-4.4284e-3,2.4211e-3,-1.6689e-2
50128 REM
50130 REM - old bottom - small vials
50131 REM G A B C HO
50132 DATA 5.7074,-1.1126,.21211,4.6839,6.003
50133 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50134 DATA -1.8370,1.1014,-.30294,-.20342,5.7149e-2,3.6757e-2
50135 REM E3H0 E2H1 E1H2 EOH3
50136 DATA 1.2026e-2,-3.6859e-3,-4.7735e-4,-3.1522e-3
50138 REM

```

```

50210 REM - bottom - large vials
50211 REM G A B C HO
50212 DATA 5.7118,-.95483,.24005,4.6652,7.397
50213 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50214 DATA -.84914,.53672,-.16315,-.10173,3.5614e-2,3.8510e-3
50215 REM E3H0 E2H1 E1H2 EOH3
50216 DATA 5.9538e-3,-1.8056e-3,9.0641e-5,-8.4979e-5
50218 REM
50220 REM - bottom - medium vials
50221 REM G A B C HO
50222 DATA 5.5596,-.99324,.11750,4.6283,5.654
50223 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50224 DATA -1.0950,.61684,-.18324,-.10899,2.9329e-2,.039674
50225 REM E3H0 E2H1 E1H2 EOH3
50226 DATA 6.0818e-3,-1.1207e-3,1.4525e-3,-1.0103e-2
50228 REM
50230 REM - bottom - small vials
50231 REM G A B C HO
50232 DATA 6.9078,-1.0034,.14180,4.6445,6.062
50233 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50234 DATA -1.3356,.84971,-.35531,-.16112,7.3339e-2,3.2921e-2
50235 REM E3H0 E2H1 E1H2 EOH3
50236 DATA 9.5563e-3,-3.9038e-3,-2.5714e-3,-1.0877e-3
50238 REM

```

50310 REM - PGT - large vials
50311 REM G A B C HO
50312 DATA 5.6178,-1.1037,.22675,4.7750,7.24
50313 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50314 DATA -.94519,.60293,-.16770,-.11411,2.3146e-2,2.3744e-2
50315 REM E3H0 E2H1 E1H2 EOH3
50316 DATA 6.8136e-3,-8.6104e-4,-1.1750e-3,-1.1721e-3
50318 REM
50320 REM - PGT - medium vials
50321 REM G A B C HO
50322 DATA 6.8314,-1.1308,.19434,4.7262,6.069
50323 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50324 DATA -1.2944,.77826,-.27900,-.14790,5.8072e-2,8.7308e-2
50325 REM E3H0 E2H1 E1H2 EOH3
50326 DATA 9.1381e-3,-5.5818e-3,2.8548e-3,-2.1603e-2
50328 REM
50330 REM - PGT - small vials
50331 REM G A B C HO
50332 DATA 7.2229,-1.1263,.20277,4.7064,5.782
50333 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50334 DATA -1.6299,.94264,-.12584,-.17231,1.8464e-2,2.3372e-2
50335 REM E3H0 E2H1 E1H2 EOH3
50336 DATA 1.0238e-2,-1.8209e-3,1.6860e-3,-3.6783e-3
50338 REM

50410 REM - N det - large vials
50411 REM G A B C HO
50412 DATA 12.569,-1.0943,.50073,4.4488,7.476
50413 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50414 DATA -1.5842,.91457,-.10516,-.16421,7.4871e-3,1.2681e-2
50415 REM E3H0 E2H1 E1H2 EOH3
50416 DATA 9.4591e-3,-7.1558e-5,7.4850e-4,-1.0872e-3
50418 REM
50420 REM - N det - medium vials
50421 REM G A B C HO
50422 DATA 13.447,-1.1174,.53260,4.3456,5.938
50423 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50424 DATA -1.8125,1.0118,-.16445,-.18367,.0539024,-5.9739e-3
50425 REM E3H0 E2H1 E1H2 EOH3
50426 DATA 1.0773e-2,-3.6237e-3,-5.8539e-4,1.3226e-3
50428 REM
50430 REM - N det - small vials
50431 REM G A B C HO
50432 DATA 17.890,-1.1168,.59468,4.2855,6.428
50433 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50434 DATA -2.5550,1.3753,-1.3984e-2,-.24109,3.7961e-3,-1.0639e-2
50435 REM E3H0 E2H1 E1H2 EOH3
50436 DATA 1.3739e-2,1.2988e-4,3.8284e-4,1.3968e-3
50438 REM

50510 REM - well - large vials
50511 REM G A B C HO
50512 DATA 10.591,-.99167,.26381,4.7396,7.629
50513 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50514 DATA -.63778,.35642,-3.6448e-2,-5.8856e-2,-1.0121e-2,8.2828e-3
50515 REM E3H0 E2H1 E1H2 EOH3
50516 DATA 2.9691e-3,1.7735e-3,-7.9877e-5,-3.2997e-4
50518 REM
50520 REM - well - medium vials
50521 REM G A B C HO
50522 DATA 10.945,-1.0388,.31110,4.7111,6.33
50523 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50524 DATA -1.0642,.62530,-.13400,-.11857,5.2083e-2,-3.7060e-2
50525 REM E3H0 E2H1 E1H2 EOH3
50526 DATA 7.1595e-3,-3.9512e-3,3.8403e-3,2.6001e-3
50528 REM
50530 REM - well - small vials
50531 REM G A B C HO
50532 DATA 13.615,-1.0274,.25885,4.7210,7.164
50533 REM EOH0 E1H0 EOH1 E2H0 E1H1 EOH2
50534 DATA -1.0828,.60697,-3.1321e-2,-.10531,-1.9860e-2,2.4438e-2
50535 REM E3H0 E2H1 E1H2 EOH3
50536 DATA 5.8314e-3,2.6979e-3,-8.3090e-4,-1.9521e-3
50538 REM

MERGBACK: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
5-50/Print instr	
100-230/Print bkg	<--- 6000-6100/Select and print file <--- <u>backgnd.BKG</u>
900-1020/DIM new bkg	
1025-1400/Manual in	<--- 20000-23000/DATA for isotope matches <--- 2000-2500/Case for No-Lib situ <--- 3000-3500/Case beyond library range
1490-1550/Display	
1560-1570/Correct	<--- 7000-7090/Correct and GOTO 1490-1550
1600-1650/Output	<--- 4000-4100/WRITE file <--- <u>backgnd.BKG</u> <--- 8000-8200/Hardcopy table
1700-1730/Compare	<--- 6000-6100/Select and print file <--- <u>backgnd.BKG</u>
1900/STOP	

```

5 REM - mergback
25 CLS
50 INPUT"Use (^)- or (Ctrl)-(PrtSc) as needed in this program - press enter to p
roceed";ZZ

100 CLS:PRINT
200 PRINT:INPUT"Desire to print any background files before begin (y/n)";YES
210 PRINT
220 IF YES="y" THEN GOSUB 6000
230 IF YES="y" THEN GOTO 200

900 CLS
1000 INPUT"Live count time (sec)";LTIME:PRINT
1005 INPUT"Energy identification search (e.g +/- 2.0 keV)";EFIND
1006 PRINT
1010 BADDER =0
1020 DIM BENERGY(100),BRATE(100),BERR(100),BISO$(100)

1025 INPUT"Energy (keV) of background peak (5000 to end)";EB:BADDER=BADDER+1
1030 READ ISO$,ISOEN,ISOEN,ISOGAM,MDA
1040 IF ISO$="limit " THEN BADDER =BADDER-1:GOTO 1400
1070 IF EB-ISOEN > EFIND THEN 1030
1075 IF ISOEN-EB > EFIND THEN GOSUB 2000
1077 IF ISOEN-EB > EFIND THEN INPUT"Energy (keV) of background peak (5000 to end
)";EB:BADDER=BADDER+1:GOTO 1070
1080 INPUT"counts";COUNTS:BRATE(BADDER)=COUNTS/LTIME
1090 INPUT"% error";PERROR:BERR(BADDER)=PERROR*BRATE(BADDER)/100
1100 BISO$(BADDER)=ISO$:BENERGY(BADDER)=ISOEN
1125 PRINT
1200 READ ISO$,ISOEN,ISOEN,ISOGAM,MDA
1202 IF ABS(EB-ISOEN) <= EFIND THEN BADDER=BADDER+1:GOTO 1080
1210 INPUT"Energy (keV) of background peak (5000 to end)";EB:BADDER=BADDER+1
1300 GOTO 1040
1400 IF EB<5000 THEN GOSUB 3000:REM - include backgrounds beyond last library pe
ak

1490 CLS
1500 PRINT:PRINT"Summary of inputs"
1501 PRINT
1505 PRINT"Peak      Isotope      Energy      Rate      Error"
1506 PRINT" #          Z-A          keV          cph  N-stats"
1507 PRINT
1510 FOR I=1 TO BADDER
1515 IF BENERGY(I)=0 THEN 1550:REM - this takes care of last faked high energy
1520 PRINT USING "###";I;:PRINT"          ";BISO$(I);:PRINT USING"#####.##";BENERGY(
I);
1530 PRINT USING "#####.##";BRATE(I)*3600;:PRINT USING"#####.##";100*BERR(I)/BRATE
(I);:PRINT" %"
1540 IF CSRLIN > 23 THEN INPUT"press enter to continue";PAGE$:CLS
1550 NEXT I

1560 PRINT:INPUT"Corrections to above data (y/n)";YES:IF YES<>"n"THEN GOSUB 7000

1570 IF YES<>"n" THEN 1490

1600 GOSUB 4000:REM put data out to file
1650 GOSUB 8000 : REM hardcopy of results

1700 PRINT:INPUT"Desire to print any background files before finish (y/n)";YES
1710 PRINT
1720 IF YES="y" THEN GOSUB 6000
1730 IF YES="y" THEN GOTO 1700

1900 STOP

2000 REM - sub for nonlibrary backgrounds
2030 BENERGY(BADDER)=EB
2040 INPUT"counts";COUNTS:BRATE(BADDER)=COUNTS/LTIME
2050 INPUT"% error";PERROR:BERR(BADDER)=PERROR*BRATE(BADDER)/100
2060 BISO$(BADDER)="No-Lib"
2080 PRINT
2500 RETURN

```

```

3000 REM - sub for background peaks beyond library
3020 GOTO 3050
3030 PRINT
3040 INPUT"Energy (keV) of background peak (5000 to end)";EB:IF EB=5000 THEN 3500
0
3050 BADDER=BADDER+1
3060 BENERGY(BADDER)=EB
3070 INPUT"counts";COUNTS:BRATE(BADDER)=COUNTS/LTIME
3080 INPUT"% error";PERROR:BERR(BADDER)=PERROR*BRATE(BADDER)/100
3090 BISO$(BADDER)="No-Lib"
3100 GOTO 3030
3500 RETURN

```

```

4000 REM - sub to put data on file
4010 PRINT:INPUT"Name of disk file (-----.BKG)";BKFILES$
4020 CLS:PRINT"File name is :";BKFILES$
4025 PRINT:INPUT"File name acceptable (y=proceed/n=rename)";YES$
4027 IF YES$<>"y"THEN 4010
4030 OPEN BKFILES$ FOR OUTPUT AS #2
4040 FOR I=1 TO BADDER
4050 WRITE #2,BENERGY(I),BRATE(I),BERR(I)
4060 NEXT I
4070 CLOSE #2
4100 RETURN

```

```

6000 CLS:PRINT:INPUT"Name of background file (-----.BKG)";FILEBK$
6005 PRINT:PRINT
6010 PRINT " Peak Energy Rate Error "
6015 PRINT " # keV cph %"
6016 PRINT
6020 OPEN FILEBK$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN GOTO 6070
6050 INPUT #2,BENERGY, BRATE, BERR
6055 PRINT USING"####";CBACK;:PRINT USING"#####.##";BENERGY ;:PRINT USING"####
###.##";3600*BRATE ;:PRINT USING"#####.##";100*BERR /BRATE
6060 CBACK=CBACK+1
6065 GOTO 6040
6070 CLOSE #2
6100 RETURN

```

```

7000 REM - subroutine to correct inputs
7005 ENERGY=0:COUNTS=0:PERROR=0
7010 PRINT:INPUT"Select peak number to correct";PEAK:PRINT
7015 BRATE=BRATE(PEAK)
7020 PRINT"Press enter for parameters that need no correction"
7030 INPUT"Energy (keV)";ENERGY:IF ENERGY=0 THEN 7050
7040 BENERGY(PEAK)=ENERGY
7050 INPUT"counts";COUNTS:IF COUNTS=0 THEN 7070
7060 BRATE(PEAK)=COUNTS/LTIME
7065 IF BRATE>0 THEN BERR(PEAK)=BERR(PEAK)*BRATE(PEAK)/BRATE
7070 INPUT"Error %";PERROR:IF PERROR=0 THEN 7090
7080 BERR(PEAK)=PERROR*BRATE(PEAK)/100
7090 RETURN

```

```

8000 REM - hardcopy of results
8010 PRINT:INPUT"Hardcopy title";TITLES$
8020 LPRINT TITLES$:LPRINT
8030 LPRINT BKFILES$:LPRINT
8100 LPRINT:LPRINT"Summary of inputs"
8101 LPRINT
8105 LPRINT"Peak Isotope Energy Rate Error"
8106 LPRINT" # Z-A keV cph N-stats"
8107 LPRINT
8110 FOR I=1 TO BADDER
8115 IF BENERGY(I)=0 THEN 8150:REM-this takes care of last faked high energy
8120 LPRINT USING "####";I;:LPRINT " ";BISO$(I);:LPRINT USING"#####.##";BNER
GY(I);
8130 LPRINT USING "#####.##";BRATE(I)*3600;:LPRINT USING"#####.##";100*BERR(I)/BRA
TE(I);:LPRINT" %"
8150 NEXT I
8200 RETURN

```

20001 'isotope,half-life(d),energy,igamma,mda
20046 DATA "Pb-210",8145.1,46.5201,4.050,1
20063 DATA "Th-234",24.101,63.2901,4.471,0
20075 DATA "PbBiKX",1.00e6,74.9001,74.03,0
20086 DATA "PbBiKX",1.00e6,86.0001,21.49,0
20087 DATA "Eu-155",1741.1,86.5431,30.81,0
20088 DATA "Cd-109",464.01,88.0301,3.611,0
20093 DATA "Th-234",1632e9,92.5901,5.161,0
20105 DATA "Eu-155",1741.1,105.308,20.51,0
20122 DATA "Co-57",270.91,122.063,85.59,0
20123 DATA "Eu-154",3127.1,123.141,40.51,0
20129 DATA "Ac-228",511e10,129.201,2.929,0
20134 DATA "Ce-144",284.31,133.544,10.81,0
20136 DATA "Co-57",270.91,136.476,10.61,0
20144 DATA "U-235",2571e8,143.761,10.93,0
20145 DATA "Ce-141",32.501,145.441,48.44,0
20166 DATA "Ce-139",137.71,165.851,79.95,0
20185 DATA "U-235",2571e8,185.715,57.51,0
20186 DATA "Ra-226",5.84e5,186.211,3.281,0
20210 DATA "Ac-228",511e10,209.501,4.553,0
20238 DATA "Pb-212",511e10,238.625,44.61,0
20271 DATA "Rn-219",7952.6,271.231,9.901,0
20279 DATA "Hg-203",47.001,279.191,81.55,0
20295 DATA "Pb-214",5.84e5,295.201,20.01,0
20320 DATA "CR-51",27.701,320.081,9.831,0
20328 DATA "Ac-228",511e10,328.801,3.346,0
20338 DATA "Ac-228",511e10,338.401,11.10,0
20352 DATA "Pb-214",5.84e5,351.921,38.91,0
20364 DATA "I-131",8.0401,364.481,81.24,0
20392 DATA "Sn-113",115.01,391.691,64.16,0
20409 DATA "Ac-228",511e10,409.501,2.233,0
20427 DATA "Sb-125",996.45,427.891,29.44,0
20462 DATA "Ac-228",511e10,462.801,4.641,0
20477 DATA "Be-7",53.301,477.591,10.31,1
20487 DATA "La-140",1.6758,487.029,45.51,0
20497 DATA "Ru-103",39.351,497.080,89.51,0
20510 DATA "Tl-208",511e10,510.801,21.61,0
20511 DATA "Annihl",1.00e6,511.006,200.1,0
20514 DATA "Sr-85",64.851,513.996,98.01,0
20537 DATA "Ba-140",12.789,537.321,24.39,0
20583 DATA "Tl-208",511e10,583.139,74.71,0
20601 DATA "Sb-125",996.45,600.557,17.78,0
20603 DATA "Sb-124",60.201,602.731,97.81,0
20605 DATA "Cs-134",753.11,604.699,97.56,0
20609 DATA "Bi-214",5.84e5,609.312,43.31,0
20622 DATA "Ru-106",368.21,621.841,9.812,0
20662 DATA "Cs-137",11021.661,638.84.13,1
20724 DATA "Zr-95",64.021,724.199,44.11,0
20727 DATA "Bi-212",511e10,727.171,7.161,0
20757 DATA "Zr-95",64.021,756.729,54.51,0
20765 DATA "Nb-95",34.971,765.791,99.79,0
20768 DATA "Bi-214",5.84e5,768.356,5.041,0
20795 DATA "Ac-228",511e10,795.001,4.843,0
20796 DATA "Cs-134",753.11,795.845,85.44,0
20835 DATA "Mn-54",312.71,834.827,99.98,0
20860 DATA "Tl-208",1.4e10,860.564,12.01,0
20889 DATA "Sc-46",83.851,889.258,99.98,0
20898 DATA "Y-88",106.66,898.021,95.01,0
20911 DATA "Ac-228",511e10,911.070,26.35,0
20969 DATA "Ac-228",511e10,969.111,15.66,0
21001 DATA "Pa-234",1632e9,1001.03,5901,0
21116 DATA "Zn-65",244.11,1115.52,50.74,0
21120 DATA "Bi-214",5.84e5,1120.29,15.71,0
21121 DATA "Sc-46",83.851,1120.52,99.99,0
21173 DATA "Co-60",1924.1,1173.21,99.91,1
21238 DATA "Bi-214",5.84e5,1238.11,5.941,0
21274 DATA "Eu-154",3127.1,1274.45,35.50,0
21333 DATA "Co-60",1924.1,1332.56,99.98,1
21461 DATA "K-40",467e12,1460.75,10.71,0
21593 DATA "DE2614",511e10,1593.21,100.1,0
21596 DATA "La-140",1.6758,1596.49,95.49,0
21620 DATA "Bi-212",511e10,1620.51,2.751,0
21630 DATA "Ac-228",511e10,1630.51,1.949,0
21691 DATA "Sb-124",60.201,1690.98,47.31,0
21765 DATA "Bi-214",5.84e5,1764.49,17.01,0
21836 DATA "Y-88",106.66,1836.01,99.35,0
23000 DATA "limit",1.0000,5000.01,1.000,0

WSRC-TR-99-00187

MERGCALB: Program Structure Reference

Main	<--- Subroutines and [files]
5-28/Setup DIM	
31-32/File effs	<--- 9000-9200/Vial efficiency functions <--- B:DETLIBRY.LIB
40-63/Ref eff	<--- 46000-46090/Detector selection <--- 46100-46200/Geometry selection <--- 46500-46690/Special samples <--- 46700-46760/Air "diapers" <--- 46800-46850/Well samples <--- 46900-46990/Vials <--- 47000-47200/File geom <--- <u>detreff</u> .DCF <--- 60000-60140/Eff cal table
64-170/Anal menu (options 1-5 below)	
180/1-eff	<--- 40-63/GOTO for new ref det
190/2-plot	<--- 56000-56900/LogEff vs logE screen graph <--- 58000-58900/Plot ref eff
200/3-eff dat	<--- 20000-20500/Input measured efficiencies <--- 21000-21100/Order by energy
210/4-eff fit	<--- 600-etc/GOTO for analyzing new data
220/5-exit	<--- 990/GOTO for STOP execution
230/N-menu	<--- 100/GOTO for menu 64-170 on non-option N
600-645/Plot dat	<--- 51000-51900/LogEff vs LogE screen graph <--- 50000-50900/Plot measured efficiencies <--- 58000-58900/Plot ref eff
650-677/Plot drawing instructions	
680-798/Draw eff	<--- 51000-51900/LogEff vs LogE screen graph <--- 50000-50900/Plot measured efficiencies <--- 58000-58900/Plot ref eff <--- 52000-52030/Plot 3 hyperbola fit points <--- 52200-52290/Move red point to curve max <--- 52100-52130/Erase point <--- 52000-52030/Draw point

MERGCALB: Program Structure Reference
(continued)

Main	<--- Subroutines and [files]
680-798/Draw eff (cont'd)	<--- 52300-52330/Move yellow point to sym pt <--- 52100-52130/Erase point <--- 52000-52030/Draw point <--- 52400-52390/Move green point to asympt <--- 52100-52130/Erase point <--- 52000-52030/Draw point <--- 52500-52590/Draw hyperbola guidelines <--- 52600-52690/Erase hyperbola guidelines <--- 15000-15090/LnEff-LnE units for 3 points <--- 53000-53900/Plot resulting hyperbola eff <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs
800-865/Norm eff	<--- 42000-42900/Exam hyperbola vs meas effs <--- 53000-53900/Replot per dev=0 normalize <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs
870-890/Refine A	<--- 10000-10500/Least-squares hyperbola fit <--- 11000-1110/Chi-sq fit results <--- 53000-53900/Plot resulting final eff <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs <--- 42000-42900/Exam hyperbola vs meas effs
890-915/Refine B	<--- 16000-16300/L-S cubic fit to residuals <--- 17000-17170/Trianglize matrix <--- 18000-18100/Solve cubic coeffs <--- 19000-19100/Chi-sq fit results <--- 53000-53900/Plot resulting final eff <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs <--- 42000-42900/Exam final fit vs meas effs
920-939/OK menu	<--- 650-etc/GOTO back at draw hyperbola <--- 870-etc/GOTO back at L-S hyperbola fit <--- 900-etc/GOTO back at L-S cubic fit <--- 910-etc/GOTO back to redraw final plot <--- 938-etc/GOTO continue - fit OK
940-970/Output	<--- 34000-34100/Parameters set for output <--- 35000-35500/Create efficiency file <--- <u>detreff</u> .DCF <--- 36000-36900/Print efficiency summary
990/STOP	

MERGCALB: Program Structure Reference
(continued)

Lines not used in execution

61000-61020/Calendar data

62000-62020/Attenuation data

```

5 REM - MERGCALB.BAS
10 CLS:PRINT" MERGCALB.BAS - setting up records"
18 DIM A(3),TC(3,3),TD(3),TN(3,3)
19 DIM ENATT(21),MUATT(21)
20 DIM MONTH(12),GAMRATE(25),EFFCAL(25),ERRCAL(25),J(25),ECAL(25),SUMCOR(25)
21 DIM H1(100),H2(100),RATERR(100)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CE0H1(5,3),CE2H0(5,3),CE1H1(5,3),CE0H2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CE0H3(5,3)
25 DIM YLOC(20),DETNAM$(10),BENERGY(100),BRATE(100),BERR(100),DETLAB$(10)
26 DIM ISOTH(100),MDA(100),ACTRAT(100),LIBEN(100),SBRATE(100),SBERR(100)
27 DIM RATE(100),ENERGY(100),ISOEN(100),ISOID$(100),ISO$(100),ISOGAM(100)
28 DIM NPC(4096),AREA(100),EAREA(100),LOCH(100),FWHM(100),TAIL(100),CENT(100)

31 GOSUB 9000:REM read in detector efficiency parameters for vials
32 DETNAM$(1)="Old Bottom Detector":DETNAM$(2)="New Bottom Detector":DETNAM$(3)="
  PGT Detector":DETNAM$(4)="N-side Detector":DETNAM$(5)="Well Detector"

40 CLS
46 GOSUB 46000:REM - get efficiency parameters - part 1
47 PRINT:INPUT"Repeat this frame due to input errors (y/n)";FRAMER$:IF FRAMER$="
  y" THEN CLS:GOTO 40
50 GOSUB 46100:REM - get efficiency parameters - part 2
51 PRINT:INPUT"Repeat this frame due to input errors (y/n)";FRAMER$:IF FRAMER$="
  y" THEN CLS:GOTO 50
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
  EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX))*(DOEFF+D1EFF*LOG
  (EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFVEN$:
  CLS:IF EFFVEN$ <> "y" THEN GOTO 64
62 GOSUB 60000:REM check on efficiency data EFF vs EN
63 IF NEWEFF$="y" THEN CLS:GOTO 46:REM replace efficiency data case

64 CLS
100 CLS:REM - main menu option for plot
105 PRINT"Currently selected detector : ";DETNAM$(DETN):PRINT:PRINT
110 PRINT"      Menu for plot of detector efficiencies":PRINT
120 PRINT"      (1) Select different detector"
130 PRINT"      (2) Plot selected detector alone"
140 PRINT"      (3) Input data for new calibration"
150 PRINT"      (4) Analyze data for new calibration file"
160 PRINT"      (5) Exit program - finished":PRINT
170 INPUT"Option";OP

180 IF OP=1 THEN 40

190 IF OP=2 THEN GOSUB 56000:GOSUB 58000:LOCATE 24,4:INPUT"OK(press enter)";ZZ:S
  CREEN 2:SCREEN 0:GOTO 100

200 IF OP=3 THEN GOSUB 20000:GOTO 100

210 IF OP=4 THEN GOTO 600:REM - if op=4 then continue on

220 IF OP=5 THEN 990
230 GOTO 100:REM - catch all for incorrect option

600 REM - plot initial results and continue analysis
605 GOSUB 51000:REM - set up graph paper
610 GOSUB 50000:REM - plot data points
615 GOSUB 58000:REM plot selected existing case
620 LOCATE 24,4
630 INPUT"OK(press enter)";YES$:PRINT
645 SCREEN 2:SCREEN 0

650 CLS:PRINT"Calibration curve fitting":PRINT
651 S=0
655 PRINT"      First order fit with hyperbola"
660 PRINT"      (Will apply second order cubic later)":PRINT:PRINT
665 PRINT"      Instructions":PRINT
666 PRINT"      (1) Turn on Num Lock to use arrows"
667 PRINT"      (2) Select options below while looking at graph"
668 PRINT"          (r)ed point - adjust to curve max estimate"
669 PRINT"          (y)ellow point - adjust to origin point of hyperbola"
670 PRINT"          (g)reen point - adjust to asymptote point of hyperbola"
671 PRINT"          (d)raw lines - examine above settings"
672 PRINT"          (e)rase lines - as needed for new (d) cases"
673 PRINT"          (f)inished - clean replot with calib curve"
674 PRINT"      (3) Move a point in (2) with number pad arrows (5 = finished)"
675 PRINT"      (4) Draw hyperbola characteristic lines (2-d and 2-e)"
676 PRINT"      (5) Plot resulting calibration curve (2-f)"
677 PRINT"      (6) Repeat this process until satisfactory curve fit":PRINT

```



```

680 INPUT "To begin, press enter";ZZ
685 RED=2:YELLOW=3:GREEN=1
690 XR=120:YR=40:XY=120:YY=20:XG=250:YG=160
700 GOSUB 51000:GOSUB 50000:GOSUB 58000
710 XP=XR:YP=YR:COLOUR=RED:GOSUB 52000:REM - point plot with no error
712 XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000
714 XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000
720 RYGDEF$=INKEY$:IF RYGDEF$="" THEN 720
725 IF RYGDEF$="r" THEN GOSUB 52200
730 IF RYGDEF$="y" THEN GOSUB 52300
735 IF RYGDEF$="g" THEN GOSUB 52400
740 IF RYGDEF$="d" THEN GOSUB 52500
745 IF RYGDEF$="e" THEN GOSUB 52600
750 IF RYGDEF$<>"f" THEN 720
755 REM - now ready to plot calib curve (hyperbola)
760 XEN=XR:YEFF=YR:GOSUB 15000:LNENR=LNEN:LNEFFR=LNEFF
765 XEN=XY:YEFF=YY:GOSUB 15000:LNENY=LNEN:LNEFFY=LNEFF
770 XEN=XG:YEFF=YG:GOSUB 15000:LNENG=LNEN:LNEFFG=LNEFF
775 D=LNEFFY/A=(LNEFFG-LNEFFY)/(LNENG-LNENY):B=(LNEFFY-LNEFFR)/A:C=LNENR
776 A(0)=1:A(1)=0:A(2)=0:A(3)=0:SP=0
780 GOSUB 53000:REM - plot hyperbola
797 LOCATE 24,4
798 INPUT "Satisfactory (y/n)";YES:IF YES="n" THEN CLS:GOTO 700

800 GOSUB 42000:REM - compare data analysis results for hyperbola
855 PRINT:INPUT "Desire to renormalize to make average deviation zero (y/n)";YES:
IF YES<>"y" THEN 870
860 D=D+TOTDEV/NCAL:GOSUB 53000:LOCATE 24,4
865 INPUT "OK(dev/ncal enter)";ZZ:GOSUB 42000

870 PRINT:INPUT "Desire LSQ-fit to hyperbola (y/n)";YES:IF YES<>"y" THEN 900
875 GOSUB 10000:REM LSQ-fit to hyperbola
880 GOSUB 53000:LOCATE 24,4
890 INPUT "OK(press enter)";ZZ:GOSUB 42000

900 PRINT:INPUT "Apply LSQ cubic fit to perturbations from hyperbola (y/n)";YES:I
F YES<>"y" THEN 920
905 GOSUB 16000:REM LSQ cubic fit to hyperbola perturbations
910 GOSUB 53000:LOCATE 24,4
915 INPUT "OK(press enter)";ZZ:GOSUB 42000

920 PRINT:INPUT "Press enter to continue";ZZ:CLS
925 PRINT "MENU FOR REFIT OPTIONS":PRINT
926 PRINT "Note: Refit options (1-3) remove existing cubic LSQ"
927 PRINT "perturbation fit, which can be replaced within"
928 PRINT "these options if desired":PRINT:PRINT
929 PRINT "Refit beginning previous fit sequence at:":PRINT
930 PRINT "(1) Hyperbola drawing on screen"
931 PRINT "(2) Hyperbola LSQ selection"
932 PRINT "(3) Cubic LSQ perturbation selection"
933 PRINT "(4) No refit yet - view current fit and plot first"
934 PRINT "(5) None of the above - current fit acceptable":PRINT
935 INPUT "Option";OP:IF OP>3 THEN 938
936 A(0)=1:A(1)=0:A(2)=0:A(3)=0
937 ON OP GOTO 650,870,900
938 IF OP=4 THEN 910
939 EFFCAL$="No efficiency file made":REM - will change if and when file made

940 CLS:PRINT "FINAL DATA OUTPUT MENU":PRINT
941 PRINT "(1) Disk file and printout"
942 PRINT "(2) Printout only"
943 PRINT "(3) Disk file only"
944 PRINT "(4) No more output - exit program":PRINT
945 INPUT "Option number";OP:GOSUB 34000:REM - parameter notations
946 IF OP=1 THEN GOSUB 35000:GOSUB 36000:GOTO 940
947 IF OP=2 THEN GOSUB 36000:GOTO 940
948 IF OP=3 THEN GOSUB 35000:GOTO 940
970 SCREEN 2:SCREEN 0

990 STOP

9000 REM sub from line 31 - read in detector data
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 FOR I=1 TO 5
9020 FOR J=1 TO 3
9030 INPUT #3,GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
9040 INPUT #3,CE0H0(I,J)
9050 INPUT #3,CE1H0(I,J),CE0H1(I,J)
9060 INPUT #3,CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
9070 INPUT #3,CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
9080 NEXT J
9090 NEXT I
9095 CLOSE #3
9100 I=0:J=0
9200 RETURN

```

```

10000 REM-sub for least squares fit to hyperbola
10010 REM - calculate initial s0
10020 GOSUB 11000: REM calc s=chi-2
10030 S0=S
10040 INPUT "Increment divisor (usually 2)"; INCR
10100 REM - calculate 1st and 2nd derivatives for minimum cases
10110 DSDD=0:D2SDD2=0:DSDA=0:D2SDA2=0
10120 DSDB=0:D2SDB2=0:DSDC=0:D2SDC2=0
10130 FOR K=1 TO NCAL
10140 XK=LOG(ECAL(K)):YK=LOG(EFFCAL(K))
10150 EYK=ERRCAL(K)/EFFCAL(K):WTK=EYK^-2
10160 DYK=D+A*SQR(B^2+(C-XK)^2)-YK
10170 YKROOT=SQR(B^2+(C-XK)^2)
10180 DSDD=DSDD+WTK*DYK
10190 D2SDD2=D2SDD2+WTK
10200 DSDA=DSDA+WTK*YKROOT*DYK
10210 D2SDA2=D2SDA2+WTK*YKROOT^2
10220 DSDB=DSDB+WTK*B*((D-YK)/YKROOT + A)
10230 D2SDB2=D2SDB2+WTK*((D-YK)*(C-XK)^2/YKROOT^3 + A)
10240 DSDC=DSDC+WTK*(C-XK)*((D-YK)/YKROOT + A)
10250 D2SDC2=D2SDC2+WTK*((D-YK)*B^2/YKROOT^3 + A)
10260 NEXT K
10270 D=D-DSDD/D2SDD2/INCR
10280 A=A-DSDA/D2SDA2/INCR
10290 B=B-DSDB/D2SDB2/INCR
10300 C=C-DSDC/D2SDC2/INCR
10310 GOSUB 11000:REM - calc new s with above parameters
10320 IF S>S0 THEN PRINT:PRINT "Use increment factor > ";INCR:GOTO 10040
10330 IF ABS(S-S0)>.001*S0 THEN S0=S:GOTO 10110
10400 REM print results
10410 CLS
10420 PRINT "Fit to hyperbola      LNEFF = D + A*SQR(B^2 + (C-LNEN)^2 )"
10430 PRINT
10440 PRINT "D = ";D
10445 PRINT "A = ";A
10450 PRINT "B = ";B
10455 PRINT "C = ";C;" or ";EXP(C);" keV":PRINT
10460 PRINT "Chi-2 = ";S
10465 PRINT "Points fitted = ";NCAL:PRINT
10470 INPUT "Press enter to continue";ZZ
10500 RETURN

11000 REM sub to calculate s = chi-2
11020 S=0
11030 FOR K=1 TO NCAL
11040 XK=LOG(ECAL(K)):YK=LOG(EFFCAL(K))
11050 EYK=ERRCAL(K)/EFFCAL(K):WTK=EYK^-2
11060 DYK=D+A*SQR(B^2+(C-XK)^2)-YK
11070 S=S+WTK*DYK^2
11080 NEXT K
11100 RETURN

15000 REM - sub to convert pc-grid to lneff vs lnlen
15010 LNEN=((100-19+XEN)/100)*LOG(10)
15020 LNEFF=((100-YEFF)/100 + LGEFMD)*LOG(10)
15090 RETURN

16000 REM LSQ cubic fit to deviations from hyperbola
16001 M=3
16002 FOR I=1 TO M
16003 TD(I)=0
16004 FOR J=1 TO M
16005 TC(I,J)=0
16006 NEXT J
16007 NEXT I
16010 FOR K=1 TO NCAL
16020 XK=LOG(ECAL(K)):YHYPK=D+A*SQR(B^2+(C-XK)^2)
16025 YK=(LOG(EFFCAL(K))-D)/(YHYPK-D)
16030 EYK=(ERRCAL(K)/EFFCAL(K))/(YHYPK-D):WTK=EYK^-2
16040 FOR I=0 TO M
16050 TD(I)=TD(I)+WTK*YK*XK^I
16060 FOR J=0 TO M
16065 TC(I,J)=TC(I,J)+WTK*XK^(I+J)
16070 NEXT J
16080 NEXT I
16085 NEXT K
16090 GOSUB 17000
16100 GOSUB 18000
16110 GOSUB 19000
16200 PRINT:INPUT "Press enter to proceed";ZZ
16300 RETURN

```

```

17000 REM -triangulation of equations
17005 M=3
17010 FOR J=0 TO M
17015 REM - set first non zero coeff =1
17020 FOR K=J TO M
17025 TN(K,J)=TC(K,J):IF TN(K,J)=0 THEN GOTO 17070
17030 FOR L=J TO M
17040 TC(K,L)=TC(K,L)/TN(K,J)
17050 NEXT L
17060 TD(K)=TD(K)/TN(K,J)
17070 NEXT K
17080 REM - subtract out first non zero coefficients
17085 IF J+1 > M THEN GOTO 17150
17090 FOR K=J+1 TO M
17095 IF TC(K,J)=0 THEN GOTO 17140
17100 FOR L=J TO M
17110 TC(K,L)=TC(J,L)-TC(K,L)
17120 NEXT L
17130 TD(K)=TD(J)-TD(K)
17140 NEXT K
17150 NEXT J
17170 RETURN

18000 REM final results for cubic lsq fit
18001 M=3
18002 PRINT:PRINT
18005 PRINT "values of a(i) listed below":PRINT
18010 FOR L=M TO 0 STEP -1
18020 A(L)=TD(L):IF L=M THEN GOTO 18060
18030 FOR J=L+1 TO M
18040 A(L)=A(L)-TC(L,J)*A(J)
18050 NEXT J
18060 NEXT L
18080 FOR L=0 TO M:PRINT"A(";L;") = ";A(L):NEXT L
18090 PRINT
18100 RETURN

19000 REM LSQ cubic fit to deviations from hyperbola - Chi-2 calc
19005 SP=0
19010 FOR K=1 TO NCAL
19020 XK=LOG(ECAL(K)):YHYPK=D+A*SQR(B^2+(C-XK)^2)
19025 YK=(LOG(EFFCAL(K))-D)/(YHYPK-D)
19030 EYK=(ERRCAL(K)/EFFCAL(K))/(YHYPK-D):WTK=EYK^-2
19035 YFITK=A(0)+A(1)*XK+A(2)*XK^2+A(3)*XK^3
19040 SP=SP+WTK*(YK-YFITK)^2
19050 NEXT K
19060 PRINT"Chi-2 = ";SP
19070 PRINT"Points fitted = ";NCAL:PRINT
19100 RETURN

```

```

20000 REM- sub to input data for new calib
20010 CLS
20020 PRINT"Select input form of calibration data":PRINT:PRINT
20030 PRINT" (1) Absolute efficiencies":PRINT
20040 PRINT" (2) Efficiency ratios to currently selected detector"
20041 PRINT"      (":DETNAME$(DETNUM):")":PRINT
20045 PRINT" (3) None of above - need select different detector first":PRINT:PRINT
20050 INPUT"Option";OP:IF OP=3 THEN RETURN
20055 NCAL=0
20060 CLS
20070 INPUT"Energy in keV (0 if done)";EN:IF EN=0 THEN 20140
20080 NCAL=NCAL+1:ECAL(NCAL)=EN:PRINT
20090 IF OP=1 THEN INPUT"Efficiency";EFFCAL(NCAL)
20100 IF OP=1 THEN INPUT"Error";ERRCAL(NCAL)
20110 IF OP=2 THEN INPUT"Ratio";RATO:EFFCAL(NCAL)=RATO*FNEFF(EN)
20120 IF OP=2 THEN INPUT"Error";ERATO:ERRCAL(NCAL)=ERATO*FNEFF(EN)
20130 GOTO 20060
20140 CLS:GOSUB 21000:REM - bubble sort of entries
20150 PRINT"      Summary of inputs":PRINT
20155 PRINT"Number      Energy      Efficiency      Ratio"
20156 PRINT"      #      keV      #      #":PRINT
20160 FOR K=1 TO NCAL
20170 PRINT USING"###";K;
20180 PRINT USING"#####.##";ECAL(K);
20190 PRINT USING"###.#####";EFFCAL(K);:PRINT" +/- ";
20200 PRINT USING"###.#####";ERRCAL(K);
20210 PRINT USING"###.#####";EFFCAL(K)/FNEFF(ECAL(K));:PRINT" +/- ";
20220 PRINT USING"###.#####";ERRCAL(K)/FNEFF(ECAL(K))
20230 NEXT K
20240 PRINT:INPUT"Need correction (y/n)";YES$
20250 INPUT"Print screen as needed - before pressing enter to proceed";ZZ
20260 IF YES$="n" THEN 20500
20270 CLS
20280 PRINT"      Corrections Menu":PRINT
20285 PRINT" (1) Delete entry"
20290 PRINT" (2) Add entry"
20300 PRINT" (3) Edit entry":PRINT
20310 INPUT"Option";OPE
20320 IF OPE<>1 THEN 20380
20330 PRINT:INPUT"Peak number to delete";NDEL:NCAL=NCAL-1
20340 FOR K=NDEL TO NCAL
20350 ECAL(K)=ECAL(K+1):EFFCAL(K)=EFFCAL(K+1):ERRCAL(K)=ERRCAL(K+1)
20360 NEXT K
20370 GOTO 20140
20380 IF OPE=2 THEN 20060
20390 IF OPE<>3 THEN 20270
20400 PRINT:INPUT"Peak to edit";NED:PRINT
20410 PRINT"Note 0 entries mean no change":PRINT
20420 INPUT"Energy (keV)";EN:IF EN>0 THEN ECAL(NED)=EN
20430 IF OP=1 THEN INPUT"Efficiency";EFF:IF EFF>0 THEN EFFCAL(NED)=EFF
20440 IF OP=1 THEN INPUT"Error";EROR:IF EROR>0 THEN ERRCAL(NED)=EROR
20450 IF OP=2 THEN INPUT"Ratio";RATO:IF RATO>0 THEN EFFCAL(NED)=RATO*FNEFF(EN)
20460 IF OP=2 THEN INPUT"Error";ERATO:IF ERATO>0 THEN ERRCAL(NED)=ERATO*FNEFF(EN)
20470 GOTO 20140
20500 RETURN

21000 REM - bubble sort to order en with eff and err
21010 FOR K=1 TO NCAL-1
21020 FOR J=1 TO NCAL-K
21030 IF ECAL(J+1)>ECAL(J) THEN 21070
21040 ECAL=ECAL(J+1):ECAL(J+1)=ECAL(J):ECAL(J)=ECAL
21050 EFFCAL=EFFCAL(J+1):EFFCAL(J+1)=EFFCAL(J):EFFCAL(J)=EFFCAL
21060 ERRCAL=ERRCAL(J+1):ERRCAL(J+1)=ERRCAL(J):ERRCAL(J)=ERRCAL
21070 NEXT J
21080 NEXT K
21100 RETURN

34000 REM - transform detector parameters to usual notation
34040 GOEFF=EXP(D):AOEFF=A:BOEFF=B:UOEFF=1:KOEFF=C
34050 COEFF=A(0):C1EFF=A(1):C2EFF=A(2):C3EFF=A(3)
34060 ENX=5000:DOEFF=0:D1EFF=0:D2EFF=0:D3EFF=0
34070 POEFF=0:P1EFF=0:P2EFF=0:P3EFF=0
34100 RETURN

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```

35000 REM - make detector calibration file
35010 PRINT:PRINT
35020 INPUT"Entire detector calibration file label (-----.DCF)";EFFCAL$
35030 PRINT:PRINT"File label is ";EFFCAL$;:INPUT" OK(y/n)";YES$:IF YES<>"y" THEN
GOTO 35010
35080 PRINT:INPUT"Examine transformed data before making file (y/n)";YES$
35090 IF YES<>"y" THEN 35200
35100 CLS
35110 GOSUB 60000:REM eff check list
35120 PRINT:INPUT"Still wish to make file (y/n)";YES$
35130 IF YES="n" THEN EFFCAL$="No efficiency file made":GOTO 35500
35200 OPEN EFFCAL$ FOR OUTPUT AS #3
35210 WRITE #3,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EFF,C2EFF,C3EFF
35220 WRITE #3,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
35230 CLOSE #3
35500 RETURN

36000 REM - sub to printout results
36010 CLS:INPUT"Line feed printer as needed, and press enter to print";ZZ
36020 LPRINT" ***** DETECTOR EFFICIENCY CALIBRATION *****"
36030 LPRINT:LPRINT
36040 LPRINT"Title: ";NACAL$:LPRINT
36050 LPRINT"Calibration file generated: ";EFFCAL$:LPRINT
36330 REM - this segment on file DETPRINT.BAS in A-format
36335 LPRINT
36355 LPRINT"-----EFFICIENCY CALIBRATION FORMULA-----"
36370 LPRINT
36380 LPRINT"Efficiency calibration: EFF = G*EXP(HYPERBOLA * POLYNOMIAL)*(1+PERT
URBATION)"
36385 LPRINT
36390 LPRINT" G = global calibration factor = ";GOEFF;" D = LN(G) = ";LOG(GOE
F)
36395 LPRINT
36400 LPRINT" HYPERBOLA = A*SQR( B^2 + (LN(EN)-C)^2 ) with values below:
36410 LPRINT" ( A = ";AOEFF;" B = ";BOEFF;" C = ";KOEFF;" )"
36415 LPRINT
36420 LPRINT" POLYNOMIAL = C0 + C1*LN(EN) + C2*LN(EN)^2 + C3*LN(EN)^3 with val
ues below:"
36430 LPRINT" ( C0 = ";COEFF;" C1 = ";C1EFF;" C2 = ";C2EFF;" C3 = ";C3EFF;" )"
36432 LPRINT" ";ENX;" keV = crossover between low EN (above) and high EN (belo
w) cases"
36434 LPRINT" ( C0 = ";TOEFF;" C1 = ";T1EFF;" C2 = ";T2EFF;" C3 = ";T3EFF;" )"
36435 LPRINT
36440 LPRINT" PERTURBATION = P0 + P1*LN(EN) + P2*LN(EN)^2 + P3*LN(EN)^3 with v
alues below:"
36450 LPRINT" ( P0 = ";POEFF;" P1 = ";P1EFF;" P2 = ";P2EFF;" P3 = ";P3EFF;" )"
36460 LPRINT
36470 LPRINT"-----FIT INFORMATION-----"
36480 LPRINT
36505 LPRINT"Comparison of measured (Eff) and calculated (Hypeff) results"
36506 LPRINT:LPRINT
36507 LPRINT"Peak Energy Eff Hypeff Diff"
36508 LPRINT" # keV # # #":LPRINT
36509 TOTDEV=0:RMSDEV=0
36510 FOR K=1 TO NCAL
36512 LNEFF = LOG(ECAL(K))
36515 LNEFF=D + A*SQR(B^2+(LNEFF-C)^2)*(A(0)+A(1)*LNEFF+A(2)*LNEFF^2+A(3)*LNEFF^3)
36520 DEVEFF=LOG(EFFCAL(K))-LNEFF
36525 TOTDEV=TOTDEV+DEVEFF:RMSDEV=RMSDEV+DEVEFF^2
36530 LPRINT USING"###";K;
36531 LPRINT USING"#####";ECAL(K);
36532 LPRINT USING"#####";EFFCAL(K);
36533 LPRINT USING"#####";EXP(LNEFF);
36534 LPRINT USING"#####";100*DEVEFF
36540 NEXT K
36545 LPRINT:LPRINT"RMS deviation = ";:LPRINT USING"#####";100*SQR(RMSDEV/NCAL);
:LPRINT" %"
36550 LPRINT:LPRINT"Average deviation = ";:LPRINT USING"#####";100*TOTDEV/NCAL;
:LPRINT" %"
36560 LPRINT:LPRINT"Chi-2 for hyperbola = ";S:IF S=0 THEN 36580
36570 LPRINT"SQR(chi-2/n-r) = ";SQR(S/(NCAL-4))
36580 LPRINT:LPRINT"Chi-2 for cubic perturbation = ";SP:IF SP=0 THEN 36600
36590 LPRINT"SQR(chi-2/n-r) = ";SQR(SP/(NCAL-4))
36600 LPRINT
36610 LPRINT"-----RAW DATA REFERENCE-----"
36620 LPRINT:LPRINT
36655 LPRINT"Number Energy Efficiency Ratio"
36656 LPRINT" # keV # #":LPRINT
36660 FOR K=1 TO NCAL
36670 LPRINT USING"#####";K;
36680 LPRINT USING"#####";ECAL(K);
36690 LPRINT USING"#####";EFFCAL(K);:LPRINT" +/- ";
36700 LPRINT USING"#####";ERRCAL(K);
36710 LPRINT USING"#####";EFFCAL(K)/FNEFF(ECAL(K));:LPRINT" +/- ";
36720 LPRINT USING"#####";ERRCAL(K)/FNEFF(ECAL(K))
36730 NEXT K
36900 RETURN

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42000 REM- summary of hyperbola fit - tabular
42801 CLS:SCREEN 2:SCREEN 0
42805 PRINT"Comparison of measured (Eff) and calculated (Hypeff) results"
42806 PRINT:PRINT
42807 PRINT"Peak Energy    Eff    Hypeff    Diff"
42808 PRINT"    #      keV    #      #      #":PRINT
42809 TOTDEV=0:RMSDEV=0
42810 FOR K=1 TO NCAL
42812 LNEN = LOG(ECAL(K))
42815 LNEFF=D + A*SQR(B^2+(LNEN-C)^2)*(A(0)+A(1)*LNEN+A(2)*LNEN^2+A(3)*LNEN^3)
42820 DEVEFF=LOG(EFFCAL(K))-LNEFF
42825 TOTDEV=TOTDEV+DEVEFF:RMSDEV=RMSDEV+DEVEFF^2
42830 PRINT USING"###";K;
42831 PRINT USING"#####.##";ECAL(K);
42832 PRINT USING"###.#####";EFFCAL(K);
42833 PRINT USING"###.#####";EXP(LNEFF);
42834 PRINT USING"###.#####";100*DEVEFF
42840 NEXT K
42845 PRINT:PRINT"RMS deviation = ";:PRINT USING"###.##";100*SQR(RMSDEV/NCAL);:P
RINT" %"
42850 PRINT:PRINT"Average deviation = ";:PRINT USING"###.##";100*TOTDEV/NCAL;:P
RINT" %"
42900 RETURN

46000 REM - subroutine from line 46 - detector efficiencies - part 1
46005 DETLAB$(6)="<normal>":OTHERDET$="<normal>".DCF"
46010 PRINT "Efficiency calibration - select detector below"
46030 PRINT
46040 PRINT "      (1) Bottom-old"
46045 PRINT "      (2) Bottom-new"
46050 PRINT "      (3) PGT-top"
46055 PRINT "      (4) N-side"
46060 PRINT "      (5) Well"
46062 PRINT "      (6) Other"
46065 PRINT
46070 INPUT"Detector number";DETN
46090 RETURN

46100 REM - subroutine from line 47 - detector efficiencies - part 2
46105 CLS:OPTDT6=0
46110 GOEFF=1:A0EFF=1:B0EFF=1:U0EFF=0:COEFF=1:C1EFF=0:C2EFF=0:C3EFF=0
46115 POEFF=0:P1EFF=0:P2EFF=0:P3EFF=0:D0EFF=0:D1EFF=0:D2EFF=0:D3EFF=0:ENX=5000
46117 IF DETN=6 THEN GOSUB 47000
46118 PRINT:IF OPTDT6=1 THEN GOSUB 46500
46119 IF OPTDT6>0 THEN 46200
46120 PRINT"Efficiency calibration data for ";DETNAM$(DETN)
46130 PRINT
46140 PRINT"      (1) Special samples (manual input)"
46145 PRINT"      (2) Diaper samples (auto input)"
46150 PRINT"      (3) Well samples (auto input)"
46160 PRINT"      (4) Vial samples (auto input)"
46165 PRINT
46170 INPUT"Calibration case number";OPNUM:PRINT
46180 ON OPNUM GOSUB 46500,46700,46800,46900
46190 REM eff sub-parts 2a 2b 2c 2d
46200 RETURN

46500 REM - manual input efficiencies - part 2a of efficiency calcs/line46180
46505 INPUT"Type of fit - (0) None<eff=1> (1) Polynomial, (2) Hyperbola, (3) Bot
h ";PHB:PRINT
46510 ON PHB GOTO 46600,46530,46520
46515 IF PHB=0 THEN A0EFF=0:GOTO 46690
46520 PRINT"LN(EFF) = D + A*SQR(B^2+(LN(E)-C)^2) * (C0 + C1*LN(E) + C2*LN(E)^2 +
C3*LN(E)^3)"
46525 IF PHB=3 THEN GOTO 46535
46530 PRINT"LN(EFF) = D + A*SQR(B^2+(LN(E)-C)^2)":PRINT
46535 U0EFF=1
46540 INPUT"      D";DAEFF:GOEFF=EXP(DAEFF)
46550 INPUT"      A";A0EFF
46560 INPUT"      B";B0EFF
46570 INPUT"      C";C0EFF
46590 IF PHB=3 THEN GOTO 46620
46595 IF PHB=2 THEN GOTO 46690
46600 PRINT"LN(EFF) = C0 + C1*LN(E) + C2*LN(E)^2 + C3*LN(E)^3":PRINT
46610 U0EFF=0
46612 INPUT" Crossover energy (keV).....if none enter 0 ";ENX:IF ENX=0 THEN ENX
=5000
46614 PRINT"      Coefficients below crossover point"
46620 INPUT"      C0";C0EFF
46630 INPUT"      C1";C1EFF
46640 INPUT"      C2";C2EFF
46650 INPUT"      C3";C3EFF:IF PHB=3 THEN GOTO 46690
46651 IF ENX = 5000 THEN GOTO 46690
46652 PRINT"      Coefficients above crossover point"
46655 INPUT"      C0";T0EFF:D0EFF=T0EFF-C0EFF
46660 INPUT"      C1";T1EFF:D1EFF=T1EFF-C1EFF
46665 INPUT"      C2";T2EFF:D2EFF=T2EFF-C2EFF
46670 INPUT"      C3";T3EFF:D3EFF=T3EFF-C3EFF
46690 RETURN

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46700 REM - diaper coefficients effs - part 2b of efficiency calib/line46180
46710 IF DETN=1 THEN COEFF=-32.9019:C1EFF=15.5286:C2EFF=-2.63121:C3EFF=.137454
46720 IF DETN=2 THEN COEFF=-33.7619:C1EFF=15.949:C2EFF=-2.69313:C3EFF=.141663
46730 IF DETN=3 THEN COEFF=-44.2381:C1EFF=21.0238:C2EFF=-3.50398:C3EFF=.183542
46740 IF DETN=4 THEN PRINT"not available - make another choice"
46750 IF DETN=5 THEN COEFF=-30.373:C1EFF=14.4228:C2EFF=-2.4183:C3EFF=.125452
46760 RETURN

46800 REM - well coefficients effs - part 2c of efficiency calib/line46180
46810 IF DETN<>5 THEN PRINT "NOT APPLICABLE - MAKE ANOTHER CHOICE"
46820 UOEFF=1:A0EFF=-.921*SQR(1.6952):B0EFF=SQR(1.21/1.6952):K0EFF=LOG(60)
46830 GOEFF=EXP(.921*.9)
46850 RETURN

46900 REM - vial coefficients effs - part 2d of efficiency calib/line46180
46910 PRINT"Vial sizes":PRINT
46911 PRINT" (1) Large"
46912 PRINT" (2) Medium"
46913 PRINT" (3) Small":PRINT
46920 INPUT"Vial size number";VIALN:PRINT
46930 INPUT"Vial sample height (mm) ";HMM:H=HMM/10
46940 UOEFF=1:A0EFF=A0EFF(DETN,VIALN):B0EFF=B0EFF(DETN,VIALN):K0EFF=K0EFF(DETN,VIALN)
46950 POEFF=CE0H0(DETN,VIALN)+CE0H1(DETN,VIALN)*H+CE0H2(DETN,VIALN)*H^2+CE0H3(DETN,VIALN)*H^3
46955 P1EFF=CE1H0(DETN,VIALN)+CE1H1(DETN,VIALN)*H+CE1H2(DETN,VIALN)*H^2
46960 P2EFF=CE2H0(DETN,VIALN)+CE2H1(DETN,VIALN)*H
46965 P3EFF=CE3H0(DETN,VIALN)
46970 GOEFF=GOEFF(DETN,VIALN)/(H+H0EFF(DETN,VIALN))^2
46975 DAEFF=LOG(GOEFF)
46990 RETURN

47000 REM- sub for detector #6 (other detector)
47001 ON ERROR GOTO 47120
47002 CLS
47003 INPUT"Descriptive name of detector";DETNAM$(6):PRINT:PRINT
47015 PRINT"Detector efficiency options":PRINT
47020 PRINT" (1) Manual input (includes eff=1 case )
47030 PRINT" (2) File input":PRINT
47040 INPUT"Option";OPTDT6
47050 IF OPTDT6<>2 THEN 47200
47060 PRINT:PRINT
47070 INPUT"Detector calibration file (-----.DCF)";OTHERDET$
47080 OPEN OTHERDET$ FOR INPUT AS #3
47090 INPUT #3,GOEFF,A0EFF,B0EFF,UOEFF,K0EFF,COEFF,C1EFF,C2EFF,C3EFF
47100 INPUT #3,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
47110 CLOSE #3
47120 IF ERR=53 THEN PRINT:INPUT"Above file not found. Press return for retry";Z
Z:CLS:RESUME 47000
47200 RETURN

50000 REM - sub to plot data points
50010 FOR K=1 TO NCAL
50020 XEN=19 + 100*LOG(ECAL(K))/LOG(10) -100
50030 YEFF=100-100*( LOG(EFFCAL(K))/LOG(10) - LGFMD )
50040 YEFFA=100-100*( LOG(EFFCAL(K)+ERRCAL(K))/LOG(10) - LGFMD )
50050 YEFFB=100-100*( LOG(EFFCAL(K)-ERRCAL(K))/LOG(10) - LGFMD )
50060 LINE(XEN-1,YEFF-1)-(XEN+1,YEFF+1),3,B:REM point plotted
50070 LINE(XEN,YEFFA)-(XEN,YEFFB),3:REM error plotted
50080 NEXT K
50900 RETURN

```

```

51000 REM - subroutine for graph paper
51600 REM - plot initial results and continue analysis
51610 SCREEN 1:CLS
51620 COLOR 8,0
51625 MINEFF=1:MAXEFF=0
51630 FOR K=1 TO NCAL:REM find graph limits
51632 IF EFFCAL(K)>MAXEFF THEN MAXEFF = EFFCAL(K)
51634 IF EFFCAL(K)<MINEFF THEN MINEFF = EFFCAL(K)
51636 NEXT K
51640 LGEFMD=(LOG(MAXEFF)+LOG(MINEFF))/(2*LOG(10)):REM mid y-axis
51650 LINE(19,0)-(319,199),1,B:REM draw axis frame
51651 LINE(119,0)-(119,199),1
51652 LINE(219,0)-(219,199),1
51654 IF LGEFMD = INT(LGEFMD) THEN YGR1=100:YGR2=100:LINE(19,100)-(319,100),1:GO
TO 660
51655 YGR1=INT(100 + 100*(LGEFMD-INT(LGEFMD)) + .5)
51656 IF YGR1<199 THEN LINE(19,YGR1)-(319,YGR1),1
51657 YGR2=YGR1-100
51658 IF YGR2>0 THEN LINE(19,YGR2)-(319,YGR2),1
51660 FOR XXGRID=19 TO 219 STEP 100
51662 FOR XGRID=1 TO 10
51664 XTIC=INT(100*LOG(XGRID)/LOG(10) + .5) + XXGRID
51666 LINE(XTIC,0)-(XTIC,5),1
51667 LINE(XTIC,199)-(XTIC,194),1
51668 NEXT XGRID
51669 NEXT XXGRID
51670 FOR YYGRID=YGR1+100 TO YGR2 STEP -100
51671 FOR YGRID=1 TO 10
51672 YTIC=YYGRID - INT(100*LOG(YGRID)/LOG(10) + .5)
51673 IF YTIC > 199 THEN 51677
51674 IF YTIC < 0 THEN 51677
51675 LINE(19,YTIC)-(24,YTIC),1
51676 LINE(319,YTIC)-(314,YTIC),1
51677 NEXT YGRID
51678 NEXT YYGRID
51900 RETURN

52000 REM - sub to draw point
52010 LINE(XP-1,YP-1)-(XP+1,YP+1),COLOUR,BF
52030 RETURN

52100 REM - sub to erase point
52110 LINE(XP-1,YP-1)-(XP+1,YP+1),0,BF
52130 RETURN

52200 REM - sub to move red point for max of hyperbola
52210 VECT$=INKEY$:IF VECT$="" THEN 52210
52220 IF INT(VAL(VECT$)/2)<>VAL(VECT$)/2 THEN 52270
52225 XP=XR:YP=YR:GOSUB 52100
52230 IF VECT$="8" THEN YR=YR-1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000:GOTO 52210
52235 IF VECT$="2" THEN YR=YR+1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000:GOTO 52210
52240 XP=XY:YP=YY:GOSUB 52100
52245 IF VECT$="6" THEN 52260
52250 XR=XR-1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52255 XY=XY-1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52210
52260 XR=XR+1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52265 XY=XY+1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52210
52270 IF VECT$<>"5" THEN 52210
52290 RETURN

52300 REM - sub to move yellow point for origin of hyperbola
52310 VECT$=INKEY$:IF VECT$="" THEN 52310
52320 IF INT(VAL(VECT$)/2)<>VAL(VECT$)/2 THEN 52370
52325 XP=XY:YP=YY:GOSUB 52100
52330 IF VECT$="8" THEN YY=YY-1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52310
52335 IF VECT$="2" THEN YY=YY+1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52310

52340 XP=XR:YP=YR:GOSUB 52100
52345 IF VECT$="6" THEN 52360
52350 XR=XR-1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52355 XY=XY-1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52310
52360 XR=XR+1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52365 XY=XY+1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52310
52370 IF VECT$<>"5" THEN 52310
52390 RETURN

52400 REM - sub to move green point for asymptote of hyperbola
52410 VECT$=INKEY$:IF VECT$="" THEN 52410
52420 IF INT(VAL(VECT$)/2)<>VAL(VECT$)/2 THEN 52470
52425 XP=XG:YP=YG:GOSUB 52100
52430 IF VECT$="8" THEN YG=YG-1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52435 IF VECT$="2" THEN YG=YG+1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52445 IF VECT$="6" THEN 52460
52450 XG=XG-1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52460 XG=XG+1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52470 IF VECT$<>"5" THEN 52410
52490 RETURN

```



```

52500 REM - sub to draw hyperbola characteristics
52510 LINE(XR,YR)-(XY,YY),GREEN
52520 LINE(XY,YY)-(XG,YG),GREEN
52530 XRE=XR:YRE=YR:XYE=XY:YYE=YY:XGE=XG:YGE=YG
52590 RETURN

52600 REM - sub to erase hyperbola characteristics
52610 LINE(XRE,YRE)-(XYE,YYE),0
52620 LINE(XYE,YYE)-(XGE,YGE),0
52690 RETURN

53000 REM - sub to plot hyperbola calib
53780 CLS:GOSUB 51000:GOSUB 50000
53785 FOR XEN=20 TO 318
53787 LNEF=((100-19+XEN)/100)*LOG(10)
53788 LNEFF=D + A*SQR(B^2+(LNEF-C)^2)*(A(0)+A(1)*LNEF+A(2)*LNEF^2+A(3)*LNEF^3)
53789 YEFF=100-100*(LNEFF/LOG(10) - LGEFMD)
53790 IF YEFF>198 THEN 53795
53791 IF YEFF<1 THEN 53795
53792 PSET (XEN,YEFF),RED
53795 NEXT XEN
53796 GOSUB 50000
53900 RETURN

56000 REM - subroutine for graph paper
56600 REM - plot initial results and continue analysis
56610 SCREEN 1:CLS
56620 COLOR 8,0
56625 MINEFF=1:MAXEFF=0
56630 MAXEFF=FNEFF(100)
56632 MINEFF=MAXEFF/30
56640 LGEFMD=(LOG(MAXEFF)+LOG(MINEFF))/(2*LOG(10)):REM mid y-axis
56650 LINE(19,0)-(319,199),1,B:REM draw axis frame
56651 LINE(119,0)-(119,199),1
56652 LINE(219,0)-(219,199),1
56654 IF LGEFMD = INT(LGEFMD) THEN YGR1=100:YGR2=100:LINE(19,100)-(319,100),1:GO
TO 56660
56655 YGR1=INT(100 + 100*(LGEFMD-INT(LGEFMD)) + .5)
56656 IF GR1<199 THEN LINE(19,YGR1)-(319,YGR1),1
56657 YGR2=YGR1-100
56658 IF YGR2>0 THEN LINE(19,YGR2)-(319,YGR2),1
56660 FOR XXGRID=19 TO 219 STEP 100
56662 FOR XGRID=1 TO 10
56664 XTIC=INT(100*LOG(XGRID)/LOG(10) + .5) + XXGRID
56666 LINE(XTIC,0)-(XTIC,5),1
56667 LINE(XTIC,199)-(XTIC,194),1
56668 NEXT XGRID
56669 NEXT XXGRID
56670 FOR YYGRID=YGR1+100 TO YGR2 STEP -100
56671 FOR YGRID=1 TO 10
56672 YTIC=YYGRID - INT(100*LOG(YGRID)/LOG(10) + .5)
56673 IF YTIC > 199 THEN 56677
56674 IF YTIC < 0 THEN 56677
56675 LINE(19,YTIC)-(24,YTIC),1
56676 LINE(319,YTIC)-(314,YTIC),1
56677 NEXT YGRID
56678 NEXT YYGRID
56900 RETURN

58000 REM - sub to plot FNEFF
58780 RED=2
58785 FOR XEN=20 TO 318
58787 LNEF=((100-19+XEN)/100)*LOG(10)
58788 LNEFF=LOG(FNEFF(EXP(LNEF)))
58789 YEFF=100-100*(LNEFF/LOG(10) - LGEFMD)
58790 IF YEFF>198 THEN 58795
58791 IF YEFF<1 THEN 58795
58792 PSET (XEN,YEFF),RED
58795 NEXT XEN
58900 RETURN

60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";EFFCAL$
60006 PRINT
60010 PRINT "EN","EFF"
60011 PRINT"kev"," "
60020 PRINT USING"#####";88.03::PRINT USING"#####";FNEFF(88.03)
60030 PRINT USING"#####";122.06::PRINT USING"#####";FNEFF(122.06)
60040 PRINT USING"#####";165.85::PRINT USING"#####";FNEFF(165.85)
60050 PRINT USING"#####";279.19::PRINT USING"#####";FNEFF(279.19)
60060 PRINT USING"#####";391.69::PRINT USING"#####";FNEFF(391.69)
60070 PRINT USING"#####";514.1::PRINT USING"#####";FNEFF(514.1)
60080 PRINT USING"#####";661.64::PRINT USING"#####";FNEFF(661.64)
60090 PRINT USING"#####";898.02::PRINT USING"#####";FNEFF(898.02)
60100 PRINT USING"#####";1173.21::PRINT USING"#####";FNEFF(1173.21)
60110 PRINT USING"#####";1332.56::PRINT USING"#####";FNEFF(1332.56)
60120 PRINT USING"#####";1836.01::PRINT USING"#####";FNEFF(1836.01)
60130 PRINT:INPUT"Ready to proceed - press enter";ZZ
60140 RETURN

```

61000 REM month days data
61010 DATA 31,28,31,30,31,30
61020 DATA 31,31,30,31,30,31

62000 REM - data for mass atten coeffs in barns/atom - convert to cm-1 by
62010 REM - multiplying by 0.008297 x 5.35 gm/cm3
62020 REM Energy(keV) b/atom , etc
62030 DATA 15,11000,20,5070,30,1680,40,746,50,400,60,243,80,115
62040 DATA 100,66.4,150,29.6,200,20.0,300,13.5,400,11.2,500,9.87
62050 DATA 600,8.96,800,7.73
62060 DATA 1000,6.89,1500,5.60,2000,4.92,3000,4.24,4000,3.95,5000,3.81

GRABDKR1: Program Structure Reference

Main	<--- Subroutines and [files]
1-12/DIM and COMMON	
16-18/CRT #1: printer	
19-38/CRT #2: intro	
29/Peak initl	
31/Detrs : Efficacy	<--- 9000-9200/Vial Data <--- [B:DETLIBRY.LIB]
32/Detrs : Names	
39/CRT #3: Info	<--- 5000-5190/User background and rates
40-47/CRT #4: Energy	<--- 40000-40100/E vs chn
: FWHM	<--- 43000-43100/E vs FWHM*
: Detrs	<--- 46000-46090/Detector selection
50-51/CRT #5: Efficacy	<--- 46100-46200/Driver for choices
	<--- 47000-47200/Other Detector
	<--- [backgnd.BKG]
	<--- [detreff.DCF]
	<--- 46500-46690/Manual input
	<--- 46700-46760/Air filters
	<--- 46800-46850/Well samples
	<--- 46900-46990/Vial samples
58-63/Efficacy: Functs	<--- 60000-60140/CRT effs vs Es
64-298/CRT #6: Spect	<--- [spectrum.CHN] leader
: Analys	<--- 1000-1999/parameter selection
	<--- 11000-11500/Print input data
300-390/Spect : Readin	<--- [spectrum.CHN] spectrum counts/chn
: Peaks	<--- 2000-2900/Find peak driver
	<--- 12000-12120/3-rope/CRT peak init
	<--- 12400-12430/2-ch rope filter
	<--- 12500-12530/4-ch rope filter
	<--- 12600-12630/8-ch rope filter
	<--- 12200-12290/Peak resolver
400/Chain GRABDKR2	
500/Stop	

```

1 'VERSION GRABDKR1
2 DIM H1(150),H2(150),GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3),A(2
0),MINXM(20),MCENT(20)
3 COMMON H1(),H2(),GOEFF(),HOEFF(),AOEFF(),BOEFF(),KOEFF(),A(),MINXM(),MCENT()
4 DIM CEOH0(5,3),CE1H0(5,3),CEOH1(5,3),CE2H0(5,3),CE1H1(5,3),CEOH2(5,3),CE3H0(5,
3),CE2H1(5,3),CE1H2(5,3),CEOH3(5,3),GEOM$(10)
5 COMMON CEOH0(),CE1H0(),CEOH1(),CE2H0(),CE1H1(),CEOH2(),CE3H0(),CE2H1(),CE1H2()
,CEOH3(),GEOM$(10)
6 DIM YLOC(20),DETNAME$(10),BENERGY(150),BRATE(150),BERR(150),DETLAB$(10),ISOTH(25
0),MDA(250),ISOACT(250),LIBEN(250),SBRATE(150),SBERR(150)
7 COMMON YLOC(),DETNAME$(10),BENERGY(),BRATE(),BERR(),DETLAB$(10),ISOTH(),MDA(),ISOACT
(),LIBEN(),SBRATE(),SBERR()
8 DIM RATE(150),ENERGY(150),ISOEN(250),ISOIDS$(250),ISO$(250),ISOGAM(250),NPC(409
6),AREA(150),EAREA(150),LOCH(150),TAIL(150),FWHM(150),CENT(150)
9 COMMON RATE(),ENERGY(),ISOEN(),ISOIDS$(250),ISO$(250),ISOGAM(250),NPC(4096),AREA
(),EAREA(),LOCH(),TAIL(),FWHM(),CENT(),FACILITY$,DETLAB$,DETNAME$,LIBRY$
10 COMMON LTIME,RTIME,STTIME,STDATE$,LOCH$,NPC,COENC,C1ENC,TDAYS,RUNITS,SAMBAC,S
TCH,ENCH,CRES,HCRES,EFIND,SBRATE,RATE,RATERR,SBERR,CENT,FWHM,TAIL,AREA,RTCN,ACTR
AT,EAREA,IP,SENSIT,COFWHM,C1FWHM,ANAME$,RTCN$,AUNIT$
11 COMMON GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,COEFF,C1EFF,C2EFF,C3EFF,EN,ENX
12 COMMON DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF,FETHICK

16 CLS
17 INPUT"Printer used...(1) IBM (2) TOSHIBA";PRUSED:PRINT:PRINT
18 INPUT"Do you need a form feed on printer first (y/n)";FFYES:IF FFYES <> "n"
THEN LPRINT CHR$(12):REM - far away from next lprint statement

19 CLS
20 PRINT:PRINT:PRINT
21 PRINT"***** GRABGAM *****":PRINT:PRINT
22 PRINT"Gamma Ray BASIC Generated At MCA/PC":PRINT:PRINT:PRINT

23 PRINT"Overview of Operations":PRINT
24 PRINT"1. Insert diskette with data files.":PRINT
25 PRINT"2. Enter all data on following Input Frames.":PRINT
26 PRINT"3. Assure input data correct before leaving each Input Frame.":P
RINT
27 PRINT"4. Analysis will take about 2 min per 4000 ch spectrum.":PRINT
28 PRINT"5. Next prompt will appear below after data libraries read.":PRI
NT

29 IP=0:PEAK=0:B1=0:G=0:B2=0

31 GOSUB 9000:REM read in detector efficiency parameters for vials

32 DETNAME$(1)="Old Bottom Detector":DETNAME$(2)="New Bottom Detector":DETNAME$(3)=
"PGT Detector":DETNAME$(4)="N-side Detector":DETNAME$(5)="Well Detector"

38 INPUT"Press enter for Input Frame";PAGE$:CLS

39 GOSUB 5000 REM-background/sample menu

40 GOSUB 40000:REM - get energy calibration parameters
41 DEF FNENC(CHAN)= COENC + C1ENC*CHAN
42 PRINT
43 GOSUB 43000:REM - get FWHM calibration parameters
44 DEF FNFWM(CHAN)=SQR( COFWHM + C1FWHM*CHAN )
45 PRINT
46 GOSUB 46000:REM - get efficiency parameters - part 1
47 PRINT:INPUT"Repeat this frame due to input errors (y/n)";FRAMER$:IF FRAMER$="
y" THEN CLS:GOTO 40

50 GOSUB 46100:REM - get efficiency parameters - part 2
51 PRINT:INPUT"Repeat this frame due to input errors (y/n)";FRAMER$:IF FRAMER$="
y" THEN CLS:GOTO 50

58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX)))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFVEN$:
CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 GOSUB 60000:REM check on efficiency data EFF vs EN
63 IF NEWEFF$="y" THEN CLS:GOTO 46:REM replace efficiency data case

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64 CLS
65 INPUT" (1) SPECTRUM FILE (-----.CHN)";SP$:YLOC(1)=CSRLIN-1:REM pick up from i
nputs editing routine in 1000
68 'SINCE BASIC CANNOT HANDLE 4 BYTE INTEGERS, INTEGER4 DATA IS READ
69 'AS 1-BYTE STRINGS AND CONVERTED TO REAL BY THE FOLLOWING
70 OPEN SP$ AS #1 LEN = 32 : 'PICKUP HEADER RECORD
80 FIELD #1, 2 AS FLAG$, 2 AS MCBNUM$, 2 AS SEG$, 2 AS PCOUNT$, 4 AS RTIME$,
4 AS LTIME$, 8 AS STDATE$, 4 AS STTIME$, 2 AS STCHAN$, 2 AS NUMCHAN$
90 GET #1
100 PRINT"          THE MCB IS NUMBER";CVI(MCBNUM$)
102 PRINT"          THE MCB SEGMENT ";CVI(SEG$)
110 PRINT"          THE ACQUISITION DATE WAS";STDATE$
120 PRINT"          THE ACQUISITION TIME WAS ";STTIME$
130 B1% = ASC(MID$(RTIME$,1,1)):B1#=B1%
140 B2% = ASC(MID$(RTIME$,2,1)):B2#=B2%
150 B3% = ASC(MID$(RTIME$,3,1)):B3#=B3%
160 B4% = ASC(MID$(RTIME$,4,1)):B4#=B4%
170 'REMEMBER THE TIMES ARE IN 20 MILLISECOND TICS
175 RTIME = (B1#+256*B2#+65536!*B3#+16777216#*B4#)*.02
178 PRINT"          THE REAL TIME WAS : ";RTIME
180 REM PRINT"          THE REAL TIME WAS : ";FNCV4#(B1%,B2%,B3%,B4%)*.02
190 B1% = ASC(MID$(LTIME$,1,1)):B1#=B1%
200 B2% = ASC(MID$(LTIME$,2,1)):B2#=B2%
210 B3% = ASC(MID$(LTIME$,3,1)):B3#=B3%
220 B4% = ASC(MID$(LTIME$,4,1)):B4#=B4%
230 'REMEMBER THE TIMES ARE IN 20 MILLISECOND TICS
235 LTIME = (B1#+256*B2#+65536!*B3#+16777216#*B4#)*.02
236 PRINT"          THE LIVE TIME WAS : ";LTIME
240 REM PRINT"          THE LIVE TIME WAS : ";FNCV4#(B1%,B2%,B3%,B4%)*.02
241 LTIME = (B1#+256*B2#+65536!*B3#+16777216#*B4#)*.02
250 STCHAN% = CVI(STCHAN$)
260 NUMCHAN% = CVI(NUMCHAN$)
270 LASTCHAN% = STCHAN% + CVI(NUMCHAN$)-1
280 CLOSE #1
285 IF CORRIN>0 THEN LOCATE YLOC(0),1:GOTO 1520:REM jump back to input section
290 'NOW REOPEN WITH NEWLENGTH AND GET CHANNEL COUNTS
298 GOSUB 1000:REM - input parameters (last section) and print inputs (all)

300 OPEN SP$ AS #1 LEN = 4
310 FIELD #1, 1 AS F1$, 1 AS F2$, 1 AS F3$, 1 AS F4$
320 FOR I = STCH TO ENCH
330 GET #1, I + 8 'SKIP OVER HEADER
340 B1% = ASC(F1$): B2% = ASC(F2$): B3% = ASC(F3$)
341 B1#=B1%:B2#=B2%:B3#=B3%
345 COUNT# = B1#+256*B2#+65536!*B3#
350 REM COUNT# = FNCV3#(B1%,B2%,B3%)
355 NPC(I)=COUNT#
357 GOSUB 2000:REM - identify peaks while read spectrum above
358 IF YNCH$ <> "y" THEN GOTO 380
360 PRINT"CHANNEL = ";I-1;TAB(20);"COUNT = ";
370 PRINT USING "#####";COUNT#
380 NEXT
390 CLOSE #1

400 CHAIN "grabdkr2"

500 STOP

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```

1000 REM SUB for problem input parameters
1002 PRINT
1004 INPUT" (2) SAMPLE NAME :";ANAME$:YLOC(2)=CSRLIN-1:IF CORRIN>0 THEN LOCATE Y
LOC(0),1:GOTO 1520
1006 INPUT" (3) SAMPLE AGE (days) :";TDAYS:YLOC(3)=CSRLIN-1:IF CORRIN>0 THEN LOCA
TE YLOC(0),1:GOTO 1520
1015 PRINT
1020 INPUT " (4) ACTIVITY UNITS (eg nCi/cc)";AUNIT$:YLOC(4)=CSRLIN-1:IF LEN(AUNI
T$)>=8 THEN GOTO 1028
1022 SPARE$=" ":SLH=(8-LEN(AUNIT$))/2:ISLH=INT(SLH)
1024 IF SLH=ISLH THEN SL1=ISLH:SL2=ISLH:GOTO 1026
1025 SL1=ISLH+1:SL2=ISLH
1026 FOR SX=1 TO SL1:AUNIT$=SPARE$+AUNIT$:NEXT SX
1027 FOR SX=1 TO SL2:AUNIT$=AUNIT$+SPARE$:NEXT SX
1028 IF CORRIN>0 THEN LOCATE YLOC(0),1:GOTO 1520
1030 PRINT"--- Activity in pCi converted to above units with factors below"
1040 INPUT" (5) NUMERATOR FACTOR (eg 1.0E-06 for uCi)";UNUM:YLOC(5)=CSRLIN-1:IF
CORRIN>0 THEN LOCATE YLOC(0),1:GOTO 1520
1050 INPUT" (6) DENOMINATOR FACTOR (eg sample volume)";UDEM:YLOC(6)=CSRLIN-1:IF
CORRIN>0 THEN LOCATE YLOC(0),1:GOTO 1520
1060 RUNITS=UNUM/(UDEM*.037) :REM raw rate in cps - also in line 1525
1070 PRINT
1310 PRINT"--- Peak analysis parameters below"
1330 INPUT" (7) START CHANNEL (eg 50)";STCH:YLOC(7)=CSRLIN-1:IF CORRIN>0 THEN LO
CATE YLOC(0),1:GOTO 1520
1340 INPUT" (8) END CHANNEL (eg 3950)";ENCH:YLOC(8)=CSRLIN-1:IF CORRIN>0 THEN LO
CATE YLOC(0),1:GOTO 1520
1350 INPUT" (9) SEARCH CHANNELS PER PEAK (eg 8)";CRES:HCREC=CRES/2:YLOC(9)=CSRLI
N-1:IF CORRIN>0 THEN LOCATE YLOC(0),1:GOTO 1520
1360 INPUT "(10) +/- KEV FOR PEAK ID (eg 2)";EFIND:YLOC(10)=CSRLIN-1:IF CORRIN>0
THEN LOCATE YLOC(0),1:GOTO 1520
1500 REM check inputs scheme
1510 PRINT
1520 INPUT"Correct above inputs by number (0 for no corrections)";CORRIN:YLOC(0)
=CSRLIN-1
1525 RUNITS=UNUM/(UDEM*.037) :REM raw rate in cps - also in line 1060
1530 IF CORRIN = 0 THEN GOTO 1700
1540 IF CORRIN > 10 THEN LOCATE YLOC(0),1:GOTO 1520
1550 LOCATE YLOC(CORRIN) ,1
1560 ON CORRIN GOTO 65,1004,1006,1020,1040,1050,1330,1340,1350,1360
1700 INPUT"Include screen print of each channel (y/usually n)";YNCH$
1800 GOSUB 11000:REM printout of data id for sample
1999 RETURN

```

```
2000 REM sub to identify peaks
2010 IF I-STCH = 23 THEN GOSUB 12000
2020 IF I-STCH <= 23 THEN 2900:REM return
2030 B1R8 = -NPC(I-24)+B1R8+NPC(I-20)
2040 GR8 = -NPC(I-16)+GR8+NPC(I-8)
2050 B2R8 = -NPC(I-4)+B2R8+NPC(I)
2060 B1R4 = -NPC(I-18)+B1R4+NPC(I-16)
2070 GR4 = -NPC(I-14)+GR4+NPC(I-10)
2080 B2R4 = -NPC(I-8)+B2R4+NPC(I-6)
2090 B1R2 = -NPC(I-15)+B1R2+NPC(I-14)
2100 GR2 = -NPC(I-13)+GR2+NPC(I-11)
2110 B2R2 = -NPC(I-10)+B2R2+NPC(I-9)
2210 SA8=3:IF GR8+B1R8+B2R8>0 THEN SA8=3*SQR(GR8+B1R8+B2R8)
2220 SA4=3:IF GR4+B1R4+B2R4>0 THEN SA4=3*SQR(GR4+B1R4+B2R4)
2230 SA2=3:IF GR2+B1R2+B2R2>0 THEN SA2=3*SQR(GR2+B1R2+B2R2)
2240 A8=GR8-B1R8-B2R8
2250 A4=GR4-B1R4-B2R4
2260 A2=GR2-B1R2-B2R2
2300 IF IP<1 THEN IP=1:A2MAX=0:A4MAX=0:A8MAX=0:PEAK2=0:PEAK4=0:PEAK8=0
2400 IF A2>SA2 THEN GOSUB 12400:GOTO 2900
2410 IF PEAK2=1 THEN PRINT IP;" ";X2PK,FNENC(X2PK),A2MAX,PERA2,"2-pt":LOCH(IP)=
X2PK:GOSUB 12200:IP=IP+1:PEAK2=0:A2MAX=0:PEAK2T=1:GOTO 2900
2420 IF PEAK2T=1 AND A4>SA4 THEN 2900
2430 IF PEAK2T=1 AND A8>SA8 THEN 2900
2440 PEAK2T=0
2500 IF A4>SA4 THEN GOSUB 12500:GOTO 2900
2510 IF PEAK4=1 THEN PRINT IP;" ";X4PK,FNENC(X4PK),A4MAX,PERA4,"4-pt":LOCH(IP)=
X4PK:GOSUB 12200:IP=IP+1:PEAK4=0:A4MAX=0:PEAK4T=1:GOTO 2900
2520 IF PEAK4T=1 AND A8>SA8 THEN 2900
2530 PEAK4T=0
2600 IF A8>SA8 THEN GOSUB 12600:GOTO 2900
2610 IF PEAK8=1 THEN PRINT IP;" ";X8PK,FNENC(X8PK),A8MAX,PERA8,"8-pt":LOCH(IP)=
X8PK:GOSUB 12200:IP=IP+1:PEAK8=0:A8MAX=0
2900 RETURN
```

```

5000 REM - sub for sample/background/analysis menus
5010 PRINT"Select type of analysis below":PRINT
5020 PRINT"    (1) Results with background subtraction (usual case)"
5030 PRINT"    (2) Results without background subtraction (last resort)"
5080 PRINT:INPUT"Analysis number";SAMBAC
5085 DETLAB$(1)="OLDBOTTM":DETLAB$(2)="NEWBOTTM":DETLAB$(3)="PGTDETOR":DETLAB$(4)
)="NSIDEDET":DETLAB$(5)="WELLDETR"
5090 PRINT:PRINT
5100 PRINT"Select sample type per appropriate countrate units":PRINT
5110 PRINT"    (1) Normal low level activities - rates in cph"
5120 PRINT"    (2) Calibration standards - rates in cps"
5130 PRINT"    (3) Other cases - rates in cpm":PRINT
5140 INPUT"Sample type";SOP
5150 RTCN=3600:RTCN$="cph"
5160 IF SOP=2 THEN RTCN=1:RTCN$="cps"
5170 IF SOP=3 THEN RTCN=60:RTCN$="cpm"
5175 PRINT:PRINT:INPUT"Repeat this frame due to input errors (y/n)";YES$
5180 CLS:IF YES$<>"n" THEN 5010
5190 RETURN

```

```

9000 REM sub from line 31 - read in detector data
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 FOR I=1 TO 5
9020 FOR J=1 TO 3
9030 INPUT #3,GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
9040 INPUT #3,CE0H0(I,J)
9050 INPUT #3,CE1H0(I,J),CE0H1(I,J)
9060 INPUT #3,CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
9070 INPUT #3,CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
9080 NEXT J
9090 NEXT I
9095 CLOSE #3
9100 I=0:J=0
9200 RETURN

```



```

11000 REM - sub from sub 1000 - sample info printout
11002 LPRINT" ***** ";ANAME$;" *****"
11003 LPRINT:LPRINT:LPRINT
11010 LPRINT" ----- Sample Counting Information -----"
11020 LPRINT
11030 LPRINT"          Sample disk file ";SP$
11040 LPRINT
11050 LPRINT"          MCB number ";CVI(MCBNUM$)
11060 LPRINT"          Segment ";CVI(SEG$)
11070 LPRINT
11080 LPRINT"          Start time ";STTIME$
11090 LPRINT"          Date ";STDATE$:BGDATE$=STDATE$
11100 LPRINT
11110 LPRINT"          Live time ";LTIME;" sec"
11120 LPRINT"          Real time ";RTIME;" sec"
11130 LPRINT:LPRINT:LPRINT
11140 LPRINT" ----- Sample Analysis Information -----"
11150 LPRINT
11160 LPRINT"          Start channel ";STCH
11170 LPRINT"          End channel ";ENCH
11180 LPRINT
11185 LPRINT
11190 LPRINT"          Peak search channels ";CRES
11195 LPRINT
11200 LPRINT"          Isotope ID ( +/- keV ) ";EFIND
11205 LPRINT
11207 LPRINT"          Decay corrected to ";TDAYS;" days earlier"
11208 LPRINT
11210 LPRINT"          Activity units (pCi modified per factors below) ";AUNIT$
11220 LPRINT"          Numerator factor = ";UNUM
11230 LPRINT"          Denominator factor = ";UDEM
11240 LPRINT:LPRINT
11250 LPRINT" ----- Detector Status Information -----"
11260 LPRINT
11270 LPRINT"          ";DETNAME$(DETNAME);" with ";DETLAB$(6);".BKG and ";OTHERDET$
11280 LPRINT:LPRINT
11285 LPRINT:IF OPTDT6>0 THEN OPNUM=1
11290 LPRINT"Configuration = ";OPNUM;"....(1) SPECIAL (2) DIAPER (3) WELL (4) VI
AL"
11300 LPRINT
11310 IF OPNUM <> 4 THEN GOTO 11350
11320 LPRINT"Vial size = ";VIALN;".....(1) Large (2) Medium (3) Small"
11330 LPRINT"Sample height (mm) = ";HMM:LPRINT
11335 LPRINT
11350 LPRINT"Energy(keV) calibration:      EN = ";COENC;" + ";CIENC;"*CHAN"
11355 LPRINT
11360 LPRINT"FWHM(channel) calibration: FWHM =  SQR(";COFWHM;" + ";CIFWHM;"*CHAN
)"
11370 LPRINT
11380 LPRINT"Efficiency calibration: EFF = G*EXP(HYPERBOLA * POLYNOMIAL)*(1+PERT
URBATION)"
11385 LPRINT
11390 LPRINT"      G = global calibration factor = ";GOEFF;" D = LN(G) = ";LOG(GOEF
F)
11395 LPRINT
11400 LPRINT"      HYPERBOLA = A*SQR( B^2 + (LN(EN)-C)^2 ) with values below:
11410 LPRINT"      ( A = ";AOEFF;" B = ";BOEFF;" C = ";KOEFF;" )"
11415 LPRINT
11420 LPRINT"      POLYNOMIAL = C0 + C1*LN(EN) + C2*LN(EN)^2 + C3*LN(EN)^3 with val
ues below:"
11430 LPRINT"      ( C0 = ";COEFF;" C1 = ";C1EFF;" C2 = ";C2EFF;" C3 = ";C3EFF;" )"
11432 LPRINT"      ";ENX;" keV = crossover between low EN (above) and high EN (belo
w) cases"
11434 LPRINT"      ( C0 = ";TOEFF;" C1 = ";T1EFF;" C2 = ";T2EFF;" C3 = ";T3EFF;" )"
11435 LPRINT
11440 LPRINT"      PERTURBATION = P0 + P1*LN(EN) + P2*LN(EN)^2 + P3*LN(EN)^3 with v
alues below:"
11450 LPRINT"      ( P0 = ";POEFF;" P1 = ";P1EFF;" P2 = ";P2EFF;" P3 = ";P3EFF;" )"
11460 LPRINT:LPRINT:LPRINT
11500 RETURN

```

```

12000 REM subroutine from 2000 subroutine
12010 FOR KR=0 TO 3
12020 B1R8=B1R8+NPC(STCH + KR)
12030 B2R8=B2R8+NPC(STCH + 20 +KR)
12040 NEXT KR
12050 FOR KR=0 TO 7:GR8=GR8+NPC(STCH+8+KR):NEXT KR
12060 B1R4=NPC(STCH+6)+NPC(STCH+7)
12070 B2R4=NPC(STCH+16)+NPC(STCH+17)
12080 FOR KR=0 TO 3:GR4=GR4+NPC(STCH+10+KR):NEXT KR
12090 B1R2=NPC(STCH+9)
12100 B2R2=NPC(STCH+14)
12110 GR2=NPC(STCH+11)+NPC(STCH+12)
12115 PRINT:PRINT"peak channel   KeV           Area           %error           Rope":
PRINT
12120 RETURN

```

```

12200 REM - sub to test if new resolved peak found
12210 IF ABS(LOCH(IP)-LOCH(IP-1))>.47*FNFWHM(LOCH(IP)) THEN GOTO 12290
12220 LOCH(IP-1)=INT((LOCH(IP-1)+LOCH(IP))/2):IP=IP-1
12230 PRINT IP,LOCH(IP),"Above nonresolved peaks combined as one"
12290 RETURN

```

```

12400 REM - sub from line 2400
12410 PEAK2=1:A4MAX=0:A8MAX=0:PEAK4=0:PEAK8=0
12420 IF A2>A2MAX THEN X2PK=I-12:A2MAX=A2:PORA2=100*SA2/(3*A2)
12430 RETURN

```

```

12500 REM - sub from line 2500
12510 PEAK4=1:A8MAX=0:PEAK8=0
12520 IF A4>A4MAX THEN X4PK=I-12:A4MAX=A4:PORA4=100*SA4/(3*A4)
12530 RETURN

```

```

12600 REM - sub from line 2600
12610 PEAK8=1
12620 IF A8>A8MAX THEN X8PK=I-12:A8MAX=A8:PORA8=100*SA8/(3*A8)
12630 RETURN

```

```

40000 REM - subroutine from line 40 - energy calibrations
40005 PRINT
40010 PRINT"Energy calibration - enter two peaks as below"
40020 INPUT"      LOW ENERGY (eg 661.638 keV) ";ELOW
40030 INPUT"      LOW CHANNEL (eg 1321.20) ";CLOW
40040 INPUT"      HIGH ENERGY (eg 1332.56 keV) ";EHIGH
40050 INPUT"      HIGH CHANNEL (eg 2665.12) ";CHIGH
40060 C1ENC=(EHIGH-ELOW)/(CHIGH-CLOW)
40070 COENC=ELOW-C1ENC*CLOW
40100 RETURN

```

```

43000 REM - sub from line 43 - FWHM data
43010 PRINT"FWHM calibration - 2 input cases "
43020 INPUT"      LOW ENERGY (eg 100 keV)";ELOW
43030 INPUT"      LOW FWHM (eg 1.5 keV)";FWHMLO
43040 INPUT"      HIGH ENERGY (eg 1500 keV)";EHIGH
43050 INPUT"      HIGH FWHM (eg 2.5 keV)";FWHMHI
43060 C1FWHM = (FWHMHI^2-FWHMLO^2)/(EHIGH-ELOW)
43070 COFWHM = FWHMLO^2 - C1FWHM*ELOW
43080 C1FWHM = C1FWHM/C1ENC
43090 COFWHM = COFWHM/C1ENC^2
43100 RETURN

```

```

46000 REM - subroutine from line 46 - detector efficiencies - part 1
46005 DETLAB$(6)="

```

```

46100 REM - subroutine from line 47 - detector efficiencies - part 2
46105 CLS:OPTDT6=0
46110 GOEFF=1:A0EFF=1:B0EFF=1:U0EFF=0:C0EFF=1:C1EFF=0:C2EFF=0:C3EFF=0
46115 POEFF=0:P1EFF=0:P2EFF=0:P3EFF=0:D0EFF=0:D1EFF=0:D2EFF=0:D3EFF=0:ENX=5000
46117 IF DETN=6 THEN GOSUB 47000
46118 PRINT:IF OPTDT6=1 THEN GOSUB 46500
46119 IF OPTDT6>0 THEN 46200
46120 PRINT"Efficiency calibration data for ";DETNAME$(DETNI)
46130 PRINT
46140 PRINT"          (1) Special samples (manual input)"
46145 PRINT"          (2) Diaper samples  (auto input)"
46150 PRINT"          (3) Well samples   (auto input)"
46160 PRINT"          (4) Vial samples    (auto input)"
46165 PRINT
46170 INPUT"Calibration case number";OPNUM:PRINT
46180 ON OPNUM GOSUB 46500,46700,46800,46900
46190 REM eff sub-parts 2a  2b    2c    2d
46200 RETURN

46500 REM - manual input efficiencies - part 2a of efficiency calcs/line46180
46505 INPUT"Type of fit - (0) None<eff=1> (1) Polynomial, (2) Hyperbola, (3) Bot
h ";PHB:PRINT
46510 ON PHB GOTO 46600,46530,46520
46515 IF PHB=0 THEN A0EFF=0:GOTO 46690
46520 PRINT"LN(EFF) = D + A*SQR(B^2+(LN(E)-C)^2) * (C0 + C1*LN(E) + C2*LN(E)^2 +
C3*LN(E)^3)"
46525 IF PHB=3 THEN GOTO 46535
46530 PRINT"LN(EFF) = D + A*SQR(B^2+(LN(E)-C)^2)":PRINT
46535 U0EFF=1
46540 INPUT"          D";DAEFF:GOEFF=EXP(DAEFF)
46550 INPUT"          A";A0EFF
46560 INPUT"          B";B0EFF
46570 INPUT"          C";K0EFF
46590 IF PHB=3 THEN GOTO 46620
46595 IF PHB=2 THEN GOTO 46690
46600 PRINT"LN(EFF) = C0 + C1*LN(E) + C2*LN(E)^2 + C3*LN(E)^3":PRINT
46610 U0EFF=0
46612 INPUT" Crossover energy (keV).....if none enter 0 ";ENX:IF ENX=0 THEN ENX
=5000
46614 PRINT"          Coefficients below crossover point"
46620 INPUT"          C0";C0EFF
46630 INPUT"          C1";C1EFF
46640 INPUT"          C2";C2EFF
46650 INPUT"          C3";C3EFF:IF PHB=3 THEN GOTO 46690
46651 IF ENX = 5000 THEN GOTO 46690
46652 PRINT"          Coefficients above crossover point"
46655 INPUT"          C0";T0EFF:D0EFF=T0EFF-C0EFF
46660 INPUT"          C1";T1EFF:D1EFF=T1EFF-C1EFF
46665 INPUT"          C2";T2EFF:D2EFF=T2EFF-C2EFF
46670 INPUT"          C3";T3EFF:D3EFF=T3EFF-C3EFF
46690 RETURN

```

```

46700 REM - diaper coefficients effs - part 2b of efficiency calib/line46180
46710 IF DETN=1 THEN COEFF=-32.9019:C1EFF=15.5286:C2EFF=-2.63121:C3EFF=.137454
46720 IF DETN=2 THEN COEFF=-33.7619:C1EFF=15.949:C2EFF=-2.69313:C3EFF=.141663
46730 IF DETN=3 THEN COEFF=-44.2381:C1EFF=21.0238:C2EFF=-3.50398:C3EFF=.183542
46740 IF DETN=4 THEN PRINT"not available - make another choice"
46750 IF DETN=5 THEN COEFF=-30.373:C1EFF=14.4228:C2EFF=-2.4183:C3EFF=.125452
46760 RETURN

```

```

46800 REM - well coefficients effs - part 2c of efficiency calib/line46180
46810 IF DETN<>5 THEN PRINT "NOT APPLICABLE - MAKE ANOTHER CHOICE"
46820 UOEFF=1:AOEFF=-.921*SQR(1.6952):BOEFF=SQR(1.21/1.6952):KOEFF=LOG(60)
46830 GOEFF=EXP(.921*.9)
46850 RETURN

```

```

46900 REM - vial coefficients effs - part 2d of efficiency calib/line46180
46910 PRINT"Vial sizes":PRINT
46911 PRINT" (1) Large"
46912 PRINT" (2) Medium"
46913 PRINT" (3) Small" :PRINT
46920 INPUT"Vial size number":VIALN:PRINT
46930 INPUT"Vial sample height (mm) " :HMM:H=HMM/10
46940 UOEFF=1:AOEFF=AOEFF(DETN,VIALN):BOEFF=BOEFF(DETN,VIALN):KOEFF=KOEFF(DETN,VIALN)
46950 POEFF=CEOH0(DETN,VIALN)+CEOH1(DETN,VIALN)*H+CEOH2(DETN,VIALN)*H^2+CEOH3(DETN,VIALN)*H^3
46955 P1EFF=CE1H0(DETN,VIALN)+CE1H1(DETN,VIALN)*H+CE1H2(DETN,VIALN)*H^2
46960 P2EFF=CE2H0(DETN,VIALN)+CE2H1(DETN,VIALN)*H
46965 P3EFF=CE3H0(DETN,VIALN)
46970 GOEFF=GOEFF(DETN,VIALN)/(H+HOEFF(DETN,VIALN))^2
46975 DAEFF=LOG(GOEFF)
46990 RETURN

```

```

47000 REM- sub for detector #6 (other detector)
47001 ON ERROR GOTO 47120
47002 CLS
47003 INPUT"Descriptive name of detector";DETNAME$(6):PRINT:PRINT
47004 IF SAMBAC <> 1 THEN 47015
47005 ISAVE=0:INPUT"Background file (-----BKG)";DETLAB$(6):PRINT:PRINT
47006 FOR I=1 TO LEN(DETLAB$(6))
47007 IF MID$(DETLAB$(6),I,1)="." THEN ISAVE=I-1
47008 NEXT I
47009 IF ISAVE>0 THEN DETLAB$(6)=LEFT$(DETLAB$(6),ISAVE)
47010 OPEN DETLAB$(6)+".BKG" FOR INPUT AS #3
47011 CLOSE #3
47015 PRINT"Detector efficiency options":PRINT
47020 PRINT"      (1) Manual input (includes eff=1 case )
47030 PRINT"      (2) File input":PRINT
47040 INPUT"Option";OPTDT6
47050 IF OPTDT6<>2 THEN 47200
47060 PRINT:PRINT
47070 INPUT"Detector calibration file (-----DCF)";OTHERDET$
47080 OPEN OTHERDET$ FOR INPUT AS #3
47090 INPUT #3,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EFF,C2EFF,C3EFF
47100 INPUT #3,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
47110 CLOSE #3
47120 IF ERR=53 THEN PRINT:INPUT"Above file not found. Press return for retry";Z
Z:CLS:RESUME 47000
47200 RETURN

```

```

60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";DETNAME$(6)
60006 PRINT
60010 PRINT "EN", "EFF"
60011 PRINT"keV", " # "
60020 PRINT USING"#####";88.03;:PRINT USING"#####";FNEFF(88.03)
60030 PRINT USING"#####";122.06;:PRINT USING"#####";FNEFF(122.06)
60040 PRINT USING"#####";165.85;:PRINT USING"#####";FNEFF(165.85)
60050 PRINT USING"#####";279.19;:PRINT USING"#####";FNEFF(279.19)
60060 PRINT USING"#####";391.69;:PRINT USING"#####";FNEFF(391.69)
60070 PRINT USING"#####";514!;:PRINT USING"#####";FNEFF(514!)
60080 PRINT USING"#####";661.64;:PRINT USING"#####";FNEFF(661.64)
60090 PRINT USING"#####";898.02;:PRINT USING"#####";FNEFF(898.02)
60100 PRINT USING"#####";1173.21;:PRINT USING"#####";FNEFF(1173.21)
60110 PRINT USING"#####";1332.56;:PRINT USING"#####";FNEFF(1332.56)
60120 PRINT USING"#####";1836.01;:PRINT USING"#####";FNEFF(1836.01)
60130 INPUT"Need to re-enter new efficiency case (y/n)";NEWEFF$
60140 RETURN

```

GRABDKR2: Program Structure Reference

Main	<--- Subroutines and [files]
1-12/DIM and COMMON	
30/Gammas: IsoIDs	<--- 8000-8100/File read driver <--- [B:ISOLIBRY.LIB]
41-60/Functs: GRABDKR1	
391-397/Header: Multiplets	
398-400/Peaks :Analys	<--- 4000-4900/peak analyses
Isotopes	<--- 14500-15900/Multiplet option <--- 16000-16200/Variable bkgs <--- 16500-16700/B _i s LS fit <--- 16800-16899/Find A so F=1 <--- 14200-14250/ISO ID/Calcs <--- 14000-14130/Singlet cent & FWHM <--- 14200-14250/Singlet ID/ISO Calcs
410-412/Debug : test	
413/F-MDAs: print #	
450/MDAs : Analys	<--- 3000-3400/merge peaks & selected MDAs <--- 13000-13100/E to CHAN calc <--- 13300-13490/Selected MDAs calcs
460/Bkgnd : Option	<--- 5200-5400/User file read driver <--- [<u>backgnd</u> .BKG]
461-467/Peaks : Header	
475-485/Peaks : Print	<--- 3500-3690/Print peak table data <--- 3900-3990/Notations for "±" <--- 3800-3830/REM tests
490-495/Supplementary analysis	<--- 6000-6500/File write driver <--- [B:DATACALB.DAT] <--- [B:DATASPEC.DAT] <--- [B:DATAISOS.DAT] <--- [B:DATAPEAK.DAT] <--- [B:DATAMISC.DAT]
500/Stop	

```

1 'VERSION GRABDKR2.BAB 3/12/99 fix
2 DIM H1(150),H2(150),GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3),A(2
0),MINXM(20),MCENT(20)
3 COMMON H1(),H2(),GOEFF(),HOEFF(),AOEFF(),BOEFF(),KOEFF(),A(),MINXM(),MCENT()
4 DIM CEOH0(5,3),CE1H0(5,3),CE0H1(5,3),CE2H0(5,3),CE1H1(5,3),CE0H2(5,3),CE3H0(5,
3),CE2H1(5,3),CE1H2(5,3),CE0H3(5,3),GEOM$(10)
5 COMMON CEOH0(),CE1H0(),CE0H1(),CE2H0(),CE1H1(),CE0H2(),CE3H0(),CE2H1(),CE1H2()
,CE0H3(),GEOM$()
6 DIM YLOC(20),DETNAME$(10),BENERGY(150),BRATE(150),BERR(150),DETLAB$(10),ISOTH(25
0),MDA(250),ISOACT(250),LIBEN(250),SBRATE(150),SBERR(150)
7 COMMON YLOC(),DETNAME$(),BENERGY(),BRATE(),BERR(),DETLAB$(),ISOTH(),MDA(),ISOACT
(),LIBEN(),SBRATE(),SBERR()
8 DIM RATE(150),ENERGY(150),ISOEN(250),ISOIDS$(250),ISO$(250),ISOGAM(250),NPC(409
6),AREA(150),EAREA(150),LOCH(150),TAIL(150),FWHM(150),CENT(150)
9 COMMON RATE(),ENERGY(),ISOEN(),ISOIDS$(),ISO$(),ISOGAM(),NPC(),AREA(),EAREA(),L
OCH(),TAIL(),FWHM(),CENT(),FACILITY$,DETLAB$,DETN,LIBRY$
10 COMMON LTIME,RTIME,STTIME,STDATE$,LOCH$,NPC,COENC,C1ENC,TDAYS,RUNITS,SAMBAC,S
TCH,ENCH,CRES,HCRES,EFIND,SBRATE,RATE,RATERR,SBERR,CENT,FWHM,TAIL,AREA,RTCN,ACTR
AT,EAREA,IP,SENSIT,COFWHM,C1FWHM,ANAME$,RTCN$,AUNIT$
11 COMMON GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,COEFF,C1EFF,C2EFF,C3EFF,EN,ENX
12 COMMON DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF,FETHICK

30 GOSUB 8000:REM read in isotope data

41 DEF FNENC(CHAN)= COENC + C1ENC*CHAN
44 DEF FNFWMH(CHAN)=SQRT( COFWHM + C1FWHM*CHAN )
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQRT(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)

391 LPRINT:REM 2/4/99 earlier lines 391-397 now 461-467 to allow below
392 LPRINT" ***** ";ANAME$;" *****"
393 LPRINT:LPRINT:LPRINT" ----- Multiplet Peak Details -----
-----"
394 LPRINT:LPRINT
395 LPRINT" Peak ----- Channel ----- Area +/- Error Energy Isotope"
396 LPRINT" # min1 max min2 counts +/- counts keV Z-A"
397 LPRINT

398 IP=IP-1:REM correct rope search number of peaks
400 GOSUB 4000:REM - peak areas and isotope calcs

410 FOR XP=NMDA+1 TO KPMAX
411 REM IF ABS(ENERGY(XP)-250) < 50 THEN PRINT"Line 411 xp/energy/area";XP,ENERG
Y(XP),AREA(XP):REM debug exploration 12/98
412 NEXT XP

413 PRINT:PRINT"MDAs Flagged in Isotope Library = NMDA =" ;NMDA

450 GOSUB 3000:REM - merge identified peaks and MDA cases

455 REM PRINT"line 455 peak 25 area = ";AREA(25):REM debug exploration 12/98

460 IF SAMBAC=1 THEN GOSUB 5200:REM - input background data

461 LPRINT
462 LPRINT" ***** ";ANAME$;" *****"
463 LPRINT:LPRINT:LPRINT" ----- Detailed Sample Analysis -----
-----"
464 LPRINT:LPRINT
465 LPRINT "Peak Channel Energy FWHM Tail Counts Rate Bkgnd Isotope Acti
vity Error"
466 LPRINT " # # keV keV # # ";RTCN$;" ";RTCN$;"
Z-A ";AUNIT$;" N-stats";
467 LPRINT

475 GOSUB 3500:REM - output first results table

480 LPRINT "Key: spect spect spect spect spect spect file lib to-
left to-left";
485 LPRINT " - - lib calc - +/- +/- +/- - +
/- - "

490 PRINT:INPUT"Desire Supplementary Analyses (y/n)";YES$
495 IF YES$="y" THEN GOSUB 6000:REM - make files for supplementary analyses

500 STOP

```



```
3000 REM - sub to merge identified peaks and mda cases
3010 JOS=0:MP=0
3020 FOR XP=NMDA+1 TO KPMAX
3030 MP=MP+1
3040 JOS=JOS+1:ENERGY=ISOEN(JOS):GOSUB 13000:REM - calc channel from energy
3045 IF CHAN<STCH + 2*HCRES THEN GOTO 3040: REM - no isotopes below start chan
3050 IF ENERGY(XP)-ISOEN(JOS)>EFIND AND MDA(JOS)=0 THEN GOTO 3040
3060 IF ENERGY(XP)-ISOEN(JOS)>EFIND AND MDA(JOS)=1 THEN GOSUB 13300
3065 IF ENERGY(XP)-ISOEN(JOS)>EFIND AND MDA(JOS)=1 THEN GOTO 3030
3070 AREA(MP)=AREA(XP):EAREA(MP)=EAREA(XP):FWHM(MP)=FWHM(XP):TAIL(MP)=TAIL(XP)
3080 CENT(MP)=CENT(XP):RATE(MP)=RATE(XP):ENERGY(MP)=ENERGY(XP):LIBEN(MP)=LIBEN(X
P):H1(MP)=H1(XP):H2(MP)=H2(XP)
3085 ISOID$(MP)=ISOID$(XP):ISOACT(MP)=ISOACT(XP)
3090 IF ABS(ENERGY(XP)-ISOEN(JOS))<EFIND AND MDA(JOS) =1 THEN GOTO 3200
3100 JOS=JOS-1
3200 IF XP<KPMAX THEN GOTO 3300
3210 MP=MP+1
3220 JOS=JOS+1
3230 IF ISO$(JOS)="limit " THEN MP=MP-1:GOTO 3300
3240 IF MDA(JOS)=0 THEN GOTO 3220
3250 ENERGY=ISOEN(JOS):GOSUB 13000:REM energy to channel conv
3260 IF CHAN=>ENCH-4*FNFWMH(CHAN) THEN MP=MP-1:GOTO 3300
3270 GOSUB 13300:REM - sub to calculate undetected MDA peak parameters
3280 GOTO 3210
3300 NEXT XP
3350 MPMAX=MP
3400 RETURN
```

```

3500 REM - subroutine to print first table
3510 FOR KP=1 TO MPMAX
3511 PEKMDA=1:IF AREA(KP)=0 THEN AREA(KP)=1
3512 RATERR=EAREA(KP)/LTIME:ACTRAT=ISOACT(KP)*LTIME/AREA(KP)
3513 IRATE=RATE(KP)-SBRATE(KP):IRATER=SQR(RATERR^2 + SBERR(KP)^2)
3514 IF IRATE < 3*IRATER THEN PEKMDA=2
3520 LPRINT USING "###";KP;:LPRINT USING "#####.##";CENT(KP);
3530 LPRINT USING "#####.##";ENERGY(KP);:LPRINT USING "###.##";FWHM(KP);:LPRINT US
ING "###.##";TAIL(KP);
3540 LPRINT USING "#####.##";AREA(KP);:LPRINT USING "#####.##";RTCN*RATE(KP);:LPR
INT USING "#####.##";RTCN*SBRATE(KP);
3542 LPRINT " ";ISOID$(KP);" ";
3543 ON PEKMDA GOTO 3550,3544
3544 LPRINT " <";:LPRINT USING "###.##^--";3*IRATER*ACTRAT;
3546 LPRINT"3";:LPRINT CHR$(229);:VSIG=IRATE/IRATER:IF VSIG<0 THEN VSIG=0
3547 LPRINT USING"/#.##";VSIG;:LPRINT CHR$(229);
3548 GOTO 3580
3550 LPRINT " ";:LPRINT USING "###.##^--";IRATE*ACTRAT;
3560 LPRINT USING"#####.##";100*IRATER/IRATE;:LPRINT " %";
3580 LPRINT TAB(12);:LPRINT USING"#####.##";LIBEN(KP);:LPRINT USING"###.##";FNFWM
(CENT(KP))*CIENC;
3590 LPRINT " ";
3592 PMX=EAREA(KP):SPCS=8:DECI=1:GOSUB 3900
3594 PMX=RTCN*RATERR:SPCS=7:DECI=10:GOSUB 3900
3596 PMX=RTCN*SBERR(KP):SPCS=7:DECI=10:GOSUB 3900
3600 LPRINT " ";
3610 ON PEKMDA GOTO 3640,3620
3620 REM Less than calculation REMed out for MDA (line 3630)
3622 REM LPRINT " <";:LPRINT USING "###.##^--";ACTRAT*(YRATE+1.65*IRATER);
3625 REM LPRINT"v+1.65";:LPRINT CHR$(229);:GOTO 3670
3630 BKTOT = ((IRATER*LTIME)^2-IRATE*LTIME)/2:IF BKTOT<=0 THEN BKTOT=1
3632 MDACX = ACTRAT*(2.71+4.65*SQR(BKTOT))/LTIME
3634 LPRINT " <";:LPRINT USING "###.##^--";MDACX;
3636 LPRINT"MDA=c+b";:GOTO 3670
3640 VALEXP = INT(LOG(IRATE*ACTRAT)/LOG(10))
3645 LPRINT " ";
3650 PMX=IRATER*ACTRAT/10^VALEXP:SPCS=5:DECI=100:GOSUB 3900
3660 LPRINT
3670 LPRINT
3680 NEXT KP
3690 RETURN

```

```

3800 REM INPUT"pmx";PMX
3810 REM INPUT"deci";DECI
3820 REM INPUT"spcs";SPCS
3830 REM INPUT"prused";PRUSED

3900 REM - subroutine to put in proper +/- notations
3901 PMY=INT(DECI*PMX + .5):PPMY$=STR$(PMY)
3902 DECPL=INT(LOG(DECI)/LOG(10)+.5):PMY=PMY/DECI:PMY$=""
3903 IF LEN(PPMY$)<DECPL+1 THEN PPMY$=" 0"+RIGHT$(PPMY$,LEN(PPMY$)-1):GOTO 3903
3904 FOR PPP=1 TO LEN(PPMY$)
3905 PMY$=PMY$+MID$(PPMY$,PPP,1)
3906 IF PPP=LEN(PPMY$)-DECPL THEN IF PPP<LEN(PPMY$) THEN PMY$=PMY$+"."
3907 NEXT PPP
3913 IF DECPL=0 THEN GOTO 3920
3914 IF PMY < 1 THEN PMY$ = " 0"+RIGHT$(PMY$,LEN(PMY$)-1)
3916 REM IF PMY = INT(PMY) THEN PMY$=PMY$+" ":FOR DS=1 TO DECPL:PMY$=PMY$+"0":NE
XT DS:GOTO 3920
3917 REM IF LEFT$(RIGHT$(PMY$,DECPL+1),1) = "." THEN GOTO 3920
3918 REM PMY$=PMY$+"0":GOTO 3917
3920 IF SPCS-LEN(PMY$)<1 THEN 3922
3921 LPRINT STRING$(SPCS-LEN(PMY$)," ");
3922 ON PRUSED GOTO 3925,3930
3925 LPRINT CHR$(241);:GOTO 3940
3930 LPRINT " ";;LPRINT CHR$(8);:LPRINT "+";
3940 LPRINT RIGHT$(PMY$,LEN(PMY$)-1);
3990 RETURN

```

```

4000 REM examine detected peaks in detail
4001 KP=NMDA:ISO=1
4002 FOR JP=1 TO IP
4003 IF ABS(LOCH(JP+1)-LOCH(JP))<3.5*FNFWM(LOCH(JP)) THEN GOSUB 14500:GOTO 4500

4012 B1=0:B2=0:HCRES = INT(FNFWM(LOCH(JP)) + .5):IF HCRES < 3 THEN HCRES=3
4014 MAX3=0
4015 FOR L=LOCH(JP)-2*HCRES TO LOCH(JP)+2*HCRES
4016 SUM3=NPC(L-1)+NPC(L)+NPC(L+1)
4017 IF SUM3>MAX3 THEN MAX3=SUM3:MAXL=L
4018 NEXT L
4020 FOR L=1 TO HCRES
4030 B1=B1+NPC(LOCH(JP)-L)
4040 B2=B2+NPC(LOCH(JP)+L)
4050 NEXT L
4060 L1=LOCH(JP)-HCRES:L2=LOCH(JP)+HCRES
4070 H1=LOCH(JP)-1:H2=LOCH(JP)+1
4080 REM - find constant b1 background region
4090 NL1=NPC(L1-1):NH1=NPC(H1)
4100 B1=NL1+B1-NH1:B1AVE=B1/HCRES
4110 IF (NH1-B1AVE)>2*SQR(NH1+B1AVE/HCRES) THEN L1=L1-1:H1=H1-1:GOTO 4090
4120 REM - find constant b2 background region
4130 NL2=NPC(L2+1):NH2=NPC(H2)
4140 B2=NL2+B2-NH2:B2AVE=B2/HCRES
4150 IF (NH2-B2AVE)>2*SQR(NH2+B2AVE/HCRES) THEN L2=L2+1:H2=H2+1:GOTO 4130
4155 IF H2-H1+1 < 2*HCRES THEN H1=MAXL-HCRES-1:H2=MAXL+HCRES
4160 IF (H2-H1+1)/2<>INT((H2-H1+1)/2) THEN H1=H1-1
4170 L1=H1-(H2-H1+1)/2:L2=H2+(H2-H1+1)/2
4175 B1=0:G=0:B2=0
4180 FOR L=L1 TO H1-1
4190 B1=B1+NPC(L)
4200 NEXT L
4210 FOR L=H1 TO H2
4220 G=G+NPC(L)
4230 NEXT L
4240 FOR L=H2+1 TO L2
4250 B2=B2+NPC(L)
4260 NEXT L
4270 IF (G-B1-B2) < 3*SQR(G+B1+B2) THEN GOTO 4500
4275 IF MAXL=MAXLP THEN GOTO 4500
4280 KP=KP+1
4285 MAXLP=MAXL
4300 AREA(KP)=G-B1-B2:EAREA(KP)=SQR(G+B1+B2)
4310 A=AREA(KP)
4320 GOSUB 14000:REM centroid and fwhm
4330 FWHM(KP)=FWHM:TAIL(KP)=TAIL:CENT(KP)=CENT:H1(KP)=H1:H2(KP)=H2
4340 FWHM(KP)=FWHM(KP)*C1ENC:REM final fix for res in kev *****
4350 RATE(KP) = AREA(KP)/LTIME
4360 ENERGY(KP)=FNENC(CENT(KP))
4370 GOSUB 14200:REM isotope ident and calcs
4380 IF ABS(ENERGY(KP)-ISOEN(ISO+1))<EFIND THEN ISO=ISO+1:GOTO 4280
4500 NEXT JP
4550 KPMAX=KP
4900 RETURN

```

```
5200 REM - sub for background input
5210 DETFILE$=DETLAB$(DETN)+".BKG"
5220 OPEN DETFILE$ FOR INPUT AS #2
5230 CBACK=1
5240 IF EOF(2) THEN GOTO 5270
5250 INPUT #2,BENERGY(CBACK),BRATE(CBACK),BERR(CBACK)
5260 CBACK=CBACK+1:GOTO 5240
5270 CLOSE #2
5300 REM - merge background and sample data
5310 BADDER=1
5320 FOR KP=1 TO KPMAX
5325 SBRATE(KP)=0:SBERR(KP)=0
5330 IF BADDER = CBACK THEN KP=KPMAX:GOTO 5390:REM cback = 1 + act cases
5340 IF AREA(KP)<3*EAREA(KP) THEN GOTO 5390: REM MDA with no peak
5350 IF ENERGY(KP)-BENERGY(BADDER)>EFIND AND BADDER < CBACK-1 THEN BADDER=BADDER+
1:GOTO 5350:REM fixup 12/30/98 per mid spec run
5360 IF ABS(BENERGY(BADDER)-ENERGY(KP))>EFIND THEN GOTO 5390
5370 SBRATE(KP)=BRATE(BADDER):SBERR(KP)=BERR(BADDER)
5380 BADDER=BADDER+1
5390 NEXT KP
5400 RETURN
```

```

6000 REM- subroutine for supplementary analyses
6010 CLS
6020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
6030 PRINT"    (1) Background file development (GRABBACK)"
6040 PRINT"    (2) Detector efficiency calibration (GRABCALB)"
6050 PRINT"    (3) Peak/spectrum diagnostics (GRABDIAG)"
6060 PRINT"    (4) Peak/multiplet plot analysis (GRABPLOT)"
6070 PRINT"    (5) Analyses per isotopes (GRABISOS)":PRINT
6080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
6090 PRINT:PRINT"When data transfer is completed, type selected analysis (e.g. G
RABBACK) after":PRINT"C-prompt ( C> ) and press enter"
6100 OPEN "B:DATACALB.DAT" FOR OUTPUT AS #3
6110 WRITE #3,COENC,C1ENC,C0FWHM,C1FWHM,GOEFF,A0EFF,B0EFF,U0EFF,K0EFF,C0EFF,C1EF
F,C2EFF,C3EFF,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
6160 CLOSE #3
6170 OPEN "B:DATASPEC.DAT" FOR OUTPUT AS #3
6180 FOR I=STCH TO ENCH
6190 WRITE #3, NPC(I)
6200 NEXT I
6210 CLOSE #3
6220 OPEN "B:DATAISOS.DAT" FOR OUTPUT AS #3
6230 L=0
6240 L=L+1
6250 WRITE #3, ISO$(L),ISOTH(L),ISOEN(L),ISOGAM(L),MDA(L)
6260 IF ISO$(L)="limit " THEN 6280
6270 GOTO 6240
6280 CLOSE #3
6290 OPEN "B:DATAPEAK.DAT" FOR OUTPUT AS #3
6300 FOR KP=1 TO MPMAX
6310 RATERR=EAREA(KP)/LTIME:ACTRAT=ISOACT(KP)*LTIME/AREA(KP)
6330 WRITE #3,CENT(KP),ENERGY(KP),FWHM(KP),TAIL(KP),AREA(KP),RATE(KP),SBRATE(KP)
,ISOID$(KP),ACTRAT,LIBEN(KP),RATERR,SBERR(KP),H1(KP),H2(KP)
6350 NEXT KP
6360 CLOSE #3
6370 OPEN "B:DATAMISC.DAT" FOR OUTPUT AS #3
6380 WRITE #3,LTIME,STCH,ENCH,AUNIT$,UNUM,UEDEM,TDAYS,DETN,DETNAM$(DETN),DETLAB$(
DETN),BGDATE$
6390 CLOSE #3
6400 PRINT:PRINT"Data transfer complete - Proceed"
6500 RETURN

```

```

8000 REM - sub to read in isotope library data - lines 20000-23000
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 250
8020 INPUT #3,ISO$(ISO),ISOTH(ISO),ISOEN(ISO),ISOGAM(ISO),MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=250
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

```

```

13000 REM sub from sub 3000 - calc channel from energy
13010 AOEN = FNENC(0)
13020 ALEN = FNENC(1)-FNENC(0)
13030 CHANO = (ENERGY-AOEN)/ALEN
13040 CHAN = CHANO + (ENERGY-FNENC(CHANO))/ALEN
13050 IF ABS(ENERGY-FNENC(CHAN))>.1 THEN CHANO=CHAN:GOTO 13040
13055 RCHAN=CHAN
13060 CHAN=INT(CHAN+.5)
13100 RETURN

```

```

13300 REM-subroutine for MDA cases where no peaks found - from sub 3000
13310 H1=CHAN-INT(FNFWHM(CHAN))-1
13320 H2=CHAN+INT(FNFWHM(CHAN))
13330 L1=H1-(H2-H1+1)/2:L2=H2+(H2-H1+1)/2
13340 B1=0:G=0:B2=0
13350 FOR L=L1 TO H1-1
13360 B1=B1+NPC(L)
13370 NEXT L
13380 FOR L=H1 TO H2
13390 G=G+NPC(L)
13400 NEXT L
13410 FOR L=H2+1 TO L2
13420 B2=B2+NPC(L)
13430 NEXT L
13440 AREA(MP)=G-B1-B2:EAREA(MP)=SQRT(G+B1+B2):H1(MP)=H1:H2(MP)=H2
13450 ENERGY(MP)=ENERGY:TAIL(MP)=-1:ISOID$(MP)=ISO$(JOS):LIBEN(MP)=ISOEN(JOS)
13460 RATE(MP)=AREA(MP)/LTIME:IF AREA(MP)=0 THEN AREA(MP)=.1
13470 CENT(MP)=RCHAN:FWHM(MP)=(H2-H1+1)*CLENC
13480 ISOACT(MP)=(AREA(MP)/LTIME)*(2^(TDAYS/ISOTH(JOS)))*RUNITS/(ISOGAM(JOS)*FNEFF(ISOEN(JOS)))
13490 RETURN

```

```

14000 REM subroutine from subroutine 4000 - centroid and fwhm for peaks found
14010 BC1=B1/(H1-L1):BC2=B2/(L2-H2)
14020 FI=0:GL=0:L=0:DBCFI=0:FLAGA=0:FLAGB=0:FLAGC=0
14030 FOR LL=H1 TO H2
14035 L=L+1
14040 GL=GL+NPC(LL)
14050 FI=(GL-L*BC1+DBCFI)/(A-(BC1-BC2)/2)
14060 IF FL>=.16 AND FI<=.16 THEN SIGA=LL-(1/(FL-FI))*(FL-.16):FLAGA=1
14070 IF FL>=.5 AND FI<=.5 THEN CENT=LL-(1/(FL-FI))*(FL-.5):FLAGC=1
14080 IF FL>=.84 AND FI<=.84 THEN SIGB=LL-(1/(FL-FI))*(FL-.84):FLAGB=1
14090 FI=FL:DBCFI=DBCFI+(BC1-BC2)*FI
14100 NEXT LL
14110 FWHM=(2.355/2)*(SIGB-SIGA)
14115 IF SIGB-SIGA=0 THEN TAIL=-4:GOTO 14125
14116 IF SIGB-CENT=0 THEN TAIL=-5:GOTO 14125
14120 TAIL=(CENT-SIGA)/(SIGB-CENT)
14125 IF FL<0 THEN FWHM=H2-H1+1:TAIL=-2:CENT=(H1+H2)/2
14127 IF FLAGA*FLAGB*FLAGC=0 THEN FWHM=H2-H1+1:TAIL=-3:CENT=(H1+H2)/2
14130 RETURN

```

```

14200 REM subroutine from sub 4000 - isotope id and calcs
14210 IF(ENERGY(KP)-ISOEN(ISO))>EFIND THEN ISO=ISO+1:GOTO 14210
14220 IF ABS(ENERGY(KP)-ISOEN(ISO))>EFIND THEN ISOID$(KP)="No-Lib":ISOACT(KP) =
RATE(KP)*RUNITS/FNEFF(ENERGY(KP)):GOTO 14250
14230 ISOID$(KP)=ISO$(ISO):LIBEN(KP)=ISOEN(ISO):MDA(ISO)=0
14235 REM** case for two or more acceptable ids of peak - fixup in line 4380
14240 ISOACT(KP)=RATE(KP)*(2^(TDAYS/ISOTH(ISO)))*RUNITS/(ISOGAM(ISO)*FNEFF(ISOEN
(ISO)))
14250 RETURN

```



```

14500 REM sub for multiplets - from line 4003
14510 NMULT=2:KP=KP+1
14514 REM
14515 REM - find all peaks of multiplet
14520 IF ABS(LOCH(JP+NMULT)-LOCH(JP+NMULT-1))<3*FNFWHM(LOCH(JP+NMULT-1)) THEN NM
ULT=NMULT+1:GOTO 14520
14524 REM
14525 REM - find multiplet centroids
14530 FOR XMULT=0 TO NMULT-1
14540 CENT(KP+XMULT)=LOCH(JP+XMULT)+.5:REM prevalue/mod line 15485 2/9/99
14570 NEXT XMULT
14574 MENERGY=FNENC( (CENT(KP) + CENT(KP+NMULT-1))/2 ):REM keV 2/9/99 rev
14575 MFWHM=FNFWHM( (CENT(KP) + CENT(KP+NMULT-1))/2 ):REM chn 2/9/99 rev
14576 REM
14577 REM - find b1 and b2 for multiplet ends
14580 B1=0:B2=0:HCRES=INT(MFWHM+.5):IF HCRES<3 THEN HCRES=3
14590 FOR L=1 TO HCRES
14600 B1=B1+NPC(LOCH(JP)-L)
14610 B2=B2+NPC(LOCH(JP+NMULT-1)+L)
14620 NEXT L
14630 L1=LOCH(JP)-HCRES:L2=LOCH(JP+NMULT-1)+HCRES
14640 H1=LOCH(JP)-1:H2=LOCH(JP+NMULT-1)+1
14649 REM
14650 REM - find constant b1 background region
14660 NL1=NPC(L1-1):NH1=NPC(H1)
14670 B1=NL1+B1-NH1:B1AVE=B1/HCRES
14680 IF (NH1-B1AVE)>2*SQR(NH1+B1AVE/HCRES) THEN L1=L1-1:H1=H1-1:GOTO 14660
14685 IF CENT(KP)-H1<HCRES THEN H1=INT(CENT(KP)-HCRES-.5):REM 3/8/99
14689 REM
14690 REM - find constant b2 background region
14700 NL2=NPC(L2+1):NH2=NPC(H2)
14710 B2=NL2+B2-NH2:B2AVE=B2/HCRES
14720 IF (NH2-B2AVE)>2*SQR(NH2+B2AVE/HCRES) THEN L2=L2+1:H2=H2+1:GOTO 14700
14725 IF H2-CENT(KP+NMULT-1)<HCRES THEN H2=INT(CENT(KP+NMULT-1)+HCRES+.5):REM 3/
8/99
14730 B1=0:B2=0:L1=H1-HCRES:L2=H2+HCRES
14740 FOR L=H1-1 TO L1 STEP -1
14742 IF L=H1-1 THEN CHB1=1:GOTO 14750
14744 IF NPC(L)-B1/CHB1 > 3*SQR(NPC(L)+B1/(CHB1^2)) THEN 14760
14746 CHB1=CHB1+1
14750 B1=B1+NPC(L)
14760 NEXT L
14770 FOR L=H2+1 TO L2
14772 IF L=H2+1 THEN CHB2=1:GOTO 14780
14774 IF NPC(L)-B2/CHB2 > 3*SQR(NPC(L)+B2/(CHB2^2)) THEN 14790
14776 CHB2=CHB2+1
14780 B2=B2+NPC(L)
14790 NEXT L
14795 CHB12=CHB1+CHB2
14799 REM
14800 REM - find minima between peaks
14810 MINXM(0)=H1-1:MINXM(NMULT)=H2:REM h1-1 to correct to h1 in line XXXXX
14820 FOR XMULT=0 TO NMULT-2
14825 AMIN=10^6:AMIN1=10^6:LOCP0=LOCH(JP+XMULT):LOCP1=LOCH(JP+XMULT+1)
14830 FOR L=LOCP0 TO LOCP1
14840 AM=NPC(L)+NPC(L+1)
14841 AM1 = (NPC(L)+NPC(L+1))/2 - (NPC(LOCP0) + (L+.5-LOCP0)*(NPC(LOCP1)-NPC(LOC
P0)))/(LOCP1-LOCP0) )
14850 IF AM<AMIN THEN MINXM(XMULT+1)=L+.51:AMIN=AM:REM 0.51 2/9/99
14851 IF AM1<AMIN1 THEN MINX1=L+.52:AMIN1=AM1:REM 0.52 2/9/99

```

```

14860 NEXT L
14861 IF MINXM(XMULT+1)-LOCP0-.5 > 1 AND LOCP1+.5-MINXM(XMULT+1) > 1 THEN 14870:
REM abs minimum found 2/9/99 rev
14862 IF MINX1-LOCP0-.5 > 1 AND LOCP1+.5-MINX1 > 1 THEN MINXM(XMULT+1)=MINX1:GOT
O 14870:REM rel minimum found 2/9/99 rev
14863 MINXM(XMULT+1) = INT((LOCP0*NPC(LOCP1)+LOCP1*NPC(LOCP0))/(NPC(LOCP0)+NPC(L
OCP1)) + .5)+.53:REM inverse average minimum/ 0.53 2/9/99
14864 IF MINXM(XMULT+1)-LOCP0-.5<.5 THEN MINXM(XMULT+1)=LOCP0+1.53:REM 3/12/99
14865 IF LOCP1+.5-MINXM(XMULT+1)<.5 THEN MINXM(XMULT+1)=LOCP1-.47:REM 3/12/99
14870 NEXT XMULT
14879 REM
14880 REM - find total area of multiplet
14885 G=0
14890 FOR L=H1 TO H2
14900 G=G+NPC(L)
14910 NEXT L
14920 H12=H2-H1+1
14925 FLAGA=0:FLAGB=0:FLAGC=0
14930 A=G-.5*(B1/CHB1+B2/CHB2)*H12:ERRA=SQR(G+.25*(B1/CHB1^2+B2/CHB2^2)*H12^2)
14931 IF A > 3*ERRA THEN 14950
14932 IF B1/CHB1>B2/CHB2 THEN B1=B2:CHB1=CHB2:REM - min background
14933 IF B2/CHB2>B1/CHB1 THEN B2=B1:CHB2=CHB1
14934 CHB12=CHB1+CHB2
14935 A=G-H12*(B1+B2)/(CHB12):ERRA=SQR(G+(B1+B2)*(H12/(CHB12))^2)
14936 FLAGB=2
14940 REM if a<3*errra then goto end of subroutine
14949 REM
14950 REM - get fractional areas by integral technique
14951 ASAVE=A:REM 3/12/99
14955 FOR LL=0 TO 20:A(LL)=0:NEXT LL
14960 BC1=B1/(CHB1):BC2=B2/(CHB2)
14965 PWTC=0:WTCH=0:REM INITILIZE FOR PEAK C.G. 2/9-10/99
14970 IF FLAGB=2 THEN FI=0:GL=0:L=0:DBCFI=0:GOTO 14975:REM sloping bkgnd fix 149
71 12/21/98 except for FLAGB=2 of 12/30/98
14971 GOSUB 16000:REM sloping bkgnd fix 12/21/98
14972 FI=0:GL=0:L=0:DBCFI=0:REM sloping bkgnd fix 12/21/98
14973 PFI=0:PGL=0:PDBCFI=0:REM add dF/dB info 12/29/98
14975 XMULT=1:REM - will shift back to zero start later - lines
14980 FOR LL=H1 TO H2
14990 L=L+1:REM channel L relative to H1-1 origin as 0
15000 IF FLAGB=2 THEN GL=GL+NPC(LL):GOTO 15005:REM sloping background fix 15001
12/21/98 except for FLAG=2 of 12/30/98
15001 GL=GL+NPC(LL)-SLB12*L-QUD12*L^2-CUB12*L^3:REM sloping bkgnd fix 1/29/99
15002 PGL=PGL+NPC(LL)-SLB12*L-QUD12*L^2-CUB12*L^3:REM add dF/dA info 1/29/99
15005 IF FLAGB=2 AND (A-(BC1-BC2)/2)=0 THEN FI=GL-L*BC1+DBCFI:GOTO 15020 ELSE GO
TO 15010:REM slope 12/21 except for FLAGB=2 of 12/30/98
15006 IF (A-BDELTA/2)=0 THEN FI=GL-L*CBC+DBCFI:REM slope bk 1/13/99
15007 IF (PA-BDELTA/2)=0 THEN PFI=PGL-L*CBC+PDBCFI:GOTO 15020:REM 1/13/99
15008 IF (A-BDELTA/2)=0 THEN GOTO 15020:REM 1/13/99
15010 IF FLAGB=2 THEN FI=(GL-L*BC1+DBCFI)/(A-(BC1-BC2)/2):GOTO 15020:REM sloping
b 15011 12/21/98 except for FLAGB=2 of 12/30/98
15011 FI=(GL-L*CBC+DBCFI)/(A-BDELTA/2):REM sloping b fix 12/21/98
15012 PFI=(PGL-L*CBC+PDBCFI)/(PA-BDELTA/2):REM dF/dA 1/13/99
15020 IF LL>MINXM(XMULT) THEN A(XMULT)=FI:REM XMULT=XMULT+1 line 15024 2/10/99
15021 IF ABS(LL-CENT(KP+XMULT-1)) < 2 THEN PWTC=PWTC+LL*(FI-FI):REM cp 2/9-10
15022 IF ABS(LL-CENT(KP+XMULT-1)) < 2 THEN WTCH=WTCH+FI-FI:REM peak cp 2/9-10/9
15023 IF LL>MINXM(XMULT) AND WTCH>0 THEN MCENT(XMULT-1)=PWTC/WTCH:REM peak c.g.
2/9-10/99
15024 IF LL>MINXM(XMULT) THEN PWTC=0:WTCH=0:XMULT=XMULT+1:REM c.g. 2/9-10/99
15030 IF FLAGB=2 THEN FI=FI:DBCFI=DBCFI+(BC1-BC2)*FI:GOTO 15040:REM sloping B 15

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031 12/21/98 except for FLAGB=2 of 12/30/98
15031 FI=FL:DBCFI=DBCFI+(BDELTA)*FI
15032 PFI=PFL:PDBCFI=PDBCFI+(BDELTA)*PFI:REM 1/13/99
15040 NEXT LL
15041 IF FLAGB=2 THEN GOTO 15045: REM fixup 12/30/98
15042 IF PFI-FI=0 THEN GOTO 15045:REM 3/2/99 zero divide fix line 16820
15043 IF ABS(FI-1)>.001 THEN GOSUB 16800:GOTO 14972:REM find FI=1 12/29
15045 A(NMULT)=FL:A(0)=0:REM - nail down these
15049 REM
15050 REM - rearrange above areas which are one-sided integrals
15060 FOR XMULT=0 TO NMULT-1
15065 IF A(NMULT)=0 THEN A(NMULT)=1
15070 A(XMULT)=(A(XMULT+1)-A(XMULT))/A(NMULT):REM ASSURED NORMALIZATION
15075 IF A(XMULT)<=0 THEN FLAGA=1
15080 NEXT XMULT
15090 REM above a( ) is 0th order multiplet analysis (TD( ) for A( ) later)
15480 FOR XMULT=0 TO NMULT-1
15482 IF ABS(MCENT(XMULT)-CENT(KP+XMULT))<.5 THEN GOTO 15490:REM 2/9+3/12/99
15485 CXM=CENT(KP+XMULT):REM rev 2/9/99
15486 MCENT(XMULT) = (CXM-.5)*NPC(CXM-.5)+(CXM+.5)*NPC(CXM+.5):REM add 2/9/99
15487 IF NPC(CXM-.5)+NPC(CXM+.5)=0 THEN MCENT(XMULT)=CXM:GOTO 15490:REM 3/2/99
15488 MCENT(XMULT) = MCENT(XMULT)/(NPC(CXM-.5)+NPC(CXM+.5)):REM add 2/9/99
15490 NEXT XMULT
15500 REM setup to print results
15510 FOR XMULT=0 TO NMULT-1
15515 CENT(KP)=MCENT(XMULT)
15520 ENERGY(KP)=FNENC(CENT(KP))
15521 IF FLAGA=0 THEN 15530:REM - otherwise negative or zero a()
15522 GXMULT=0:MINXMQ=INT(MINXM(XMULT)+1):MINXMP=INT(MINXM(XMULT+1))
15523 FOR LL=MINXMQ TO MINXMP:GXMULT=GXMULT+NPC(LL):NEXT LL
15524 B1XM=BC1+(BC2-BC1)*(MINXMQ-H1)/(H2-H1)
15525 B2XM=BC1+(BC2-BC1)*(MINXMP-H1)/(H2-H1)
15526 BXM=.5*(B1XM+B2XM)*(MINXMP-MINXMQ+1):IF BXM<0 THEN FLAGB=1
15527 AREA(KP)=GXMULT-BXM:RATE(KP)=AREA(KP)/LTIME:EAREA(KP)=SQR(GXMULT+ABS(BXM))

15528 IF AREA(KP)<0 AND FLAGA=1 THEN B1XM=NPC(MINXMQ-1):B2XM=NPC(MINXMP+1):FLAGA
=2:GOTO 15526
15529 GOTO 15560
15530 AREA(KP)=A(XMULT)*A:RATE(KP)=AREA(KP)/LTIME
15535 REM IF ABS(ENERGY(KP)-250) < 50 THEN PRINT"Line 15535 jp/kp/energy/area)":
JP,KP,ENERGY(KP),AREA(KP):REM 12/98 debugger
15536 REM IF JP=11 THEN INPUT"continue(y/n) or ctl-bk";YES:REM debugger 12/98
15540 EAREA(KP)=ERRA*SQR(A(XMULT))
15560 FWHM(KP)=NMULT+FLAGA/10+FLAGB/100:TAIL(KP)=XMULT+1+FLAGA/10+FLAGB/100
15565 IF FLAGA>0 THEN FLAGA=1
15569 IF AREA(KP)=0 THEN AREA(KP)=1:RATE(KP)=AREA(KP)/LTIME
15570 GOSUB 14200:REM iso ident
15573 H1END=0:IF MINXM(XMULT)=H1-1 THEN H1END=.5:REM 3/8/99
15574 H2END=0:IF MINXM(XMULT+1)=H2 THEN H2END=.5:REM 3/8/99 and 15575
15575 LPRINT USING" ### #####.## ###.## #####.## +/ - #### #####.## ";
XMULT+1,MINXM(XMULT)-H1END,MCENT(XMULT),MINXM(XMULT+1)+H2END,AREA(KP),EAREA(KP),
ENERGY(KP);
15576 LPRINT ISOID$(KP):REM lines 15575-15576 added 2/4/99 for mult params
15580 IF ABS(ENERGY(KP)-ISOEN(ISO+1))<EFIND THEN ISO=ISO+1:KP=KP+1:GOTO 15515
15590 KP=KP+1:JP=JP+1
15600 NEXT XMULT
15605 LPRINT:REM 2/4/99 for multiplet parameters
15610 KP=KP-1:JP=JP-1
15900 RETURN

```

```

16000 REM - Subroutine for Sloping Background Calculations 12/21/98
16005 MAXBDEL = .04*(100/MENERGY)*(A/MFWHM)
16010 REM - set up B1 region straight-line fit
16020 LCHB1=8:IF (H1-LOCH(JP-1)-HCRES)<8 THEN LCHB1=H1-LOCH(JP-1)-HCRES
16025 IF LCHB1<3 THEN LCHB1=3
16030 XISLOW=H1-LCHB1:XISHI=H1-1
16040 GOSUB 16500
16050 C1B=ACONST:SL1B=BSLOPE
16060 REM - set up B2 region straight-line fit
16070 LCHB2=8:IF (LOCH(JP+NMULT)-H2-HCRES)<8 THEN LCHB2=LOCH(JP+NMULT)-H2-HCRES
16075 IF LCHB2<3 THEN LCHB2=3
16080 XISLOW=H2+1:XISHI=H2+LCHB2
16090 GOSUB 16500
16100 C2B=ACONST:SL2B=BSLOPE
16110 QUD12=.5*(SL2B-SL1B)/(H2-H1+2):REM 1/13/99
16120 B1FIT0=C1B:REM relative origin at H1-1 as 0
16130 B2FIT0=C2B:REM relative origin at H1-1 as 0
16135 B2FITR=C2B+SL2B*(H2-H1+2):REM at right of peak or h2+1
16140 SLB12=SL1B:REM changed 1/14/99
16150 BDELTA=C1B-C2B-QUD12*(H2-H1+2)^2:REM 1/13/99
16155 REM BDSTEP=.1*BDELTA:IF BDSTEP=0 THEN BDSTEP=1:rem 1/13/99
16156 ADSTEP = .01*A:REM 1/13/99
16157 CBC=B1FIT0
16158 CUB12=0:REM add 1/29/99
16160 IF BDELTA=>0 AND BDELTA<=MAXBDEL THEN GOTO 16171
16161 IF BDELTA<0 THEN BDELTA=0:REM 1/29/99 QUD12=0:SLB12=(B2FITR-B1FIT0+BDELTA)/(H2-H1+2):REM 1/19/99
16162 IF BDELTA>MAXBDEL THEN BDELTA=MAXBDEL:REM 1/29/99 QUD12=0:SLB12=(B2FITR-B1FIT0+BDELTA)/(H2-H1+2):REM 1/19/99
16163 QUD12=3*(C2B-C1B+BDELTA)/(H2-H1+2)^2+2*(SL2B-SL1B)/(H2-H1+1):REM 1/29/99
16164 CUB12=-2*(C2B-C1B+BDELTA)/(H2-H1+2)^3-(SL2B-SL1B)/(H2-H1+1)^2:REM 1/29/99
16165 REM PBDELTA=BDELTA+BDSTEP:rem 1/13/99
16170 REM PSLB12=(B2FITR-B1FIT0+PBDELTA)/(H2-H1+2):rem 1/13/99
16171 PA=A+ADSTEP:REM 1/13/99
16200 RETURN

```

```

16500 REM - Linear least squares fits for B1 and B2 regions 12/21/98
16510 SUMX=0:SUMY=0:SUMXY=0:SUMX2=0:SUMNC=0:ERRY2=0
16520 FOR XIS=XISLOW TO XISHI
16530 XREL=XIS-(H1-1):REM rel origin at H1-1
16540 SUMX=SUMX+XREL
16550 SUMY=SUMY+NPC(XIS)
16555 ERRY2=ERRY2+NPC(XIS):IF NPC(XIS)=0 THEN ERRY2=ERRY2+1:REM 3/8/99and16510
16560 SUMXY=SUMXY+XREL*NPC(XIS)
16570 SUMX2=SUMX2+XREL^2
16580 SUMNC=SUMNC+1
16590 NEXT XIS
16600 ACONST = (SUMX2*SUMY-SUMX*SUMXY)/(SUMNC*SUMX2-SUMX^2)
16610 BSLOPE = (SUMNC*SUMXY-SUMX*SUMY)/(SUMNC*SUMX2-SUMX^2)
16620 ERRBSL = SQR(ERRY2/(SUMNC*SUMX2-SUMX^2)):REM 3/8/99
16630 IF 1.5*ERRBSL-ABS(BSLOPE)>0 THEN ACONST=SUMY/SUMNC:BSLOPE=0:REM 3/8/99
16700 RETURN

```

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16800 REM - subroutine to iterate parammeters for FI=1 find 12/29/98
16810 SDFDA=(PFI-FI)/ADSTEP:IF SDFDA=0 THEN GOTO 16899:REM 1/13 and 3/2/99
16820 A=A+(1-FI)/SDFDA:REM 1/13/99
16821 IF A<=0 THEN A=ASAVE:FLAGB=2:GOTO 16899:REM 3/12/99
16825 PA=A+ADSTEP:REM 1/13/99
16830 REM SLB12=(B2FITR-B1FIT0+BDELTA)/(H2-H1+2):rem 1/13/99
16835 REM PSLB12=(B2FITR-B1FIT0+PBDELTA)/(H2-H1+2):rem 1/13/99
16899 RETURN

```

GRABISOS: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
5-28/DIM setup	
30-35/Input data	<--- 1000-1100/Miscellaneous data <--- B:DATAMISC.DAT <--- 2000-2200/Efficiency data <--- B:DATAALB.DAT
41-65/Eff Formula	
70-95/Input data	<--- 3000-3100/Gamma peaks <--- B:DATAPEAK.DAT
97-98/Print header	
100-250/Sort peak A	<--- 20000-21000/Bubble sort exchanger
300-360/Sort peak Z	<--- 20000-21000/Bubble sort exchanger
400-470/Sort peak E	<--- 20000-21000/Bubble sort exchanger
500-705/Examine peaks	
710-790/Average peaks	
800-900/Print summary	<--- 30000-30100/Peak formater
980-990/Continue/STOP	<--- 9000-9100/Supplementary analysis menu

Lines not used in execution

4000-4100/Spectrum input of B:DATASPEC.DAT
 5000-5080/Isotope data input of B:DATAISOS.DAT
 6000-6100/Background input of backgnd.BKG
 7000-7200/Efficiency parameters of DETLIBRY.LIB
 8000-8100/Isotope library of B:DETLIBRY.LIB
 13000-13100/Energy to channel transformer
 60000-60140/Efficiency vs energy table for calib gammas

```

5 REM file GRABISOS.BAS
6 PRINT"Reading in data files":PRINT
20 DIM ANUM(150),AVE$(150),ACT(150),ERRACT(150)
21 DIM H1(150),H2(150),RATERR(150)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CEOH1(5,3),CE2H0(5,3),CE1H1(5,3),CEOH2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CEOH3(5,3)
25 DIM YLOC(20),DETNAM$(10),BENERGY(150),BRATE(150),BERR(150),DETLAB$(10)
26 DIM ISOTH(250),MDA(250),ACTRAT(150),LIBEN(250),SBRATE(150),SBERR(150)
27 DIM RATE(150),ENERGY(150),ISOEN(250),ISOID$(250),ISO$(250),ISOGAM(250)
28 DIM NPC(4096),AREA(150),EAREA(150),LOCH(150),FWHM(150),TAIL(150),CENT(150)

30 GOSUB 1000:REM read file B:DATAMISC.DAT
35 GOSUB 2000:REM read file B:DATACALB.DAT

41 DEF FNENC(CHAN)=COENC+C1ENC*CHAN
44 DEF FNFWMH(CHAN)=SQR(COFWMH + C1FWMH*CHAN)
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX)))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 REM INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFV
EN$:CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 REM GOSUB 60000:REM check on efficiency data EFF vs EN
65 REM - tempory continue

70 GOSUB 3000:REM read file B:DATAPEAK.DAT
75 REM GOSUB 4000:REM read file B:DATASPEC.DAT
80 REM GOSUB 5000:REM read file B:DATAISOS.DAT
85 REM GOSUB 6000:REM read file DETFILE$.BKG
90 REM GOSUB 7000:REM read file B:DETLIBRY.LIB
95 REM gosub 8000:rem read file B:ISOLIBRY.LIB (when needed for B:DATAISOS.DAT)

97 INPUT"Hit form feed before proceeding";ZZ:PRINT
98 LPRINT"          ***** AVERAGED RESULTS PER ISOTOPE *****"

100 REM-get A numbers
105 ISOTOT=0
110 FOR KP=1 TO MPMAX
120 FOR J=5 TO 1 STEP -1
130 ANUM=VAL(RIGHT$(ISOID$(KP),J))
135 IF ANUM>300 THEN ANUM(KP)=1000:J=1:GOTO 160
140 IF ANUM>0 THEN ANUM(KP)=ANUM:J=1:ISOTOT=ISOTOT+1:GOTO 160
150 IF J=1 THEN ANUM(KP)=1000
160 NEXT J
170 NEXT KP
200 PRINT"Bubble sorting on A":REM - bubble sort on anum
210 FOR J=MPMAX TO 2 STEP -1
220 FOR K=MPMAX TO MPMAX-J+2 STEP -1
230 IF ANUM(K)<ANUM(K-1) THEN GOSUB 20000
240 NEXT K
250 NEXT J

300 PRINT"Bubble sorting on isotope name":REM - followup bubble sort on isotope
name (in case two isos have same A)
310 FOR J= ISOTOT TO 2 STEP -1
320 FOR K=ISOTOT TO ISOTOT-J+2 STEP -1
330 IF ANUM(K)<>ANUM(K-1) THEN 350
340 IF ISOID$(K)<ISOID$(K-1) THEN GOSUB 20000
350 NEXT K
360 NEXT J

400 PRINT"Bubble sorting on isotope energy":REM - followup bubble sort to assure
energies monotonic
410 FOR J= ISOTOT TO 2 STEP -1
420 FOR K=ISOTOT TO ISOTOT-J+2 STEP -1
430 IF ANUM(K)<>ANUM(K-1) THEN 460
440 IF ISOID$(K)<>ISOID$(K-1) THEN 460
450 IF LIBEN(K)<LIBEN(K-1) THEN GOSUB 20000
460 NEXT K
470 NEXT J

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500 REM - commence examining tables for averages
505 NEWISOS=1
510 FOR J=1 TO MPMAX
515 IF NEWISOS=0 THEN 550
518 NUMGAM=1
520 CLS
525 IF J>ISOTOT THEN PRINT"Summary of left over peaks":PRINT:GOTO 540
530 PRINT"Summary results for ";ISOID$(J):PRINT
540 PRINT"Gamma      Energy      FWHM Tail      Rate      Bkgnd      Activity"
545 PRINT" #          keV          keV      #          cph          cph          ";AUNIT$:PRINT
550 ACT(J)=ACTRAT(J)*(RATE(J)-SBRATE(J))
560 ERRACT(J)=ACTRAT(J)*SQR(RATERR(J)^2+SBERR(J)^2)
570 PRINT USING"####.###";NUMGAM;:PRINT USING"#####.##";ENERGY(J);
580 PRINT USING"####.###";FWHM(J);:PRINT USING"####.###";TAIL(J);
590 PRINT USING"#####.##";3600*RATE(J);:PRINT USING"#####.##";3600*SBRATE(J);
600 IF ACT(J)<3*ERRACT(J) THEN 620
610 PRINT"      ";:PRINT USING"###.###^";ACT(J):GOTO 630
620 PRINT" < ";:PRINT USING"###.###^ 3";3*ERRACT(J);:PRINT CHR$(229);
622 VSIG = ACT(J)/ERRACT(J):IF VSIG < 0 THEN VSIG = 0
625 PRINT USING"/#.##";VSIG;:PRINT CHR$(229)
630 PRINT ISOID$(J);:PRINT USING"#####.##";LIBEN(J);
640 PRINT USING"####.###";CLENC*FNFWM(CENT(J));:PRINT"      ";
650 PRINT CHR$(241);:PRINT USING"###.##";3600*RATERR(J);:PRINT"      ";CHR$(241);
660 PRINT USING"###.##";3600*SBERR(J);
670 IF ACT(J)<3*ERRACT(J) THEN 681
680 PRINT"      ";CHR$(241);:PRINT"      ";:PRINT USING"###.###^";ERRACT(J):PRINT:GOTO 6
90
681 REM LESSTH=ACT(J)+1.65*ERRACT(J):IF ACT(J)<0 THEN LESSTH = 1.65*ERRACT(J)
682 REM PRINT" < ";:PRINT USING"###.###^ v+1.65";LESSTH;:PRINT CHR$(229):PRINT
683 REM lines 681-682 less than calculation removed
684 IRATE=ACT(J)/ACTRAT(J):IRATER=ERRACT(J)/ACTRAT(J)
685 BKTOT = ((IRATER*LTIME)^2 - IRATE*LTIME)/2:IF BKTOT<=0 THEN BKTOT=1
686 MDACX = ACTRAT(J)*(2.71 + 4.65*SQR(BKTOT))/LTIME
687 PRINT" < ";:PRINT USING"###.###^ MDA=c+b";MDACX:PRINT
690 IF J=MPMAX THEN 710
700 IF ISOID$(J)=ISOID$(J+1) THEN NUMGAM=NUMGAM+1:NEWISOS=0:GOTO 900
705 IF J>ISOTOT THEN NUMGAM=NUMGAM+1:NEWISOS=0:GOTO 900

710 INPUT"Average above results (y/n)";YES:IF NUMGAM=1 THEN YES="n"
715 IF YES="n" THEN 800
718 AVEACT=0:WTACT=0
720 FOR L=J+1-NUMGAM TO J
730 PRINT"      Include gamma entry #";L+NUMGAM-J;:INPUT" (y/n)";AVE$(L)
740 IF AVE$(L)<>"y" THEN 780
760 AVEACT=AVEACT + ACT(L)*(1/ERRACT(L))^2
770 WTACT=WTACT + (1/ERRACT(L))^2
780 NEXT L
790 AVEACT=AVEACT/WTACT:ACTERR=SQR(1/WTACT)

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```

800 LPRINT:LPRINT"-----":
LPRINT
810 LPRINT"Source   Gamma   Energy   Activity   Average"
820 LPRINT"          #       keV      ";AUNIT$;"          y/n"
825 LPRINT
830 FOR L=J+1-NUMGAM TO J
835 LPRINT ISOID$(L);" ";
836 IF LIBEN(L)>0 THEN 840
837 LPRINT USING"###";L+NUMGAM-J;:LPRINT USING"#####.##";ENERGY(L);
838 IF ACT(L)=>3*ERRACT(L) THEN LPRINT" ";
839 GOTO 842
840 LPRINT USING"###";L+NUMGAM-J;:LPRINT USING"#####.##";LIBEN(L);
841 IF ACT(L)=>3*ERRACT(L) THEN LPRINT" ";
842 IF ACT(L) => 3*ERRACT(L) THEN 850
843 LPRINT USING" <#.##^3";3*ERRACT(L);:LPRINT CHR$(229);
844 VSIG = ACT(L)/ERRACT(L):IF VSIG<0 THEN VSIG=0
845 LPRINT USING"/#.##";VSIG;
846 IRATE=ACT(L)/ACTRAT(L):IRATER=ERRACT(L)/ACTRAT(L)
847 BKTOT = ((IRATER*LTIME)^2-IRATE*LTIME)/2:MDACX=ACTRAT(L)*(2.71+4.65*SQR(BKTO
T))/LTIME
848 LPRINT USING" #.##^3=MDA";MDACX;
849 GOTO 855
850 PV=ACT(L):EPV=ERRACT(L):GOSUB 30000
855 AVE$=AVE$(L):IF YES="n" THEN AVE$="n"
858 IF ACT(L)<3*ERRACT(L) THEN LPRINT" ";AVE$:GOTO 870
860 LPRINT"      ";AVE$
870 NEXT L
880 PRINT
882 NEWISOS=1
885 IF YES="n" THEN 900
890 LPRINT:LPRINT"              Average = ";:IF AVEACT > 3*ACTERR THEN 895
891 VSIG=AVEACT:IF VSIG <0 THEN VSIG=0
892 LPRINT USING" <#.##^3";3*ACTERR;:LPRINT CHR$(229);:LPRINT USING"/#.##";V
SIG;:LPRINT CHR$(229);
893 LPRINT" MDA=min/list"
894 GOTO 900
895 PV=AVEACT:EPV=ACTERR:GOSUB 30000
896 LPRINT
900 NEXT J

980 GOSUB 9000:REM - continuation menu
990 STOP

1000 REM - subroutine to read miscellaneous parameters file B:MISCDAT.DAT
1010 OPEN "B:DATAMISC.DAT" FOR INPUT AS #3
1020 INPUT #3,LTIME,STCH,ENCH,AUNIT$,UNUM,UEM,TDAY$,DETN,DETNAM$(DETN),DETLAB$(
DETN),STDATE$
1030 CLOSE #3
1100 RETURN

2000 REM - subroutine to read data calib file B:DATAALB.DAT
2100 OPEN "B:DATAALB.DAT" FOR INPUT AS #3
2110 INPUT #3,COENC,C1ENC,COFWHM,C1FWHM,GOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EFF
F,C2EFF,C3EFF,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
2160 CLOSE #3
2200 RETURN

3000 REM - subroutine to read data peak file B:DATAPEAK.DAT
3010 OPEN "B:DATAPEAK.DAT" FOR INPUT AS #3
3015 KP=1
3020 IF EOF(3) THEN MPMAX=KP-1:GOTO 3060
3040 INPUT #3,CENT(KP),ENERGY(KP),FWHM(KP),TAIL(KP),AREA(KP),RATE(KP),SBRATE(KP)
,ISOID$(KP),ACTRAT(KP),LIBEN(KP),RATER(KP),SBERR(KP),H1(KP),H2(KP)
3050 KP=KP+1:GOTO 3020
3060 CLOSE #3
3100 RETURN

4000 REM -subroutine to read in spectrum file B:DATASPEC.DAT
4010 OPEN "B:DATASPEC.DAT" FOR INPUT AS #3
4020 FOR I=STCH TO ENCH
4030 INPUT #3, NPC(I)
4040 NEXT I
4050 CLOSE #3
4100 RETURN

```

```

5000 REM - subroutine to read in isotope library file B:DATAISOS.DAT
5010 OPEN "B:DATAISOS.DAT" FOR INPUT AS #3
5020 L=0
5030 L=L+1
5040 INPUT #3, ISO$(L), ISOTH(L), ISOEN(L), ISOGAM(L), MDA(L)
5050 IF ISO$(L)="limit " THEN 5070
5060 GOTO 5030
5070 CLOSE #3
5080 RETURN

```

```

6000 REM - subroutine to read in background library
6010 DETFILE$=DETLAB$(DETN)+".BKG"
6020 OPEN DETFILE$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN BAMAX=CBACK-1:GOTO 6070
6050 INPUT #2, BENERGY(CBACK), BRATE(CBACK), BERR(CBACK)
6060 CBACK=CBACK+1:GOTO 6040
6070 CLOSE #2
6100 RETURN

```

```

7000 REM - subroutine to read in detector library B:DETLIBRY.LIB
7005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
7010 FOR I=1 TO 5
7020 FOR J=1 TO 3
7030 INPUT #3, GOEFF(I,J), AOEFF(I,J), BOEFF(I,J), KOEFF(I,J), HOEFF(I,J)
7040 INPUT #3, CEOH0(I,J)
7050 INPUT #3, CE1H0(I,J), CEOH1(I,J)
7060 INPUT #3, CE2H0(I,J), CE1H1(I,J), CEOH2(I,J)
7070 INPUT #3, CE3H0(I,J), CE2H1(I,J), CE1H2(I,J), CEOH3(I,J)
7080 NEXT J
7090 NEXT I
7095 CLOSE #3
7100 I=0:J=0
7200 RETURN

```

```

8000 REM - subroutine to read in isotope library data B:ISOLIBRY.LIB
8001 REM - note that B:DATAISOS.DAT is used instead usually
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 100
8020 INPUT #3, ISO$(ISO), ISOTH(ISO), ISOEN(ISO), ISOGAM(ISO), MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=100
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

```

```

9000 REM- subroutine for supplementary analyses
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 CLS
9020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
9030 PRINT"      (1) Background file development (GRABBACK)"
9040 PRINT"      (2) Detector efficiency calibration (GRABCALB)"
9050 PRINT"      (3) Peak/spectrum diagnostics (GRABDIAG)"
9060 PRINT"      (4) Peak/multiplet plot analysis (GRABPLOT)"
9070 PRINT"      (5) Analyses per isotopes (GRABISOS)":PRINT
9080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
9090 PRINT:PRINT"Type selected analysis (e.g. GRABBACK) after":PRINT"C-prompt (
C> ) and press enter"
9095 CLOSE #3
9100 RETURN

```

```

13000 REM sub from sub 3000 - calc channel from energy
13010 AOEN = FNENC(0)
13020 AIEN = FNENC(1)-FNENC(0)
13030 CHANO = (ENERGY-AOEN)/AIEN
13040 CHAN = CHANO + (ENERGY-FNENC(CHANO))/AIEN
13050 IF ABS(ENERGY-FNENC(CHAN))>.1 THEN CHANO=CHAN:GOTO 13040
13055 RCHAN=CHAN
13060 CHAN=INT(CHAN+.5)
13100 RETURN

```

```

20000 REM-bubble sort flip-flopper
20010 ANUM=ANUM(K):ANUM(K)=ANUM(K-1):ANUM(K-1)=ANUM
20020 ENERGY=ENERGY(K):ENERGY(K)=ENERGY(K-1):ENERGY(K-1)=ENERGY
20030 LIBEN=LIBEN(K):LIBEN(K)=LIBEN(K-1):LIBEN(K-1)=LIBEN
20040 RATE=RATE(K):RATE(K)=RATE(K-1):RATE(K-1)=RATE
20050 RATERR=RATERR(K):RATERR(K)=RATERR(K-1):RATERR(K-1)=RATERR
20060 SBRATE=SBRATE(K):SBRATE(K)=SBRATE(K-1):SBRATE(K-1)=SBRATE
20065 SBERR=SBERR(K):SBERR(K)=SBERR(K-1):SBERR(K-1)=SBERR
20070 ACTRAT=ACTRAT(K):ACTRAT(K)=ACTRAT(K-1):ACTRAT(K-1)=ACTRAT
20080 ISOID$=ISOID$(K):ISOID$(K)=ISOID$(K-1):ISOID$(K-1)=ISOID$
20090 FWHM=FWHM(K):FWHM(K)=FWHM(K-1):FWHM(K-1)=FWHM
20100 TAIL=TAIL(K):TAIL(K)=TAIL(K-1):TAIL(K-1)=TAIL
20110 CENT=CENT(K):CENT(K)=CENT(K-1):CENT(K-1)=CENT
21000 RETURN

30000 REM - subroutine for printout - works for positive value pv +/- epv
30010 PVEX=INT(LOG(PV)/LOG(10)):PVARG = PV/10^PVEX
30020 EPVARG=PVARG*EPV/PV
30030 LPRINT[";:LPRINT USING"###.###";PVARG;:LPRINT" +/- ";
30040 LPRINT USING"###.###";EPVARG;:LPRINT"] x E";:LPRINT PVEX;
30100 RETURN

60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";DETNAME$(DETN)
60006 PRINT
60010 PRINT "EN", "EFF"
60011 PRINT"keV", " # "
60020 PRINT USING"###.###";88.03;:PRINT USING"###.###";FNEFF(88.03)
60030 PRINT USING"###.###";122.06;:PRINT USING"###.###";FNEFF(122.06)
60040 PRINT USING"###.###";165.85;:PRINT USING"###.###";FNEFF(165.85)
60050 PRINT USING"###.###";279.19;:PRINT USING"###.###";FNEFF(279.19)
60060 PRINT USING"###.###";391.69;:PRINT USING"###.###";FNEFF(391.69)
60070 PRINT USING"###.###";514!;:PRINT USING"###.###";FNEFF(514!)
60080 PRINT USING"###.###";661.64;:PRINT USING"###.###";FNEFF(661.64)
60090 PRINT USING"###.###";898.02;:PRINT USING"###.###";FNEFF(898.02)
60100 PRINT USING"###.###";1173.21;:PRINT USING"###.###";FNEFF(1173.21)
60110 PRINT USING"###.###";1332.56;:PRINT USING"###.###";FNEFF(1332.56)
60120 PRINT USING"###.###";1836.01;:PRINT USING"###.###";FNEFF(1836.01)
60130 INPUT"Press return to proceed";ZZ
60140 RETURN

```

B-60

GRABBACK: Program Structure Reference
(Continued)

Lines not used in execution

4000-4100/Spectrum input of B:DATASPEC.DAT
5000-5080/Isotope data input of B:DATAISOS.DAT
7000-7200/Efficiency parameters of DETLIBRY.LIB
8000-8100/Isotope library of B:DETLIBRY.LIB
13000-13100/Energy to channel transformer
60000-60140/Efficiency vs energy table for calib gammas

```

5 REM file GRABBACK.BAS
10 PRINT:PRINT"Reading in data files"
15 PRINT:PRINT"Check printer if need form feed"
21 DIM H1(100),H2(100),RATERR(100)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CEOH1(5,3),CE2H0(5,3),CE1H1(5,3),CEOH2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CEOH3(5,3)
25 DIM YLOC(20),DETNAM$(10),BENERGY(100),BRATE(100),BERR(100),DETLAB$(10)
26 DIM ISOTH(100),MDA(100),ACTRAT(100),LIBEN(100),SBRATE(100),SBERR(100)
27 DIM RATE(100),ENERGY(100),ISOEN(100),ISOIDS(100),ISO$(100),ISOGAM(100)
28 DIM NPC(4096),AREA(100),EAREA(100),LOCH(100),FWHM(100),TAIL(100),CENT(100)

30 GOSUB 1000:REM read file B:DATAMISC.DAT
35 GOSUB 2000:REM read file B:DATACALB.DAT

41 DEF FNENC(CHAN)=COENC+CIENC*CHAN
44 DEF FNFWMH(CHAN)=SQR(COFWMH + C1FWMH*CHAN)
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 REM INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFV
EN$:CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 REM GOSUB 60000:REM check on efficiency data EFF vs EN
65 REM - temporary continue

70 GOSUB 3000:REM read file B:DATAPEAK.DAT
75 REM GOSUB 4000:REM read file B:DATASPEC.DAT
80 REM GOSUB 5000:REM read file B:DATAISOS.DAT
85 GOSUB 6000:REM read file DETFILE$.BKG
90 REM GOSUB 7000:REM read file B:DETLIBRY.LIB
95 REM gosub 8000:rem read file B:ISOLIBRY.LIB (when needed for B:DATAISOS.DAT)

100 REM - make background file for this sample
101 CLS
102 PRINT"Examine normal printout for sample vs current background":PRINT
105 BKG$=RIGHT$(STR$(DETN),1)+LEFT$(STDATES$,7)+".BKG"
110 PRINT"Proposed background label ";BKG$:PRINT
115 INPUT"Desire different background label (y/n)";YES$:IF YES$="n" THEN 125
120 PRINT:INPUT"Background file label (-----.BKG)";BKG$
125 PRINT
130 INPUT"Make above background file from sample rates (y/n)";YES$:PRINT
140 IF YES$<>"y" THEN PRINT"No changes made in current file ";DETFILE$:PRINT:INPU
T"Press enter to proceed";ZZ:GOTO 980

145 NEWBKG=0
150 OPEN BKG$ FOR OUTPUT AS #2
155 FOR KP=1 TO MPMAX
160 IF AREA(KP)<3*RATERR(KP)*LTIME THEN 200
170 ENERGY = LIBEN(KP)
180 IF ISOIDS(KP)="No-Lib" THEN ENERGY=ENERGY(KP)
190 WRITE #2,ENERGY,RATE(KP),RATERR(KP):NEWBKG=NEWBKG+1
200 NEXT KP
210 CLOSE #2

212 LPRINT " ***** Background File Development *****"
213 LPRINT:LPRINT

215 CLS
220 PRINT:PRINT"The following options can be used with ";BKG$:PRINT
222 PRINT" (1) Initial background data case - setup user analysis file"
224 PRINT" (2) Examine for merge/average with existing user analysis file"
225 PRINT
226 IF DETFILE$="missing" THEN PRINT"Option (1) defaulted - no user analysis fil
e found":GOTO 235
227 PRINT"Recommend option (2) - user analysis file ";DETFILE$;" found"
228 PRINT
229 INPUT"Option";OPNO
230 IF OPNO=2 THEN GOTO 250
235 PRINT:INPUT"Assign a user analysis file (eg yourDETR.BKG)";DETFILE$
240 GOSUB 20000:REM copy bkg$ to detfile$
245 PRINT "New user file ";DETFILE$;" created from ";BKG$
247 GOTO 980

```

```

250 PRINT:PRINT"Background file ";BKG$;" can be merged/averaged with ";DETFILE$
260 PRINT:PRINT"File merging in progress":PRINT
300 REM - arrange arrays for merge - slide down from top(100)
310 FOR I=BAMAX TO 1 STEP -1
320 BENERGY(100-BAMAX+I)=BENERGY(I)
330 BRATE(100-BAMAX+I)=BRATE(I)
340 BERR(100-BAMAX+I)=BERR(I)
350 NEXT I
360 OPEN BKG$ FOR INPUT AS #2
370 FOR I=1 TO NEWBKG
380 INPUT #2, ENERGY(I),RATE(I),RATERR(I)
390 NEXT I
400 CLOSE #2
410 FOR I=NEWBKG TO 1 STEP -1
420 ENERGY(100-NEWBKG+I)=ENERGY(I)
430 RATE(100-NEWBKG+I)=RATE(I)
440 RATERR(100-NEWBKG+I)=RATERR(I)
450 NEXT I
490 PRINT:INPUT"Energy agreement (e.g. +/- 2 keV)";EFIND

495 LPRINT:LPRINT"Energy agreement for merged files = +/- ";EFIND;" keV"
496 LPRINT

500 REM - perform table merge
505 NB=100-NEWBKG+1:J=1
510 FOR I=100-BAMAX+1 TO 100
515 IF NB=101 THEN 540
520 IF BENERGY(I)-ENERGY(NB)<=EFIND THEN 530
521 ENERGY(J)=ENERGY(NB):RATE(J)=RATE(NB):RATERR(J)=RATERR(NB)
522 BENERGY(J)=ENERGY(NB):BRATE(J)=0:BERR(J)=0
523 NB=NB+1:J=J+1:GOTO 515
530 IF BENERGY(I)-ENERGY(NB)<-EFIND THEN 540
531 ENERGY(J)=ENERGY(NB):RATE(J)=RATE(NB):RATERR(J)=RATERR(NB)
532 BENERGY(J)=BENERGY(I):BRATE(J)=BRATE(I):BERR(J)=BERR(I)
533 NB=NB+1:J=J+1:GOTO 550
540 REM - line 530 condition met
541 ENERGY(J)=BENERGY(I):RATE(J)=0:RATERR(J)=0
542 BENERGY(J)=BENERGY(I):BRATE(J)=BRATE(I):BERR(J)=BERR(I)
543 J=J+1
550 NEXT I
555 REM - below assures pick up upper energy cases missed in above loop
560 IF NB=101 THEN 610
570 FOR MB=NB TO 100
580 ENERGY(J)=ENERGY(MB):RATE(J)=RATE(MB):RATERR(J)=RATERR(MB)
590 BENERGY(J)=ENERGY(MB):BRATE(J)=0:BERR(J)=0
595 J=J+1
600 NEXT MB
610 JMAX=J-1

620 REM - print out merged data below
630 REM LPRINT" ***** Background Analysis *****"
631 LPRINT:LPRINT:LPRINT
632 LPRINT"                Data after Merger ":LPRINT:LPRINT
633 LPRINT TAB(15) BKG$ TAB(45) DETFILE$:LPRINT
634 LPRINT"Peak          Energy          Rate          Energy          Rate "
635 LPRINT"              keV              cph              keV              cph"
636 LPRINT
640 FOR J=1 TO JMAX
645 LPRINT USING"#####";J;
650 LPRINT USING"#####.##";ENERGY(J),3600*RATE(J);:LPRINT" +/-";:LPRINT USING
"#####.##";3600*RATERR(J);
655 LPRINT USING"#####.##";BENERGY(J),3600*BRATE(J);:LPRINT" +/-";:LPRINT USIN
G"#####.##";3600*BERR(J)
670 NEXT J

700 REM - print out average merged data and dump to disk file
701 CLS
702 PRINT"Examine merged printout to decide appropriate option below":PRINT
703 PRINT"      (1) Retain current ";DETFILE$;" as background file"
704 PRINT"      (2) Make new ";DETFILE$;" from ";BKG$;" file alone"
705 PRINT"      (3) Make new ";DETFILE$;" from average of merged files"
706 PRINT"          (i.e. ";BKG$;" and current ";DETFILE$;)"":PRINT
707 PRINT"      Note: questionable peaks can be removed in cases (2) or (3)":PRINT
708 INPUT"Select option";OPB

```

```

710 IF OPB=1 THEN LPRINT:LPRINT"Current background file kept":LPRINT:GOTO 980
711 IF OPB=2 THEN GOSUB 30000:REM - back up current detfile$ if present
712 IF OPB=2 THEN GOSUB 20000:REM - new background data only
713 IF OPB=2 THEN PRINT"New ";DETFILE$;" made from ";BKG$;" alone":GOTO 720
714 IF OPB<>3 THEN CLS:PRINT"Not a valid option - try again":PRINT:GOTO 700
715 GOSUB 30000:REM - make backup to current detfile$ if present

720 CLS:PRINT"Exclusion of questionable peaks only removes ";BKG$;" values"
721 PRINT:PRINT"Check peaks to delete (y/n) in table generated below"
722 PRINT" (Note: New Rates = Old Rates, if option #2 was selected)":PRINT
725 GOSUB 40000:REM - delete peaks subroutine

729 LPRINT:LPRINT:LPRINT
730 LPRINT"          Data after averaging merged background files"
732 LPRINT:LPRINT
733 LPRINT"          ----- Rates -----"
734 LPRINT
735 LPRINT"          New          Old          Ave/New
736 LPRINT"Peak    Energy" TAB(18) BKG$  TAB(33) DETFILE$  TAB(48) DETFILE$
737 LPRINT" #      keV      cph      cph      cph"
738 LPRINT
740 OPEN DETFILE$ FOR OUTPUT AS #2
750 PX=1
760 FOR J=1 TO JMAX
770 IF J<>NPC(PX) THEN 780
771 IF OPB=2 THEN LPRINT USING"###";J::LPRINT USING"#####.##";ENERGY(J)::LPRINT
  "    This peak deleted":PX=PX+1:GOTO 820
772 IF BRATE(J)=0 THEN LPRINT USING"###";J::LPRINT USING"#####.##";ENERGY(J)::L
PRINT"    This peak deleted":PX=PX+1:GOTO 820
773 LPRINT USING"###";J::LPRINT USING"#####.##";BENERGY(J)::LPRINT"    Deleted
  ";
774 LPRINT USING"#####.##";3600*BRATE(J)::LPRINT" +/--;:LPRINT USING"###.##";3600*B
ERR(J);
775 LPRINT USING"#####.##";3600*BRATE(J)::LPRINT" +/--;:LPRINT USING"###.##";3600*B
ERR(J)
777 BENERGY=BENERGY(J):BRATE=BRATE(J):BERR=BERR(J):PX=PX+1:GOTO 810
780 BENERGY=.5*(ENERGY(J)+BENERGY(J)):BRATE=.5*(RATE(J)+BRATE(J)):BERR=.5*SQR(RATE
RR(J)^2 + BERR(J)^2)
782 IF OPB=2 THEN BERR = BERR(J)
785 LPRINT USING"###";J::LPRINT USING"#####.##";BENERGY;
790 LPRINT USING"#####.##";3600*RATE(J)::LPRINT" +/--;:LPRINT USING"###.##";3600*RA
TERR(J);
795 LPRINT USING"#####.##";3600*BRATE(J)::LPRINT" +/--;:LPRINT USING"###.##";3600*B
ERR(J);
800 LPRINT USING"#####.##";3600*BRATE::LPRINT" +/--;:LPRINT USING"###.##";3600*BERR

810 WRITE #2, BENERGY,BRATE,BERR
820 LPRINT
830 NEXT
850 CLOSE #2

980 GOSUB 9000:REM - continuation menu
990 STOP

1000 REM - subroutine to read miscellaneous parameters file B:MISCDAT.DAT
1010 OPEN "B:DATAMISC.DAT" FOR INPUT AS #3
1020 INPUT #3,LTIME,STCH,ENCH,AUNIT$,UNUM,UEM,TDAY$,DETN,DETNAM$(DETN),DETLAB$(
DETN),STDATES$
1030 CLOSE #3
1100 RETURN

2000 REM - subroutine to read data calib file B:DATACALB.DAT
2100 OPEN "B:DATACALB.DAT" FOR INPUT AS #3
2110 INPUT #3,COENC,C1ENC,COFWHM,C1FWHM,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EF
F,C2EFF,C3EFF,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
2160 CLOSE #3
2200 RETURN

3000 REM - subroutine to read data peak file B:DATAPEAK.DAT
3010 OPEN "B:DATAPEAK.DAT" FOR INPUT AS #3
3015 KP=1
3020 IF EOF(3) THEN MPMAX=KP-1:GOTO 3060
3040 INPUT #3,CENT(KP),ENERGY(KP),FWHM(KP),TAIL(KP),AREA(KP),RATE(KP),SBRATE(KP)
,ISIDS$(KP),ACTRAT(KP),LIBEN(KP),RATERR(KP),SBERR(KP),H1(KP),H2(KP)
3050 KP=KP+1:GOTO 3020
3060 CLOSE #3
3100 RETURN

```



```

4000 REM -subroutine to read in spectrum file B:DATASPEC.DAT
4010 OPEN "B:DATASPEC.DAT" FOR INPUT AS #3
4020 FOR I=STCH TO ENCH
4030 INPUT #3, NPC(I)
4040 NEXT I
4050 CLOSE #3
4100 RETURN

5000 REM - subroutine to read in isotope library file B:DATAISOS.DAT
5010 OPEN "B:DATAISOS.DAT" FOR INPUT AS #3
5020 L=0
5030 L=L+1
5040 INPUT #3, ISO$(L), ISOTH(L), ISOEN(L), ISOGAM(L), MDA(L)
5050 IF ISO$(L)="limit " THEN 5070
5060 GOTO 5030
5070 CLOSE #3
5080 RETURN

6000 REM - subroutine to read in background library
6005 IF LEN(DETLAB$(DETN))=0 THEN DETFILE$="missing":GOTO 6100
6010 DETFILE$=DETLAB$(DETN)+".BKG"
6020 OPEN DETFILE$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN BAMAX=CBACK-1:GOTO 6070
6050 INPUT #2, BENERGY(CBACK), BRATE(CBACK), BERR(CBACK)
6060 CBACK=CBACK+1:GOTO 6040
6070 CLOSE #2
6100 RETURN

7000 REM - subroutine to read in detector library B:DETLIBRY.LIB
7005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
7010 FOR I=1 TO 5
7020 FOR J=1 TO 3
7030 INPUT #3, GOEFF(I,J), AOEFF(I,J), BOEFF(I,J), KOEFF(I,J), HOEFF(I,J)
7040 INPUT #3, CEOH0(I,J)
7050 INPUT #3, CE1H0(I,J), CE0H1(I,J)
7060 INPUT #3, CE2H0(I,J), CE1H1(I,J), CE0H2(I,J)
7070 INPUT #3, CE3H0(I,J), CE2H1(I,J), CE1H2(I,J), CE0H3(I,J)
7080 NEXT J
7090 NEXT I
7095 CLOSE #3
7100 I=0:J=0
7200 RETURN

8000 REM - subroutine to read in isotope library data B:ISOLIBRY.LIB
8001 REM - note that B:DATAISOS.DAT is used instead usually
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 100
8020 INPUT #3, ISO$(ISO), ISOTH(ISO), ISOEN(ISO), ISOGAM(ISO), MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=100
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

9000 REM- subroutine for supplementary analyses
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 CLS
9020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
9030 PRINT"      (1) Background file development (GRABBACK)"
9040 PRINT"      (2) Detector efficiency calibration (GRABCALB)"
9050 PRINT"      (3) Peak/spectrum diagnostics (GRABDIAG)"
9060 PRINT"      (4) Peak/multiplet plot analysis (GRABPLOT)"
9070 PRINT"      (5) Analyses per isotopes (GRABISOS)":PRINT
9080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
9090 PRINT:PRINT"Type selected analysis (e.g. GRABBACK) after":PRINT"C-prompt (
C> ) and press enter"
9095 CLOSE #3
9100 RETURN

```

```

13000 REM sub from sub 3000 - calc channel from energy
13010 AOEN = FNENC(0)
13020 ALEN = FNENC(1)-FNENC(0)
13030 CHANO = (ENERGY-AOEN)/ALEN
13040 CHAN = CHANO + (ENERGY-FNENC(CHANO))/ALEN
13050 IF ABS(ENERGY-FNENC(CHAN))>.1 THEN CHANO=CHAN:GOTO 13040
13055 RCHAN=CHAN
13060 CHAN=INT(CHAN+.5)
13100 RETURN

```

```

20000 REM -subroutine for copying bkg$ file to detfile$/problem ends soon after
20010 OPEN BKG$ FOR INPUT AS #2
20020 FOR KP=1 TO NEWBKG
20030 INPUT #2,BENERGY(KP),BRATE(KP),BERR(KP)
20040 NEXT KP
20050 CLOSE #2
20110 OPEN DETFILE$ FOR OUTPUT AS #2
20120 FOR KP=1 TO NEWBKG
20130 WRITE #2,BENERGY(KP),BRATE(KP),BERR(KP)
20140 NEXT KP
20150 CLOSE #2
20160 LPRINT:LPRINT"New user analysis file ";DETFIL$
20170 LPRINT"made solely from copy of file ";BKG$:LPRINT
21000 RETURN

```

```

30000 REM - subroutine to backup current detfile$ if present
30010 IF DETFILE$="missing" THEN GOTO 31000
30020 OPEN DETFILE$ FOR INPUT AS #2
30030 FOR I=1 TO BAMAX
30040 INPUT #2, NPC(1000+I),NPC(2000+I),NPC(3000+I):REM unused npc(n) locations
30050 NEXT I
30060 CLOSE #2
30100 BACKUPBKG$=DETLAB$(DETN)+".BUB"
30120 OPEN BACKUPBKG$ FOR OUTPUT AS #2
30130 FOR I=1 TO BAMAX
30140 WRITE #2, NPC(1000+I),NPC(2000+I),NPC(3000+I):REM unused npc(n) locations
30150 NEXT I
30160 CLOSE #2
30170 LPRINT:LPRINT"Above background file ";DETFIL$
30180 LPRINT"may be overwritten, as it is backed up as ";BACKUPBKG$:LPRINT
31000 RETURN

```

```

40000 REM sub to delete questionable peaks
40010 PRINT:PRINT
40020 PRINT"                Data Prior to Merger ":PRINT:PRINT
40030 PRINT TAB(15) BKG$ TAB(45) DETFILE$:PRINT
40040 PRINT"Peak          Energy          Rate          Energy          Rate          De
lete"
40050 PRINT"                keV                cph                keV                cph                y
/n"
40060 PRINT:PX=1
40070 FOR J=1 TO JMAX
40080 PRINT USING"####";J;
40090 PRINT USING"#####.##";ENERGY(J),3600*RATE(J);:PRINT" +/-";:PRINT USING"
###.##";3600*RATERR(J);
40100 PRINT USING"#####.##";BENERGY(J),3600*BRATE(J);:PRINT" +/-";:PRINT USING"
###.##";3600*BERR(J);
40110 INPUT"      ";YES:NPC(PX)=0:IF YES<>"n"THEN NPC(PX)=J:PX=PX+1
40120 NEXT J
41000 RETURN

```

```

60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";DETNAM$(DETN)
60006 PRINT
60010 PRINT "EN", "EFF"
60011 PRINT"keV", " # "
60020 PRINT USING"#####.##";88.03;:PRINT USING"#####";FNEFF(88.03)
60030 PRINT USING"#####.##";122.06;:PRINT USING"#####";FNEFF(122.06)
60040 PRINT USING"#####.##";165.85;:PRINT USING"#####";FNEFF(165.85)
60050 PRINT USING"#####.##";279.19;:PRINT USING"#####";FNEFF(279.19)
60060 PRINT USING"#####.##";391.69;:PRINT USING"#####";FNEFF(391.69)
60070 PRINT USING"#####.##";514!;:PRINT USING"#####";FNEFF(514!)
60080 PRINT USING"#####.##";661.64;:PRINT USING"#####";FNEFF(661.64)
60090 PRINT USING"#####.##";898.02;:PRINT USING"#####";FNEFF(898.02)
60100 PRINT USING"#####.##";1173.21;:PRINT USING"#####";FNEFF(1173.21)
60110 PRINT USING"#####.##";1332.56;:PRINT USING"#####";FNEFF(1332.56)
60120 PRINT USING"#####.##";1836.01;:PRINT USING"#####";FNEFF(1836.01)
60130 INPUT"Press return to proceed";ZZ
60140 RETURN

```

GRABCALB: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
5-28/DIM setup	
30-35/Input data	<--- 1000-1100/Miscellaneous data <--- B:DATAMISC.DAT <--- 2000-2200/Efficiency data <--- B:DATAALB.DAT
41-65/Eff Formula	
70-95/Input data	<--- 3000-3100/Gamma peaks <--- B:DATAPEAK.DAT <--- 5000-5080/Isotope data <--- B:DATAISOS.DAT
100-130/Calendar	<--- 61000-61020/Calendar data
135-140/Attenuation	<--- 62000-62060/Ge coefficients
145-260/Source Age	<--- 20000-21000/Dates to age calc
300-490/Calib peaks	
500-510/Display peaks	<--- 30000-30100/Peak listing
520-530/Edit peaks	<--- 31000-31100/Corrections menu <--- 32000-32300/Add peak <--- 33000-33100/Delete peak <--- 34000-34100/Change peak <--- 30000-31100/List peaks
600-620/Plot calibs	<--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs
630-645/Fixup summing	<--- 40000-4090/Make summing corrections <--- 4000-4100/Get spectrum <--- B:DATASPEC.DAT <--- 41000-41100/Atten-eff calcs <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs
650-677/Plot drawing instructions	
680-798/Draw eff	<--- 51000-51900/LogEff vs LogE graph <--- 50000-50900/Plot measured effs

GRABCALB: Program Structure Reference
(continued)

Main	<--- Subroutines and [files]
680-798/Draw eff (cont'd)	<--- 52000-52030/Plot 3 hyperbola points <--- 52200-52290/Move red point to max <--- 52100-52130/Erase point <--- 52000-52030/Draw point <--- 52300-52330/Yellow point to sym pt <--- 52100-52130/Erase point <--- 52000-52030/Draw point <--- 52400-52390/Green point to asympt <--- 52100-52130/Erase point <--- 52000-52030/Draw point <--- 52500-52590/Draw hyperbola guidelines <--- 52600-52590/Erase hyperbola guidelines <--- 15000-15090/LnEff-LnE units for 3 pts <--- 53000-53900/Plot result hyperbola eff <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs
800-865/Norm eff	<--- 42000-42900/Hyperbola vs. meas effs <--- 53000-53900/Replot per dev=0 norm <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs
870-890/Refine A	<--- 10000-10500/L-S hyperbola fit <--- 11000-1110/Chi-sq fit results <--- 53000-53900/Plot resulting final eff <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs <--- 42000-42900/Hyperbola vs meas effs
890-915/Refine B	<--- 16000-16300/L-S cubic residuals fit <--- 17000-17170/Trianglize matrix <--- 18000-18100/Solve cubic coeffs <--- 19000-19100/Chi-sq fit results <--- 53000-53900/Plot resulting final eff <--- 51000-51900/LogEff-LogE graph <--- 50000-50900/Plot measured effs <--- 42000-42900/Final fit vs meas effs
920-939/OK menu	<--- 650-etc/GOTO back at draw hyperbola <--- 870-etc/GOTO back at L-S hyperbola <--- 900-etc/GOTO back at L-S cubic fit <--- 910-etc/GOTO back to redraw final eff <--- 938-etc/GOTO continue - fit OK

GRABCALB: Program Structure Reference
(continued)

<u>Main</u>	<u><--- Subroutines and [files]</u>
940-970/Output	<--- 44000-44100/Parameters set for output
	<--- 45000-45500/Create efficiency file
	<--- <u>detreff</u> .DCF
	<--- 46000-46900/Print efficiency summary
980-990/Continue/STOP	<--- 9000-9100/Supplementary analysis menu

Lines not used in execution

6000-6100/Background input of backgnd.BKG

7000-7200/Efficiency parameters of DETLIBRY.LIB

8000-8100/Isotope library of B:DETLIBRY.LIB

13000-13100/Energy to channel transformer

60000-60140/Efficiency vs energy table for calib gammas

```

5 REM file GRABCALB.BAS
18 DIM A(3),TC(3,3),TD(3),TN(3,3)
19 DIM ENATT(21),MUATT(21)
20 DIM MONTH(12),GAMRATE(25),EFFCAL(25),ERRCAL(25),J(25),ECAL(25),SUMCOR(25)
21 DIM H1(100),H2(100),RATERR(100)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CEOH1(5,3),CE2H0(5,3),CE1H1(5,3),CEOH2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CEOH3(5,3)
25 DIM YLOC(20),DETNUMS(10),BENERGY(100),BRATE(100),BERR(100),DETLABS(10)
26 DIM ISOTH(100),MDA(100),ACTRAT(100),LIBEN(100),SBRATE(100),SBERR(100)
27 DIM RATE(100),ENERGY(100),ISOEN(100),ISOIDS(100),ISO$(100),ISOGAM(100)
28 DIM NPC(4096),AREA(100),EAREA(100),LOCH(100),FWHM(100),TAIL(100),CENT(100)

30 GOSUB 1000:REM read file B:DATAMISC.DAT
35 GOSUB 2000:REM read file B:DATACALB.DAT

41 DEF FNENC(CHAN)=COENC+CIENC*CHAN
44 DEF FNFWMH(CHAN)=SQR(COFWMH + C1FWMH*CHAN)
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX)))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 REM INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFV
EN$:CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 REM GOSUB 60000:REM check on efficiency data EFF vs EN
65 REM - temporary continue

70 GOSUB 3000:REM read file B:DATAPEAK.DAT
75 REM GOSUB 4000:REM read file B:DATASPEC.DAT
80 GOSUB 5000:REM read file B:DATAISOS.DAT
85 REM GOSUB 6000:REM read file DETFILE$.BKG
90 REM GOSUB 7000:REM read file B:DETLIBRY.LIB
95 REM gosub 8000:rem read file B:ISOLIBRY.LIB (when needed for B:DATAISOS.DAT)

100 REM-read in days of month data
105 MONTH(0)=0
110 FOR I=1 TO 12
120 READ MONTH(I):MONTH(I)=MONTH(I)+MONTH(I-1)
130 NEXT I

135 REM - below reads in atenuation data
140 FOR I=1 TO 21:READ ENATT(I),BNATOM:MUATT(I)=.008297*5.35*BNATOM:NEXT I

145 CLS
150 PRINT" ***** DETECTOR CALIBRATION *****":PRINT:PRINT
160 INPUT" Descriptive name for this calibration":NACAL$
170 PRINT"Calibration : ";NACAL$
200 REM-select peaks and do experimental calibrations
210 PRINT"Enter decay information for standard":PRINT
220 PRINT" (1) Certification date (Mo-Dy-Yr)"
230 PRINT" (2) Time since certification (Days)":PRINT
240 INPUT"Option":OPD:PRINT
250 IF OPD=1 THEN GOSUB 20000:GOTO 300
260 INPUT"Decay time since standard certification (Days)":TDAY

300 REM - read in peaks and flag calibration candidates
310 PRINT:INPUT"Press enter to select calibration peaks ";ZZ
315 NCAL=0
320 FOR J=1 TO MPMAX
325 CLS
330 PRINT
340 PRINT"Isotope = ";ISOIDS(J)
350 PRINT"Energy = ";:PRINT USING"####.##";ENERGY(J);:PRINT" keV"
355 PRINT
360 PRINT"Count rate = ";:PRINT USING"####.###";RATE(J);:PRINT" cps"
365 PRINT" ";CHR$(241);:PRINT USING"####.###";RATERR(J)
370 PRINT
380 INPUT"Use this peak as calibration (y/n)";YES:PRINT
390 IF YES="n" THEN 490
395 NCAL=NCAL+1:J(NCAL)=J
400 FOR L=1 TO LMAX
410 IF ISOIDS(J)<>ISO$(L) THEN 440
420 ISOTH=ISOTH(L)
430 L=LMAX
440 NEXT L
450 INPUT"Gammas/sec at certification date";GAMRATE(NCAL)
460 ECAL(NCAL)=LIBEN(J):IF LIBEN(J)=0 THEN ECAL(NCAL)=ENERGY(J)
470 EFFCAL(NCAL)=RATE(J)*2^(TDAY/ISOTH)/GAMRATE(NCAL)
480 ERRCAL(NCAL)=RATERR(J)*2^(TDAY/ISOTH)/GAMRATE(NCAL)
485 PRINT"Eff = ";:PRINT USING"###.#####";EFFCAL(NCAL)
486 PRINT" ";CHR$(241);:PRINT USING"###.#####";ERRCAL(NCAL):PRINT
490 NEXT J

```

```

500 CLS:PRINT"Calibrations - Raw Data"
510 GOSUB 30000: REM - list calibration points

520 INPUT"Desire corrections to input data (y/n)";YES:PRINT
530 IF YES="y" THEN GOSUB 31000:GOTO 500

600 REM - plot initial results and continue analysis
605 GOSUB 51000:REM - set up graph paper
610 GOSUB 50000:REM - plot data points
620 LOCATE 24,4

630 INPUT"Fix coinc-sum (y/n)";YES:PRINT
635 FOR K=1 TO NCAL:SUMCOR(K)=1:NEXT K
640 IF YES="y" THEN SCREEN 2:SCREEN 0:GOSUB 40000
645 SCREEN 2:SCREEN 0

650 CLS:PRINT"Calibration curve fitting":PRINT
651 S=0
655 PRINT"      First order fit with hyperbola"
660 PRINT"      (Will apply second order cubic later)":PRINT:PRINT
665 PRINT"      Instructions:":PRINT
666 PRINT"          (1) Turn on Num Lock to use arrows"
667 PRINT"          (2) Select options below while looking at graph"
668 PRINT"              (r)ed point - adjust to curve max estimate"
669 PRINT"              (y)ellow point - adjust to origin point of hyperbola"
670 PRINT"              (g)reen point - adjust to asymptote point of hyperbola"
671 PRINT"              (d)raw lines - examine above settings"
672 PRINT"              (e)rase lines - as needed for new (d) cases"
673 PRINT"              (f)inished - clean replot with calib curve"
674 PRINT"          (3) Move a point in (2) with number pad arrows (5 = finished)"
675 PRINT"          (4) Draw hyperbola characteristic lines (2-d and 2-e)"
676 PRINT"          (5) Plot resulting calibration curve (2-f)"
677 PRINT"          (6) Repeat this process until satisfactory curve fit":PRINT

680 INPUT"To begin, press enter";ZZ
685 RED=2:YELLOW=3:GREEN=1
690 XR=120:YR=40:XY=120:YY=20:XG=250:YG=160
700 GOSUB 51000:GOSUB 50000
710 XP=XR:YP=YR:COLOUR=RED:GOSUB 52000:REM - point plot with no error
712 XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000
714 XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000
720 RYGDEF$=INKEY$:IF RYGDEF$="" THEN 720
725 IF RYGDEF$="r" THEN GOSUB 52200
730 IF RYGDEF$="y" THEN GOSUB 52300
735 IF RYGDEF$="g" THEN GOSUB 52400
740 IF RYGDEF$="d" THEN GOSUB 52500
745 IF RYGDEF$="e" THEN GOSUB 52600
750 IF RYGDEF$<>"f" THEN 720
755 REM - now ready to plot calib curve (hyperbola)
760 XEN=XR:YEFF=YR:GOSUB 15000:LNENR=LNEN:LNEFFR=LNEFF
765 XEN=XY:YEFF=YY:GOSUB 15000:LNENY=LNEN:LNEFFY=LNEFF
770 XEN=XG:YEFF=YG:GOSUB 15000:LNENG=LNEN:LNEFFG=LNEFF
775 D=LNEFFY:A=(LNEFFG-LNEFFY)/(LNENG-LNENY):B=(LNEFFY-LNEFFR)/A:C=LNENR
776 A(0)=1:A(1)=0:A(2)=0:A(3)=0:SP=0
780 GOSUB 53000:REM - plot hyperbola
797 LOCATE 24,4
798 INPUT"Satisfactory (y/n)";YES:IF YES="n" THEN CLS:GOTO 700

800 GOSUB 42000:REM - compare data analysis results for hyperbola
855 PRINT:INPUT"Desire to renormalize to make average deviation zero (y/n)";YES:
IF YES<>"y" THEN 870
860 D=D+TOTDEV/NCAL:GOSUB 53000:LOCATE 24,4
865 INPUT"OK(press enter)";ZZ:GOSUB 42000

870 PRINT:INPUT"Desire LSQ-fit to hyperbola (y/n)";YES:IF YES<>"y" THEN 900
875 GOSUB 10000:REM LSQ-fit to hyperbola
880 GOSUB 53000:LOCATE 24,4
890 INPUT"OK(press enter)";ZZ:GOSUB 42000

900 PRINT:INPUT"Apply LSQ cubic fit to perturbations from hyperbola (y/n)";YES:
IF YES<>"y" THEN 920
905 GOSUB 16000:REM LSQ cubic fit to hyperbola perturbations
910 GOSUB 53000:LOCATE 24,4
915 INPUT"OK(press enter)";ZZ:GOSUB 42000

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920 PRINT:INPUT"Press enter to continue";ZZ:CLS
925 PRINT"          MENU FOR REFIT OPTIONS":PRINT
926 PRINT" Note: Refit options (1-3) remove existing cubic LSQ"
927 PRINT"      perturbation fit, which can be replaced within"
928 PRINT"      these options if desired":PRINT:PRINT
929 PRINT" Refit beginning previous fit sequence at:":PRINT
930 PRINT"      (1) Hyperbola drawing on screen"
931 PRINT"      (2) Hyperbola LSQ selection"
932 PRINT"      (3) Cubic LSQ perturbation selection"
933 PRINT"      (4) No refit yet - view current fit and plot first"
934 PRINT"      (5) None of the above - current fit acceptable":PRINT
935 INPUT"Option";OP:IF OP>3 THEN 938
936 A(0)=1:A(1)=0:A(2)=0:A(3)=0
937 ON OP GOTO 650,870,900
938 IF OP=4 THEN 910
939 EFFCAL$="No efficiency file made":REM - will change if and when file made

940 CLS:PRINT"          FINAL DATA OUTPUT MENU":PRINT
941 PRINT"      (1) Disk file and printout"
942 PRINT"      (2) Printout only"
943 PRINT"      (3) Disk file only"
944 PRINT"      (4) No more output - exit program":PRINT
945 INPUT"Option number";OP:GOSUB 44000:REM - parameter notations
946 IF OP=1 THEN GOSUB 45000:GOSUB 46000:GOTO 940
947 IF OP=2 THEN GOSUB 46000:GOTO 940
948 IF OP=3 THEN GOSUB 45000:GOTO 940
970 SCREEN 2:SCREEN 0

980 GOSUB 9000:REM - continuation menu
990 STOP

1000 REM - subroutine to read miscellaneous parameters file B:MISCDAT.DAT
1010 OPEN "B:DATAMISC.DAT" FOR INPUT AS #3
1020 INPUT #3, LTIME, STCH, ENCH, AUNIT$, UNUM, UDEM, TDAYS, DETN, DETNAM$(DETN), DETLAB$(
DETN), STDATE$
1030 CLOSE #3
1100 RETURN

2000 REM - subroutine to read data calib file B:DATACALB.DAT
2100 OPEN "B:DATACALB.DAT" FOR INPUT AS #3
2110 INPUT #3, COENC, C1ENC, COFWHM, C1FWHM, GOEFF, AOEFF, BOEFF, UOEFF, KOEFF, COEFF, C1EF
F, C2EFF, C3EFF, ENX, DOEFF, D1EFF, D2EFF, D3EFF, POEFF, P1EFF, P2EFF, P3EFF
2160 CLOSE #3
2200 RETURN

3000 REM - subroutine to read data peak file B:DATAPEAK.DAT
3010 OPEN "B:DATAPEAK.DAT" FOR INPUT AS #3
3015 KP=1
3020 IF EOF(3) THEN MPMAX=KP-1:GOTO 3060
3040 INPUT #3, CENT(KP), ENERGY(KP), FWHM(KP), TAIL(KP), AREA(KP), RATE(KP), SBRATE(KP)
, ISOID$(KP), ACTRAT(KP), LIBEN(KP), RATERR(KP), SBERR(KP), H1(KP), H2(KP)
3050 KP=KP+1:GOTO 3020
3060 CLOSE #3
3100 RETURN

4000 REM -subroutine to read in spectrum file B:DATASPEC.DAT
4005 TOTNPC=0
4010 OPEN "B:DATASPEC.DAT" FOR INPUT AS #3
4020 FOR I=STCH TO ENCH
4030 INPUT #3, NPC(I)
4035 TOTNPC=TOTNPC+NPC(I)
4040 NEXT I
4050 CLOSE #3
4100 RETURN

5000 REM - subroutine to read in isotope library file B:DATAISOS.DAT
5010 OPEN "B:DATAISOS.DAT" FOR INPUT AS #3
5020 L=0
5030 L=L+1
5040 INPUT #3, ISO$(L), ISOTH(L), ISOEN(L), ISOGAM(L), MDA(L)
5050 IF ISO$(L)="limit " THEN 5070
5060 GOTO 5030
5070 CLOSE #3
5075 LMAX=L
5080 RETURN

6000 REM - subroutine to read in background library
6010 DETFILE$=DETLAB$(DETN)+".BKG"
6020 OPEN DETFILE$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN BAMAX=CBACK-1:GOTO 6070
6050 INPUT #2, BENERGY(CBACK), BRATE(CBACK), BERR(CBACK)
6060 CBACK=CBACK+1:GOTO 6040
6070 CLOSE #2
6100 RETURN

```



```

7000 REM - subroutine to read in detector library B:DETLIBRY.LIB
7005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
7010 FOR I=1 TO 5
7020 FOR J=1 TO 3
7030 INPUT #3,GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
7040 INPUT #3,CE0H0(I,J),CE0H1(I,J)
7050 INPUT #3,CE1H0(I,J),CE0H1(I,J)
7060 INPUT #3,CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
7070 INPUT #3,CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
7080 NEXT J
7090 NEXT I
7095 CLOSE #3
7100 I=0:J=0
7200 RETURN

8000 REM - subroutine to read in isotope library data B:ISOLIBRY.LIB
8001 REM - note that B:DATAISOS.DAT is used instead usually
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 100
8020 INPUT #3,ISO$(ISO),ISOTH(ISO),ISOEN(ISO),ISOGAM(ISO),MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=100
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

9000 REM- subroutine for supplementary analyses
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 CLS
9020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
9030 PRINT" (1) Background file development (GRABBACK)"
9040 PRINT" (2) Detector efficiency calibration (GRABCALB)"
9050 PRINT" (3) Peak/spectrum diagnostics (GRABDIAG)"
9060 PRINT" (4) Peak/multiplet plot analysis (GRABPLOT)"
9070 PRINT" (5) Analyses per isotopes (GRABISOS)":PRINT
9080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
9090 PRINT:PRINT"Type selected analysis (e.g. GRABBACK) after":PRINT"C-prompt (
C> ) and press enter"
9095 CLOSE #3
9100 RETURN

10000 REM-sub for least squares fit to hyperbola
10010 REM - calculate initial s0
10020 GOSUB 11000: REM calc s=chi-2
10030 S0=S
10040 INPUT"Increment divisor (usually 2)":INCR
10100 REM - calculate 1st and 2nd derivatives for minimum cases
10110 DSDD=0:D2SDD2=0:DSDA=0:D2SDA2=0
10120 DSDB=0:D2SDB2=0:DSDC=0:D2SDC2=0
10130 FOR K=1 TO NCAL
10140 XK=LOG(ECAL(K)):YK=LOG(EFFCAL(K))
10150 EYK=ERRCAL(K)/EFFCAL(K):WTK=EYK^-2
10160 DYK=D+A*SQR(B^2+(C-XK)^2)-YK
10170 YKROOT=SQR(B^2+(C-XK)^2)
10180 DSDD=DSDD+WTK*DYK
10190 D2SDD2=D2SDD2+WTK
10200 DSDA=DSDA+WTK*YKROOT*DYK
10210 D2SDA2=D2SDA2+WTK*YKROOT^2
10220 DSDB=DSDB+WTK*((D-YK)/YKROOT + A)
10230 D2SDB2=D2SDB2+WTK*((D-YK)*(C-XK)^2/YKROOT^3 + A)
10240 DSDC=DSDC+WTK*(C-XK)*((D-YK)/YKROOT + A)
10250 D2SDC2=D2SDC2+WTK*((D-YK)*B^2/YKROOT^3 + A)
10260 NEXT K
10270 D=D-DSDD/D2SDD2/INCR
10280 A=A-DSDA/D2SDA2/INCR
10290 B=B-DSDB/D2SDB2/INCR
10300 C=C-DSDC/D2SDC2/INCR
10310 GOSUB 11000:REM - calc new s with above parameters
10320 IF S>S0 THEN PRINT:PRINT"Use increment factor > ":INCR:GOTO 10040
10330 IF ABS(S-S0)>.001*S0 THEN S0=S:GOTO 10110
10400 REM print results
10410 CLS
10420 PRINT" Fit to hyperbola      LNEFF = D + A*SQR(B^2 + (C-LNEN)^2 )
10430 PRINT
10440 PRINT"D = ";D
10445 PRINT"A = ";A
10450 PRINT"B = ";B
10455 PRINT"C = ";C;" or ";EXP(C);" keV":PRINT
10460 PRINT"Chi-2 = ";S
10465 PRINT"Points fitted = ";NCAL:PRINT
10470 INPUT"Press enter to continue":ZZ
10500 RETURN

```

```

19000 REM LSQ cubic fit to deviations from hyperbola - Chi-2 calc
19005 SP=0
19010 FOR K=1 TO NCAL
19020 XK=LOG(ECAL(K)):YHYPK=D+A*SQR(B^2+(C-XK)^2)
19025 YK=(LOG(EFFCAL(K))-D)/(YHYPK-D)
19030 EYK=(ERRCAL(K)/EFFCAL(K))/(YHYPK-D):WTK=EYK^-2
19035 YFITK=A(0)+A(1)*XK+A(2)*XK^2+A(3)*XK^3
19040 SP=SP+WTK*(YK-YFITK)^2
19050 NEXT K
19060 PRINT"Chi-2 = ";SP
19070 PRINT"Points fitted = ";NCAL:PRINT
19100 RETURN

20000 REM - subroutine for date to days
20010 INPUT"Date of standard certification (eg 052484)";T1
20020 INPUT"Date of calibration counting (eg 031585)";T2
20030 MT1=INT(T1/10000):MT2=INT(T2/10000)
20040 DT1=INT((T1-MT1*10000)/100):DT2=INT((T2-MT2*10000)/100)
20050 YT1=T1-MT1*10000-DT1*100:YT2=T2-MT2*10000-DT2*100
20060 LD1=INT(YT1/4)
20070 IF YT1/4=INT(YT1/4) THEN IF MT1<3 THEN IF DT1<29 THEN LD1=LD1-1
20080 LD2=INT(YT2/4)
20090 IF YT2/4=INT(YT2/4) THEN IF MT2<3 THEN IF DT2<29 THEN LD2=LD2-1
20100 TDAY=365*(YT2-YT1) + MONTH(MT2-1)-MONTH(MT1-1) + DT2-DT1 + LD2-LD1
21000 RETURN

30000 REM - subroutine to list calibs
30010 PRINT"Peak Isotope Energy Gammas Efficiency"
30015 PRINT" # Z-A keV gps #":PRINT
30020 FOR K=1 TO NCAL
30030 PRINT USING"####";K:PRINT " ";
30035 PRINT ISOID$(J(K));
30040 PRINT USING"#####.##";ECAL(K);
30050 PRINT USING"#####.##";GAMRATE(K);
30060 PRINT USING"#####.##";EFFCAL(K):PRINT " ";
30070 PRINT CHR$(241):PRINT " ":PRINT USING"#####.##";ERRCAL(K)
30080 NEXT K
30090 PRINT
30100 RETURN

31000 REM - sub to correct input data
31010 PRINT"Editing options":PRINT
31020 PRINT" (1) Add calibration peak"
31030 PRINT" (2) Delete calibration peak"
31040 PRINT" (3) Change calibration peak"
31050 PRINT" (4) List current calibration peaks"
31060 PRINT" (5) Exit - editing complete":PRINT
31070 INPUT"Select option";OPE
31075 ON OPE GOSUB 32000,33000,34000,30000
31080 IF OPE<>5 THEN 31010
31100 RETURN

32000 REM - sub to add peak
32010 PRINT"Calibration peak number (0 if first peak), after which new peak is t
o be added"
32015 INPUT PNUM
32020 FOR K= NCAL TO PNUM+1 STEP -1
32030 GAMRATE(K+1)=GAMRATE(K)
32040 EFFCAL(K+1)=EFFCAL(K)
32050 ERRCAL(K+1)=ERRCAL(K)
32060 ECAL(K+1)=ECAL(K)
32070 J(K+1)=J(K)
32080 NEXT K
32090 INPUT"New peak to be added (peak number on GRABGAM output)";J
32100 J(PNUM+1)=J
32110 FOR L=1 TO LMAX
32120 IF ISOID$(J)<>ISO$(L) THEN 32150
32130 ISOTH=ISOTH(L)
32140 L=LMAX
32150 NEXT L
32160 INPUT"Gammas/sec at certification date";GAMRATE(PNUM+1)
32170 ECAL(PNUM+1)=LIBEN(J):IF LIBEN(J)=0 THEN ECAL(PNUM+1)=ENERGY(J)
32180 EFFCAL(PNUM+1)=RATE(J)*2^(TDAY/ISOTH)/GAMRATE(PNUM+1)
32190 ERRCAL(PNUM+1)=RATERR(J)*2^(TDAY/ISOTH)/GAMRATE(PNUM+1)
32200 PRINT"Eff = ";PRINT USING"#####.##";EFFCAL(PNUM+1)
32210 PRINT" ";CHR$(241):PRINT USING"#####.##";ERRCAL(PNUM+1):PRINT
32250 NCAL=NCAL+1
32300 RETURN

```

```

33000 REM - sub to remove peak
33010 INPUT"Calibration peak number to delete";PNUM
33020 FOR K=PNUM TO NCAL
33030 GAMRATE(K)=GAMRATE(K+1)
33040 EFFCAL(K)=EFFCAL(K+1)
33050 ERRCAL(K)=ERRCAL(K+1)
33060 ECAL(K)=ECAL(K+1)
33070 J(K)=J(K+1)
33080 NEXT K
33090 NCAL=NCAL-1
33100 RETURN

34000 REM - sub to change peak inputs
34010 PRINT"Note - only input to change is certified gammas/sec."
34020 PRINT"(If want to replace peak, use Delete and Add options)"
34022 PRINT:INPUT"Do you still want this option (y/n)";YES$:IF YES$<>"y" THEN 3410
0
34025 PRINT
34030 INPUT"Calibration peak number to alter";PNUM
34040 INPUT"Gammas/sec a certification date";GAMRATE
34050 EFFCAL(PNUM)=EFFCAL(PNUM)*GAMRATE(PNUM)/GAMRATE
34060 ERRCAL(PNUM)=ERRCAL(PNUM)*GAMRATE(PNUM)/GAMRATE
34070 GAMRATE(PNUM)=GAMRATE
34080 PRINT"Eff = ";:PRINT USING"###.####";EFFCAL(NCAL)
34090 PRINT"      ";CHR$(241);:PRINT USING"###.####";ERRCAL(NCAL):PRINT
34100 RETURN

40000 REM - summing correction for close geometry
40005 PRINT"Reading in data for total detection information"
40010 GOSUB 4000: REM - get npctot
40020 TOTNPC=TOTNPC*ENCH/(ENCH-STCH):REM approximation fixup
40030 TOTRATE = TOTNPC/LTIME:REM - total spectral rate sec-1
40040 CLS
40050 INPUT"Average active thickness estimate for detector (cm)";TATT
40060 SUMGAM = 0
40070 FOR K=1 TO NCAL
40080 FOR I=1 TO 20
40090 IF ECAL(K)>=ENATT(I) THEN IF ECAL(K)<=ENATT(I+1) THEN ENATT=ECAL(K):GOSUB
41000:I=20:REM gets value of muatt
40100 NEXT I
40110 SUMGAM = SUMGAM + GAMRATE(K)*2^(-TDAY/ISOTH(J(K)))*(1-EXP(-MUATT*TATT))
40120 NEXT K
40130 COINCON = TOTRATE/SUMGAM
40140 PRINT
40150 INPUT"Peak number to be corrected (0 if none)";PNUM:IF PNUM=0 THEN 40900
40155 PRINT:PRINT"Peak #";PNUM;" has energy = ";:PRINT USING"####.#";ECAL(PNUM);
:PRINT" Kev":PRINT
40160 INPUT"Energy of interferring coincident peak";ECOINC:PRINT
40170 INPUT"Fraction of coincident cases (per decay scheme)";FCOINC
40180 FOR I=1 TO 20
40190 IF ECOINC>=ENATT(I) THEN IF ECOINC<=ENATT(I+1) THEN ENATT=ECOINC:GOSUB 410
00:I=20:REM gets value of muatt
40200 NEXT I
40210 COINFIX=COINCON*(1-EXP(-MUATT*TATT))*FCOINC
40220 EFFCAL(PNUM)=ERRCAL(PNUM):ERRCAL=ERRCAL(PNUM)
40230 EFFCAL(PNUM)=EFFCAL(PNUM)/(1-COINFIX)
40240 ERRCAL(PNUM)=ERRCAL(PNUM)/(1-COINFIX)
40245 SUMCOR(PNUM)=1/(1-COINFIX)
40250 GOSUB 51000
40260 GOSUB 50000
40270 LOCATE 24,4
40280 INPUT"Accept correction (y/n)";OK$:IF OK$="y" THEN 40300
40290 EFFCAL(PNUM)=EFFCAL(PNUM):ERRCAL(PNUM)=ERRCAL(PNUM):SUMCOR(PNUM)=1
40300 CLS:SCREEN 2:SCREEN 0
40320 PRINT"Next case selection below":PRINT
40330 PRINT"      (1) Input active detector thickness and gamma peak"
40340 PRINT"      (2) Input gamma peak alone (use current detector thickness)"
40350 PRINT"      (3) Exit - summing corrections completed":PRINT
40360 INPUT"Option";OPSC
40365 CLS
40370 ON OPSC GOTO 40050,40150,40900
40900 RETURN

41000 REM - subroutine to interpolate muatt
41010 LN MUATT = LOG(MUATT(I)) + (LOG(MUATT(I+1))-LOG(MUATT(I)))*(LOG(ENATT)-LOG(
ENATT(I)))/(LOG(ENATT(I+1))-LOG(ENATT(I)))
41020 MUATT=EXP(LN MUATT)
41100 RETURN

```

```

42000 REM- summary of hyperbola fit - tabular
42801 CLS:SCREEN 2:SCREEN 0
42805 PRINT"Comparison of measured (Eff) and calculated (Hypeff) results"
42806 PRINT:PRINT
42807 PRINT"Peak Energy    Eff    Hypeff    Diff"
42808 PRINT"  #      keV      #      #      % ":PRINT
42809 TOTDEV=0:RMSDEV=0
42810 FOR K=1 TO NCAL
42812 LNEN = LOG(ECAL(K))
42815 LNEFF=D + A*SQR(B^2+(LNEN-C)^2)*(A(0)+A(1)*LNEN+A(2)*LNEN^2+A(3)*LNEN^3)
42820 DEVEFF=LOG(EFFCAL(K))-LNEFF
42825 TOTDEV=TOTDEV+DEVEFF:RMSDEV=RMSDEV+DEVEFF^2
42830 PRINT USING"###";K;
42831 PRINT USING"#####.##";ECAL(K);
42832 PRINT USING"#####.##";EFFCAL(K);
42833 PRINT USING"#####.##";EXP(LNEFF);
42834 PRINT USING"#####.##";100*DEVEFF
42840 NEXT K
42845 PRINT:PRINT"RMS deviation = ";:PRINT USING"#####.##";100*SQR(RMSDEV/NCAL);:P
RINT" %"
42850 PRINT:PRINT"Average deviation = ";:PRINT USING"#####.##";100*TOTDEV/NCAL;:P
RINT" %"
42900 RETURN

44000 REM - transform detector parameters to usual notation
44040 GOEFF=EXP(D):AOEFF=A:BOEFF=B:UOEFF=1:KOEFF=C
44050 COEFF=A(0):C1EFF=A(1):C2EFF=A(2):C3EFF=A(3)
44060 ENX=5000:DOEFF=0:D1EFF=0:D2EFF=0:D3EFF=0
44070 POEFF=0:P1EFF=0:P2EFF=0:P3EFF=0
44100 RETURN

45000 REM - make detector calibration file
45010 PRINT:PRINT
45020 INPUT"Entire detector calibration file label (-----.DCF)";EFFCAL$
45030 PRINT:PRINT"File label is ";EFFCAL$;:INPUT" OK(y/n)";YES$:IF YES$<>"y" THEN
GOTO 45010
45080 PRINT:INPUT"Examine transformed data before making file (y/n)";YES$
45090 IF YES$<>"y" THEN 45200
45100 CLS
45110 GOSUB 60000:REM eff check list
45120 PRINT:INPUT"Still wish to make file (y/n)";YES$
45130 IF YES$="n" THEN EFFCAL$="No efficiency file made":GOTO 45500
45200 OPEN EFFCAL$ FOR OUTPUT AS #3
45210 WRITE #3,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EFF,C2EFF,C3EFF
45220 WRITE #3,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
45230 CLOSE #3
45500 RETURN

```

```

46000 REM - sub to printout results
46010 CLS:INPUT"Line feed printer as needed, and press enter to print";ZZ
46020 LPRINT" ***** DETECTOR EFFICIENCY CALIBRATION *****"
46030 LPRINT:LPRINT
46040 LPRINT"Title: ";NACAL$:LPRINT
46050 LPRINT"Calibration file generated: ";EFFCAL$:LPRINT
46330 REM - this segment on file DETPRINT.BAS in A-format
46335 LPRINT
46355 LPRINT"-----EFFICIENCY CALIBRATION FORMULA-----"
46370 LPRINT
46380 LPRINT"Efficiency calibration:  $EFF = G \cdot \exp(\text{HYPERBOLA} \cdot \text{POLYNOMIAL}) \cdot (1 + \text{PERTURBATION})$ "
46385 LPRINT
46390 LPRINT"  G = global calibration factor = ";GOEFF;" D =  $\ln(G)$  = ";LOG(GOEFF)
```

46395 LPRINT

46400 LPRINT" HYPERBOLA = $A \cdot \sqrt{B^2 + (\ln(EN) - C)^2}$ with values below:

46410 LPRINT" (A = ";AOEFF;" B = ";BOEFF;" C = ";KOEFF;")"

46415 LPRINT

46420 LPRINT" POLYNOMIAL = $C_0 + C_1 \cdot \ln(EN) + C_2 \cdot \ln(EN)^2 + C_3 \cdot \ln(EN)^3$ with values below:"

46430 LPRINT" (C0 = ";COEFF;" C1 = ";C1EFF;" C2 = ";C2EFF;" C3 = ";C3EFF;")"

46432 LPRINT" ";ENX;" keV = crossover between low EN (above) and high EN (below) cases"

46434 LPRINT" (C0 = ";TOEFF;" C1 = ";T1EFF;" C2 = ";T2EFF;" C3 = ";T3EFF;")"

46435 LPRINT

46440 LPRINT" PERTURBATION = $P_0 + P_1 \cdot \ln(EN) + P_2 \cdot \ln(EN)^2 + P_3 \cdot \ln(EN)^3$ with values below:"

46450 LPRINT" (P0 = ";POEFF;" P1 = ";P1EFF;" P2 = ";P2EFF;" P3 = ";P3EFF;")"

46460 LPRINT

46470 LPRINT"-----FIT INFORMATION-----"

46480 LPRINT

46505 LPRINT"Comparison of measured (Eff) and calculated (Hypeff) results"

46506 LPRINT:LPRINT

46507 LPRINT"Peak Energy Eff Hypeff Diff"

46508 LPRINT" # keV # % ":LPRINT

46509 TOTDEV=0:RMSDEV=0

46510 FOR K=1 TO NCAL

46512 LNEN = LOG(ECAL(K))

46515 LNEFF=D + A*SQR(B^2+(LNEN-C)^2)*(A(0)+A(1)*LNEN+A(2)*LNEN^2+A(3)*LNEN^3)

46520 DEVEFF=LOG(EFFCAL(K))-LNEFF

46525 TOTDEV=TOTDEV+DEVEFF:RMSDEV=RMSDEV+DEVEFF^2

46530 LPRINT USING"###";K;

46531 LPRINT USING"#####";ECAL(K);

46532 LPRINT USING"#####";EFFCAL(K);

46533 LPRINT USING"#####";EXP(LNEFF);

46534 LPRINT USING"#####";100*DEVEFF

46540 NEXT K

46545 LPRINT:LPRINT"RMS deviation = ";:LPRINT USING"#####";100*SQR(RMSDEV/NCAL)

46550 LPRINT:LPRINT"Average deviation = ";:LPRINT USING"#####";100*TOTDEV/NCAL;

46560 LPRINT:LPRINT"Chi-2 for hyperbola = ";S:IF S=0 THEN 46580

46570 LPRINT"SQRT(chi-2/n-r) = ";SQR(S/(NCAL-4))

46580 LPRINT:LPRINT"Chi-2 for cubic perturbation = ";SP:IF SP=0 THEN 46600

46590 LPRINT"SQRT(chi-2/n-r) = ";SQR(SP/(NCAL-4))

46600 LPRINT

46610 LPRINT"-----RAW DATA REFERENCE-----"

46620 LPRINT:LPRINT

um Corr"	Num	Isotope	Energy	Gamma	Counts	Efficiency	S
46640 LPRINT" #	Z-A	keV	gps	cps	#		
46650 LPRINT							
46660 FOR K=1 TO NCAL							
46670 LPRINT USING"###";K;:LPRINT" "							
46680 LPRINT ISODS(J(K));							
46690 LPRINT USING"#####";ECAL(K);							
46700 LPRINT USING"#####";GAMRATE(K);							
46710 LPRINT USING"#####";RATE(J(K));:LPRINT" +/-";							
46720 LPRINT USING"#####";RATERR(J(K));							
46730 LPRINT USING"#####";EFFCAL(K);:LPRINT" +/-";							
46740 LPRINT USING"#####";ERRCAL(K);							
46750 LPRINT USING"#####";SUMCOR(K)							
46760 NEXT K							
46770 LPRINT:LPRINT"Average active detector thickness = ";TATT;" cm"							
46780 LPRINT:LPRINT"Decay time since standard certification = ";TDAY;" days"							
46900 RETURN							

```

50000 REM - sub to plot data points
50010 FOR K=1 TO NCAL
50020 XEN=19 + 100*LOG(ECAL(K))/LOG(10) -100
50030 YEFF=100-100*( LOG(EFFCAL(K))/LOG(10) - LGEFMD )
50040 YEFFA=100-100*( LOG(EFFCAL(K)+ERRCAL(K))/LOG(10) - LGEFMD )
50050 YEFFB=100-100*( LOG(EFFCAL(K)-ERRCAL(K))/LOG(10) - LGEFMD )
50060 LINE(XEN-1,YEFF-1)-(XEN+1,YEFF+1),3,B:REM point plotted
50070 LINE(XEN,YEFA)-(XEN,YEFOB),3:REM error plotted
50080 NEXT K
50900 RETURN

51000 REM - subroutine for graph paper
51600 REM - plot initial results and continue analysis
51610 SCREEN 1:CLS
51620 COLOR 8,0
51625 MINEFF=1:MAXEFF=0
51630 FOR K=1 TO NCAL:REM find graph limits
51632 IF EFFCAL(K)>MAXEFF THEN MAXEFF = EFFCAL(K)
51634 IF EFFCAL(K)<MINEFF THEN MINEFF = EFFCAL(K)
51636 NEXT K
51640 LGEFMD=(LOG(MAXEFF)+LOG(MINEFF))/(2*LOG(10)):REM mid y-axis
51650 LINE(19,0)-(319,199),1,B:REM draw axis frame
51651 LINE(119,0)-(119,199),1
51652 LINE(219,0)-(219,199),1
51654 IF LGEFMD = INT(LGEFMD) THEN YGR1=100:YGR2=100:LINE(19,100)-(319,100),1:GO
TO 51660
51655 YGR1=INT(100 + 100*(LGEFMD-INT(LGEFMD)) + .5)
51656 IF GR1<199 THEN LINE(19,YGR1)-(319,YGR1),1
51657 YGR2=YGR1-100
51658 IF YGR2>0 THEN LINE(19,YGR2)-(319,YGR2),1
51660 FOR XXGRID=19 TO 219 STEP 100
51662 FOR XGRID=1 TO 10
51664 XTIC=INT(100*LOG(XGRID)/LOG(10) + .5) + XXGRID
51666 LINE(XTIC,0)-(XTIC,5),1
51667 LINE(XTIC,199)-(XTIC,194),1
51668 NEXT XGRID
51669 NEXT XXGRID
51670 FOR YYGRID=YGR1+100 TO YGR2 STEP -100
51671 FOR YGRID=1 TO 10
51672 YTIC=YYGRID - INT(100*LOG(YGRID)/LOG(10) + .5)
51673 IF YTIC > 199 THEN 51677
51674 IF YTIC < 0 THEN 51677
51675 LINE(19,YTIC)-(24,YTIC),1
51676 LINE(319,YTIC)-(314,YTIC),1
51677 NEXT YGRID
51678 NEXT YYGRID
51900 RETURN

52000 REM - sub to draw point
52010 LINE(XP-1,YP-1)-(XP+1,YP+1),COLOUR,BF
52030 RETURN

52100 REM - sub to erase point
52110 LINE(XP-1,YP-1)-(XP+1,YP+1),0,BF
52130 RETURN

52200 REM - sub to move red point for max of hyperbola
52210 VECT$=INKEY$:IF VECT$="" THEN 52210
52220 IF INT(VAL(VECT$)/2)<>VAL(VECT$)/2 THEN 52270
52225 XP=XR:YP=YR:GOSUB 52100
52230 IF VECT$="8" THEN YR=YR-1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000:GOTO 52210
52235 IF VECT$="2" THEN YR=YR+1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000:GOTO 52210
52240 XP=XY:YP=YY:GOSUB 52100
52245 IF VECT$="6" THEN 52260
52250 XR=XR-1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52255 XY=XY-1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52210
52260 XR=XR+1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52265 XY=XY+1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52210
52270 IF VECT$<>"5" THEN 52210
52290 RETURN

```

```

52300 REM - sub to move yellow point for origin of hyperbola
52310 VECT$=INKEY$:IF VECT$="" THEN 52310
52320 IF INT(VAL(VECT$)/2)<>VAL(VECT$)/2 THEN 52370
52325 XP=XY:YP=YY:GOSUB 52100
52330 IF VECT$="8" THEN YY=YY-1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52310
52335 IF VECT$="2" THEN YY=YY+1:XP=XY:YP=YY:COLOUR=YELLOW:GOSUB 52000:GOTO 52310

52340 XP=XR:YP=YR:GOSUB 52100
52345 IF VECT$="6" THEN 52360
52350 XR=XR-1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52355 XY=XY-1:XP=XY:YP=YR:COLOUR=YELLOW:GOSUB 52000:GOTO 52310
52360 XR=XR+1:XP=XR:YP=YR:COLOUR=RED:GOSUB 52000
52365 XY=XY+1:XP=XY:YP=YR:COLOUR=YELLOW:GOSUB 52000:GOTO 52310
52370 IF VECT$<>"5" THEN 52310
52390 RETURN

52400 REM - sub to move green point for asymptote of hyperbola
52410 VECT$=INKEY$:IF VECT$="" THEN 52410
52420 IF INT(VAL(VECT$)/2)<>VAL(VECT$)/2 THEN 52470
52425 XP=XG:YP=YG:GOSUB 52100
52430 IF VECT$="8" THEN YG=YG-1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52435 IF VECT$="2" THEN YG=YG+1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52445 IF VECT$="6" THEN 52460
52450 XG=XG-1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52460 XG=XG+1:XP=XG:YP=YG:COLOUR=GREEN:GOSUB 52000:GOTO 52410
52470 IF VECT$<>"5" THEN 52410
52490 RETURN

52500 REM - sub to draw hyperbola characteristics
52510 LINE(XR,YR)-(XY,YY),GREEN
52520 LINE(XY,YY)-(XG,YG),GREEN
52530 XRE=XR:YRE=YR:XYE=XY:YYE=YY:XGE=XG:YGE=YG
52590 RETURN

52600 REM - sub to erase hyperbola characteristics
52610 LINE(XRE,YRE)-(XYE,YYE),0
52620 LINE(XYE,YYE)-(XGE,YGE),0
52690 RETURN

53000 REM - sub to plot hyperbola calib
53780 CLS:GOSUB 51000:GOSUB 50000
53785 FOR XEN=20 TO 318
53787 LNEN=((100-19+XEN)/100)*LOG(10)
53788 LNEFF=D + A*SQR(B^2+(LNEN-C)^2)*(A(0)+A(1)*LNEN+A(2)*LNEN^2+A(3)*LNEN^3)
53789 YEFF=100-100*(LNEFF/LOG(10) - LGFMD)
53790 IF YEFF>198 THEN 53795
53791 IF YEFF<1 THEN 53795
53792 PSET (XEN,YEFF),RED
53795 NEXT XEN
53796 GOSUB 50000
53900 RETURN

60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";EFFCAL$
60006 PRINT
60010 PRINT "EN","EFF"
60011 PRINT"kev"," "
60020 PRINT USING"####.###";88.03;:PRINT USING"###.#####";FNEFF(88.03)
60030 PRINT USING"####.###";122.06;:PRINT USING"###.#####";FNEFF(122.06)
60040 PRINT USING"####.###";165.85;:PRINT USING"###.#####";FNEFF(165.85)
60050 PRINT USING"####.###";279.19;:PRINT USING"###.#####";FNEFF(279.19)
60060 PRINT USING"####.###";391.69;:PRINT USING"###.#####";FNEFF(391.69)
60070 PRINT USING"####.###";514!;:PRINT USING"###.#####";FNEFF(514!)
60080 PRINT USING"####.###";661.64;:PRINT USING"###.#####";FNEFF(661.64)
60090 PRINT USING"####.###";898.02;:PRINT USING"###.#####";FNEFF(898.02)
60100 PRINT USING"####.###";1173.21;:PRINT USING"###.#####";FNEFF(1173.21)
60110 PRINT USING"####.###";1332.56;:PRINT USING"###.#####";FNEFF(1332.56)
60120 PRINT USING"####.###";1836.01;:PRINT USING"###.#####";FNEFF(1836.01)
60140 RETURN

61000 REM month days data
61010 DATA 31,28,31,30,31,30
61020 DATA 31,31,30,31,30,31

62000 REM - data for mass atten coeffs in barns/atom - convert to cm-1 by
62010 REM - multiplying by 0.008297 x 5.35 gm/cm3
62020 REM Energy(kev) b/atom , etc
62030 DATA 15,11000,20,5070,30,1680,40,746,50,400,60,243,80,115
62040 DATA 100,66.4,150,29.6,200,20.0,300,13.5,400,11.2,500,9.87
62050 DATA 600,8.96,800,7.73
62060 DATA 1000,6.89,1500,5.60,2000,4.92,3000,4.24,4000,3.95,5000,3.81

```

```
<--- Subroutines and [files]
```

```
30-35/Input data      <--- 1000-1100/Miscellaneous data
                        <--- B:DATAMISC.DAT
                        <--- 2000-2200/Efficiency data
                        <--- B:DATAALB.DAT
```

```
70-95/Input data      <--- 3000-3100/Gamma peaks
                        <--- B:DATAPEAK.DAT
```

```
900-990/Continue/STOP  <--- 9000-9100/Supplementary analysis menu
```

60000-60140/Efficiency vs energy table for calib gammas


```

5 REM file GRABDIAG.BAS
21 DIM H1(100),H2(100)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CE0H1(5,3),CE2H0(5,3),CE1H1(5,3),CE0H2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CE0H3(5,3)
25 DIM YLOC(20),DETNAM$(10),BENERGY(100),BRATE(100),BERR(100),DETLAB$(10)
26 DIM ISOTH(100),MDA(100),ISOACT(100),LIBEN(100),SBRATE(100),SBERR(100)
27 DIM RATE(100),ENERGY(100),ISOEN(100),ISOIDS(100),ISO$(100),ISOGAM(100)
28 DIM NPC(4096),AREA(100),EAREA(100),LOCH(100),FWHM(100),TAIL(100),CENT(100)

30 GOSUB 1000:REM read file B:DATAMISC.DAT
35 GOSUB 2000:REM read file B:DATAALB.DAT

41 DEF FNENC(CHAN)= COENC + C1ENC*CHAN
44 DEF FNFWMH(CHAN)=SQR(COFWMH +C1FWMH*CHAN)
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 REM INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFV
EN$:CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 REM GOSUB 60000:REM check on efficiency data EFF vs EN
65 REM - temporary continue

70 GOSUB 3000:REM read file B:DATAPEAK.DAT
75 REM GOSUB 4000:REM read file B:DATASPEC.DAT
80 REM GOSUB 5000:REM read file B:DATAISOS.DAT
85 REM gosub 6000:REM read file DETFILE$.BKG
90 REM GOSUB 7000:REM read file B:DETLIBRY.LIB
95 REM gosub 8000:rem read file B:ISOLIBRY.LIB (when needed for B:DATAISOS.DAT)

97 LPRINT" ***** Peak Diagnostics Summary *****":LPRINT:LPRINT:
LPRINT
100 LPRINT " Candidate           Gamma Identification           Compton Scatter "
105 LPRINT "-----"           "-----"           "-----"
110 LPRINT "Peak Isotope      Energy  SE peak  DE peak      Edge(max)  Back(min)"
120 LPRINT " #          Z-A      keV      keV      keV      keV      keV "
125 LPRINT
130 FOR I=1 TO MPMAX
140 LPRINT USING"####";I;
150 LPRINT " ";
160 LPRINT ISOIDS(I);
170 LPRINT " ";
180 LPRINT USING"#####. #";ENERGY(I);
190 LPRINT USING"#####. #";ENERGY(I)+511.006;
200 LPRINT USING"#####. #";ENERGY(I)+511.006+511.006;
210 LPRINT USING"#####. #";ENERGY(I)-1/(1/ENERGY(I)+2/511.006);
220 LPRINT USING"#####. #";1/(1/ENERGY(I)+2/511.006)
230 LPRINT
250 NEXT

900 GOSUB 9000
990 STOP

1000 REM - subroutine to read miscellaneous parameters file B:MISCDAT.DAT
1010 OPEN "B:DATAMISC.DAT" FOR INPUT AS #3
1020 INPUT #3,LTIME,STCH,ENCH,AUNIT$,UNUM,UEM,TDAY$,DETN,DETNAM$(DETN),DETLAB$(
DETN),STDATE$
1030 CLOSE #3
1100 RETURN

2000 REM - subroutine to read data calib file B:DATAALB.DAT
2100 OPEN "B:DATAALB.DAT" FOR INPUT AS #3
2110 INPUT #3,COENC,C1ENC,COFWMH,C1FWMH,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EF
F,C2EFF,C3EFF,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
2160 CLOSE #3
2200 RETURN

3000 REM - subroutine to read data peak file B:DATAPEAK.DAT
3010 OPEN "B:DATAPEAK.DAT" FOR INPUT AS #3
3015 KP=1
3020 IF EOF(3) THEN MPMAX=KP-1:GOTO 3060
3040 INPUT #3,CENT(KP),ENERGY(KP),FWHM(KP),TAIL(KP),AREA(KP),RATE(KP),SBRATE(KP)
,ISOIDS(KP),ACTRAT,LIBEN(KP),RATERR,SBERR(KP),H1(KP),H2(KP)
3050 KP=KP+1:GOTO 3020
3060 CLOSE #3
3100 RETURN

```

```

4000 REM -subroutine to read in spectrum file B:DATASPEC.DAT
4010 OPEN "B:DATASPEC.DAT" FOR INPUT AS #3
4020 FOR I=STCH TO ENCH
4030 INPUT #3, NPC(I)
4040 NEXT I
4050 CLOSE #3
4100 RETURN

5000 REM - subroutine to read in isotope library file B:DATAISOS.DAT
5010 OPEN "B:DATAISOS.DAT" FOR INPUT AS #3
5020 L=0
5030 L=L+1
5040 INPUT #3, ISO$(L), ISOTH(L), ISOEN(L), ISOGAM(L), MDA(L)
5050 IF ISO$(L)="limit " THEN 5070
5060 GOTO 5030
5070 CLOSE #3
5080 RETURN

6000 REM - subroutine to read in background library
6010 DETFILE$=DETLAB$(DETN)+".BKG"
6020 OPEN DETFILE$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN BAMAX=CBACK-1:GOTO 6070
6050 INPUT #2,BENERGY(CBACK),BRATE(CBACK),BERR(CBACK)
6060 CBACK=CBACK+1:GOTO 6040
6070 CLOSE #2
6100 RETURN

7000 REM - subroutine to read in detector library B:DETLIBRY.LIB
7005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
7010 FOR I=1 TO 5
7020 FOR J=1 TO 3
7030 INPUT #3,GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
7040 INPUT #3,CE0H0(I,J)
7050 INPUT #3,CE1H0(I,J),CE0H1(I,J)
7060 INPUT #3,CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
7070 INPUT #3,CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
7080 NEXT J
7090 NEXT I
7095 CLOSE #3
7100 I=0:J=0
7200 RETURN

8000 REM - subroutine to read in isotope library data B:ISOLIBRY.LIB
8001 REM - note that B:DATAISOS.DAT is used instead usually
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 100
8020 INPUT #3,ISO$(ISO),ISOTH(ISO),ISOEN(ISO),ISOGAM(ISO),MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=100
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

9000 REM- subroutine for supplementary analyses
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 CLS
9020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
9030 PRINT" (1) Background file development (GRABBACK)"
9040 PRINT" (2) Detector efficiency calibration (GRABCALB)"
9050 PRINT" (3) Peak/spectrum diagnostics (GRABDIAG)"
9060 PRINT" (4) Peak/multiplet plot analysis (GRABPLOT)"
9070 PRINT" (5) Analyses per isotopes (GRABISOS)":PRINT
9080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
9090 PRINT:PRINT"Type selected analysis (e.g. GRABBACK) after":PRINT"C-prompt (
C> ) and press enter"
9095 CLOSE #3
9100 RETURN

13000 REM sub from sub 3000 - calc channel from energy
13010 AOEN = FNENC(0)
13020 AIEN = FNENC(1)-FNENC(0)
13030 CHANO = (ENERGY-AOEN)/AIEN
13040 CHAN = CHANO + (ENERGY-FNENC(CHANO))/AIEN
13050 IF ABS(ENERGY-FNENC(CHAN))>.1 THEN CHANO=CHAN:GOTO 13040
13055 RCHAN=CHAN
13060 CHAN=INT(CHAN+.5)
13100 RETURN

```

```
60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";DETNAME$(DETNAME)
60006 PRINT
60010 PRINT "EN", "EFF"
60011 PRINT"keV", " # "
60020 PRINT USING"####.##";88.03;:PRINT USING"###.#####";FNEFF(88.03)
60030 PRINT USING"####.##";122.06;:PRINT USING"###.#####";FNEFF(122.06)
60040 PRINT USING"####.##";165.85;:PRINT USING"###.#####";FNEFF(165.85)
60050 PRINT USING"####.##";279.19;:PRINT USING"###.#####";FNEFF(279.19)
60060 PRINT USING"####.##";391.69;:PRINT USING"###.#####";FNEFF(391.69)
60070 PRINT USING"####.##";514!;:PRINT USING"###.#####";FNEFF(514!)
60080 PRINT USING"####.##";661.64;:PRINT USING"###.#####";FNEFF(661.64)
60090 PRINT USING"####.##";898.02;:PRINT USING"###.#####";FNEFF(898.02)
60100 PRINT USING"####.##";1173.21;:PRINT USING"###.#####";FNEFF(1173.21)
60110 PRINT USING"####.##";1332.56;:PRINT USING"###.#####";FNEFF(1332.56)
60120 PRINT USING"####.##";1836.01;:PRINT USING"###.#####";FNEFF(1836.01)
60130 INPUT"Press return to proceed";ZZ
60140 RETURN
```

```

Main                                     <--- Subroutines and [files]

5-28/DIM setup

30-35/Input data                       <--- 1000-1100/Miscellaneous data
                                         <--- B:DATAMISC.DAT
                                         <--- 2000-2200/Efficiency data
                                         <--- B:DATAALB.DAT

41-65/Eff Formula

70-95/Input data                       <--- 3000-3100/Gamma peaks
                                         <--- B:DATAPEAK.DAT
                                         <--- 4000-4100/Gamma spectrum
                                         <--- B:DATASPEC.DAT
                                         <--- 5000-5080/Isotope data
                                         <--- B:DATAISOS.DAT

100-140/Plot menu

150-160/Exit option

200-240/All peaks optn <--- 20000-21000/Printout single peak

300-350/Exam peak optn <--- 30000-31000/Screen display of peak
                                         <--- 32000-32900/Peak area calc
                                         <--- 40000-40900/Change ROIs
                                         <--- 41000-41100/Expand ROI #1
                                         <--- 32000-32900/Area calc
                                         <--- 33000-33900/Scrn info
                                         <--- 42000-42100/Expand ROI #2
                                         <--- 32000-32900/Area calc
                                         <--- 33000-33900/Scrn info
                                         <--- 43000-43100/Expand ROI #3
                                         <--- 32000-32900/Area calc
                                         <--- 33000-33900/Scrn info
                                         <--- 44000-44100/Expand ROI #4
                                         <--- 32000-32900/Area calc
                                         <--- 33000-33900/Scrn info
                                         <--- 45000-45100/Expand ROI #5
                                         <--- 32000-32900/Area calc
                                         <--- 33000-33900/Scrn info
                                         <--- 20000-21000/Printout single peak

980-990/Continue/STOP <--- 9000-9100/Supplementary analysis menu

```

GRABPLOT: Program Structure Reference
(Continued)

Lines not used in execution

6000-6100/Background input of backqnd.BKG
7000-7200/Efficiency parameters of DETLIBRY.LIB
8000-8100/Isotope library of B:DETLIBRY.LIB
13000-13100/Energy to channel transformer
60000-60140/Efficiency vs energy table for calib gammas

```

5 REM file GRABPLOT.BAS
10 PRINT:PRINT"Data being read from files"
21 DIM H1(100),H2(100),RATERR(100)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CE0H1(5,3),CE2H0(5,3),CE1H1(5,3),CE0H2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CE0H3(5,3)
25 DIM YLOC(20),DETNAM$(10),BENERGY(100),BRATE(100),BERR(100),DETLAB$(10)
26 DIM ISOTH(100),MDA(100),ACTRAT(100),LIBEN(100),SBRATE(100),SBERR(100)
27 DIM RATE(100),ENERGY(100),ISOEN(100),ISOIDS(100),ISO$(100),ISOGAM(100)
28 DIM NPC(4096),AREA(100),EAREA(100),LOCH(100),FWHM(100),TAIL(100),CENT(100)

30 GOSUB 1000:REM read file B:DATAMISC.DAT
35 GOSUB 2000:REM read file B:DATACALB.DAT

41 DEF FNENC(CHAN)=COENC+C1ENC*CHAN
44 DEF FNFWMH(CHAN)=SQR(COFWMH + C1FWMH*CHAN)
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX))*(DOEFF+D1EFF*LOG(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 REM INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFV
EN$:CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 REM GOSUB 60000:REM check on efficiency data EFF vs EN
65 REM - temporary continue

70 GOSUB 3000:REM read file B:DATAPEAK.DAT
75 GOSUB 4000:REM read file B:DATASPEC.DAT
80 GOSUB 5000:REM read file B:DATAISOS.DAT
85 REM GOSUB 6000:REM read file DETFILES.BKG
90 REM GOSUB 7000:REM read file B:DETLIBRY.LIB
95 REM gosub 8000:rem read file B:ISOLIBRY.LIB (when needed for B:DATAISOS.DAT)
99 CLS

100 REM - main menu for program
110 PRINT"Select plot option below":PRINT
120 PRINT" (1) Plot all peaks on printer (GRABGAM ROI's only)"
130 PRINT" (2) Plot individual peaks on screen and/or printer (user selected R
OI's)"
140 PRINT" (3) Exit program":PRINT

150 INPUT"Option";OPP:IF OPP=3 THEN 980
160 IF OPP <> 1 THEN 300

200 REM-printout all peaks
210 FOR I=1 TO MPMAX
220 GOSUB 20000:REM printer plot of peak
230 NEXT I
240 GOTO 100:REM- return to initial menu

300 INPUT"Peak number to be plotted(0 for none)";I:IF I=0 THEN 99
310 GOSUB 30000
350 GOTO 300

980 GOSUB 9000:REM - continuation menu
990 STOP

1000 REM - subroutine to read miscellaneous parameters file B:MISCDAT.DAT
1010 OPEN "B:DATAMISC.DAT" FOR INPUT AS #3
1020 INPUT #3,LTIME,STCH,ENCH,AUNIT$,UNUM,UDEM,TDAYS,DETN,DETNAM$(DETN),DETLAB$(DETN),STDATES$
1030 CLOSE #3
1100 RETURN

2000 REM - subroutine to read data calib file B:DATACALB.DAT
2100 OPEN "B:DATACALB.DAT" FOR INPUT AS #3
2110 INPUT #3,COENC,C1ENC,COFWMH,C1FWMH,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,COEFF,C1EFF,C2EFF,C3EFF,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
2160 CLOSE #3
2200 RETURN

3000 REM - subroutine to read data peak file B:DATAPEAK.DAT
3010 OPEN "B:DATAPEAK.DAT" FOR INPUT AS #3
3015 KP=1
3020 IF EOF(3) THEN MPMAX=KP-1:GOTO 3060
3040 INPUT #3,CENT(KP),ENERGY(KP),FWHM(KP),TAIL(KP),AREA(KP),RATE(KP),SBRATE(KP),ISOIDS(KP),ACTRAT(KP),LIBEN(KP),RATERR(KP),SBERR(KP),H1(KP),H2(KP)
3050 KP=KP+1:GOTO 3020
3060 CLOSE #3
3100 RETURN

4000 REM -subroutine to read in spectrum file B:DATASPEC.DAT
4010 OPEN "B:DATASPEC.DAT" FOR INPUT AS #3
4020 FOR I=STCH TO ENCH
4030 INPUT #3, NPC(I)
4040 NEXT I
4050 CLOSE #3
4100 RETURN

```

```

5000 REM - subroutine to read in isotope library file B:DATAISOS.DAT
5010 OPEN "B:DATAISOS.DAT" FOR INPUT AS #3
5020 L=0
5030 L=L+1
5040 INPUT #3, ISO$(L), ISOTH(L), ISOEN(L), ISOGAM(L), MDA(L)
5050 IF ISO$(L)="limit " THEN 5070
5060 GOTO 5030
5070 CLOSE #3
5080 RETURN

6000 REM - subroutine to read in background library
6010 DETFILE$=DETLABS(DETN)+".BKG"
6020 OPEN DETFILE$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN BAMAX=CBACK-1:GOTO 6070
6050 INPUT #2, BENERGY(CBACK), BRATE(CBACK), BERR(CBACK)
6060 CBACK=CBACK+1:GOTO 6040
6070 CLOSE #2
6100 RETURN

7000 REM - subroutine to read in detector library B:DETLIBRY.LIB
7005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
7010 FOR I=1 TO 5
7020 FOR J=1 TO 3
7030 INPUT #3, GOEFF(I,J), AOEFF(I,J), BOEFF(I,J), KOEFF(I,J), HOEFF(I,J)
7040 INPUT #3, CEOH0(I,J)
7050 INPUT #3, CE1H0(I,J), CEOH1(I,J)
7060 INPUT #3, CE2H0(I,J), CE1H1(I,J), CEOH2(I,J)
7070 INPUT #3, CE3H0(I,J), CE2H1(I,J), CE1H2(I,J), CEOH3(I,J)
7080 NEXT J
7090 NEXT I
7095 CLOSE #3
7100 I=0:J=0
7200 RETURN

8000 REM - subroutine to read in isotope library data B:ISOLIBRY.LIB
8001 REM - note that B:DATAISOS.DAT is used instead usually
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 100
8020 INPUT #3, ISO$(ISO), ISOTH(ISO), ISOEN(ISO), ISOGAM(ISO), MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=100
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

9000 REM- subroutine for supplementary analyses
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 CLS
9020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
9030 PRINT"      (1) Background file development (GRABBACK)"
9040 PRINT"      (2) Detector efficiency calibration (GRABCALB)"
9050 PRINT"      (3) Peak/spectrum diagnostics (GRABDIAG)"
9060 PRINT"      (4) Peak/multiplet plot analysis (GRABPLOT)"
9070 PRINT"      (5) Analyses per isotopes (GRABISOS)":PRINT
9080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
9090 PRINT:PRINT"Type selected analysis (e.g. GRABBACK) after":PRINT"C-prompt (
C> ) and press enter"
9095 CLOSE #3
9100 RETURN

13000 REM sub from sub 3000 - calc channel from energy
13010 AOEN = FNENC(0)
13020 ALEN = FNENC(1)-FNENC(0)
13030 CHANO = (ENERGY-AOEN)/ALEN
13040 CHAN = CHANO + (ENERGY-FNENC(CHANO))/ALEN
13050 IF ABS(ENERGY-FNENC(CHAN))>.1 THEN CHANO=CHAN:GOTO 13040
13055 RCHAN=CHAN
13060 CHAN=INT(CHAN+.5)
13100 RETURN

```

```

20000 REM - sub for plot of single peak to printer
20010 LPRINT:NPCMAX=0
20015 IF OPP=2 THEN 20040:REM - uses screen plot ROI's
20020 GCHS=H2(I)-H1(I)+1:B1CH=H1(I)-GCHS/2:B2CH=H2(I)+GCHS/2
20030 LCH=H1(I)-GCHS:HCH=H2(I)+GCHS:H1CH=H1(I):H2CH=H2(I)
20040 FOR J=LCH TO HCH
20050 IF NPC(J)>NPCMAX THEN NPCMAX=NPC(J)
20060 NEXT J
20070 SCALP=1:IF NPCMAX>50 THEN SCALP=50/NPCMAX
20080 LPRINT"Channel energy counts plot"
20085 LPRINT" # keV #":PRINT
20087 LCHPR=B1CH-5:HCHPR=B2CH+5
20090 FOR J=LCHPR TO HCHPR
20095 PLOTCH=INT(SCALP*NPC(J) + .5)
20100 LPRINT USING"#####";J::LPRINT USING"#####. #";FNENC(J);
20110 LPRINT USING"#####";NPC(J);
20120 LPRINT TAB(29) "1";
20130 IF J<B1CH THEN LPRINT STRING$(PLOTCH,"O"):GOTO 20180
20140 IF J<H1CH THEN LPRINT STRING$(PLOTCH,"*"):GOTO 20180
20150 IF J<=H2CH THEN LPRINT STRING$(PLOTCH,"X"):GOTO 20180
20160 IF J<=B2CH THEN LPRINT STRING$(PLOTCH,"*"):GOTO 20180
20170 LPRINT STRING$(PLOTCH,"O")
20180 NEXT J
20185 LPRINT
20188 IF OPP=1 THEN AREA=AREA(I):ERRA=INT(LTIME*RATERR(I) + .5)
20190 LPRINT TAB(29) "Peak area = ";AREA;
20200 LPRINT " +/-";INT(ERRA+.5)
20210 LPRINT
20220 ACT=ACTRAT(I)*AREA/LTIME
20230 ERRACT = ACTRAT(I)*ERRA/LTIME
20235 LPRINT TAB(29);
20240 LPRINT ISOIDS(I)::LPRINT" ";
20242 LPRINT USING"#####. #";ENERGY(I)::LPRINT " keV" :LPRINT
20243 LPRINT TAB(29);
20244 LPRINT USING"#####. #";ACT::LPRINT" ";AUNIT$
20245 LPRINT TAB(29);
20246 LPRINT " +/-";:IF ACT<=0 THEN LPRINT USING"#####. #";ERRACT:LPRINT:GOTO 2
100
20247 ARGACT=10^(LOG(ACT)/LOG(10)-INT(LOG(ACT)/LOG(10)))
20248 PRERR=ARGACT*ERRACT/ACT
20249 LPRINT USING"#####. #";PRERR:LPRINT
21000 RETURN

30000 REM - subroutine to put peak on screen
30010 SCREEN 1:CLS
30015 COLOR 8,0
30020 H1CH=H1(I):H2CH=H2(I):GCHS=H2CH-H1CH+1
30030 B1CH=H1CH-GCHS/2:B2CH=H2CH+GCHS/2
30040 LCH=H1CH-50:HCH=H2CH+50
30050 NPCMAX=0
30060 FOR J=LCH TO HCH
30070 IF NPC(J)>NPCMAX THEN NPCMAX=NPC(J)
30080 NEXT J
30090 SCALE=1:IF NPCMAX>100 THEN SCALE = 100/NPCMAX
30100 XZERO=LCH-160
30105 B=0:G=0:BNUM=0:GNUM=0
30110 FOR J=LCH TO HCH
30120 PX=J-XZERO
30130 PY=INT(SCALE*NPC(J)+.5)
30140 IF J<B1CH THEN LINE(PX,110)-(PX,110-PY),1:GOTO 30200
30150 IF J<H1CH THEN LINE(PX,110)-(PX,110-PY),2:B=B+NPC(J):BNUM=BNUM+1:GOTO 3020
0
30160 IF J<=H2CH THEN LINE(PX,110)-(PX,110-PY),3:G=G+NPC(J):GNUM=GNUM+1:GOTO 302
00
30170 IF J<=B2CH THEN LINE(PX,110)-(PX,110-PY),2:B=B+NPC(J):BNUM=BNUM+1:GOTO 302
00
30180 LINE(PX,110)-(PX,110-PY),1
30200 NEXT J
30210 LOCATE 15,1
30215 GOSUB 32000:REM - calculate peak area and error
30220 PRINT TAB(17) LCH TAB(25) INT(CENT(I)+.5) TAB(33) HCH
30230 LOCATE 2,1
30240 PRINT ISOIDS(I):PRINT
30244 PRINT USING"#####. #";ACT::PRINT" ";AUNIT$
30246 PRINT " +/-";:IF ACT<=0 THEN PRINT USING"#####. #";ERRACT:PRINT:GOTO 3025
0
30247 ARGACT=10^(LOG(ACT)/LOG(10)-INT(LOG(ACT)/LOG(10)))
30248 PRERR=ARGACT*ERRACT/ACT
30249 PRINT USING"#####. #";PRERR:PRINT
30250 PRINT USING"#####. #";ENERGY(I)::PRINT " keV" :PRINT
30260 PRINT AREA:" +/-";INT(ERRA+.5);" counts":PRINT
30270 PRINT"Peak #";I:PRINT
30275 LOCATE 17,1
30280 INPUT"1. Change ROI's (y/n)":YES
30290 IF YES="y" THEN GOSUB 40000:GOTO 30275
30300 PRINT
30305 LOCATE 19,1
30310 INPUT"2. Make hardcopy (y/n)":YES:PRINT
30320 IF YES="y" THEN GOSUB 20000
30330 INPUT"3. Done (0), redo #1 (1), Redo #2 (2)":OPT
30340 ON OPT GOTO 30275,30305
30995 SCREEN 2:SCREEN 0
31000 RETURN

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32000 REM - sub to calculate peak area and error/activity
32010 AREA = G-B*(GNUM/BNUM):AREA=INT(AREA+.5)
32020 IF G + B*(GNUM/BNUM)^2 <= 0 THEN PRINT " illegal square root":GOTO 32900
32030 ERRA = SQR(G+B*(GNUM/BNUM)^2)
32040 ACT=ACTRAT(I)*AREA/LTIME
32050 ERRACT = ACTRAT(I)*ERRA/LTIME
32900 RETURN

33000 REM - print peak info after roi changes
33200 LOCATE 15,1
33220 PRINT TAB(17) LCH TAB(25) INT(CENT(I)+.5) TAB(33) HCH
33230 LOCATE 2,1:FOR PBLANK = 1 TO 7:PRINT STRING$(20," "):NEXT PBLANK
33235 LOCATE 2,1
33240 PRINT ISODS(I):PRINT
33244 PRINT USING"###.###^";ACT;:PRINT " ";AUNIT$
33246 PRINT " +/-";:IF ACT <=0 THEN PRINT USING"###.###^";ERRACT:PRINT:GOTO 3325
0
33247 ARGACT=10^(LOG(ACT)/LOG(10)-INT(LOG(ACT)/LOG(10)))
33248 PRERR=ARGACT*ERRACT/ACT
33249 PRINT USING"###.###":PRERR:PRINT
33250 PRINT USING"###.###":ENERGY(I):PRINT " keV ":PRINT
33260 PRINT AREA;" +/-";INT(ERRA +.5);" counts":PRINT
33270 PRINT"Peak #";I:PRINT
33275 LOCATE 17,1
33900 RETURN

40000 REM - roi adjustment subroutine
40010 LOCATE 17,1
40020 PRINT"ROI increases to decrease adjacent ROI"
40030 PRINT STRING$(39," ")
40040 PRINT"First, press key for ROI (0=done) per:"
40050 PRINT"1-green 2-red 3-yellow 4-red 5-green":PRINT STRING$(39," ")
40070 ROI$=INKEY$:IF ROI$="" THEN 40070
40080 IF VAL(ROI$)<0 THEN 40070
40090 IF VAL(ROI$)>5 THEN 40070
40100 IF VAL(ROI$)=0 THEN 40800
40110 PRINT"Next, increase region (":ROI$;") per:"
40115 PRINT"q-left p-right 0-done"
40120 ON VAL(ROI$) GOSUB 41000,42000,43000,44000,45000
40130 GOTO 40800
40800 LOCATE 17,1
40810 FOR PBLANK =1 TO 7:PRINT STRING$(39," "):NEXT PBLANK
40900 RETURN

41000 REM - roi expansion for region 1
41010 DROI$=INKEY$:IF DROI$ = "" THEN 41010
41015 IF DROI$="0" THEN 41100
41020 PYP=INT(SCALE*NPC(B1CH)+.5):PYQ=INT(SCALE*NPC(LCH-1)+.5)
41025 PXP=B1CH-XZERO:PXQ=LCH-1-XZERO
41030 IF DROI$="p" THEN LINE(PXP,110)-(PXP,110-PYP),1:BNUM=BNUM-1:B=B-NPC(B1CH):
GOSUB 32000:GOSUB 33000:B1CH=B1CH+1:GOTO 41000
41040 IF DROI$="q" THEN LCH=LCH-1:LINE(PXQ,110)-(PXQ,110-PYQ),1:GOTO 41000
41100 RETURN

42000 REM - roi expansion for region 2
42010 DROI$=INKEY$:IF DROI$ = "" THEN 42010
42015 IF DROI$="0" THEN 42100
42020 PYP=INT(SCALE*NPC(H1CH)+.5):PYQ=INT(SCALE*NPC(B1CH-1)+.5)
42025 PXP=H1CH-XZERO:PXQ=B1CH-1-XZERO
42030 IF DROI$="p" THEN LINE(PXP,110)-(PXP,110-PYP),2:BNUM=BNUM+1:GNUM=GNUM-1:B=
B+NPC(H1CH):G=G-NPC(H1CH):GOSUB 32000:GOSUB 33000:H1CH=H1CH+1:GOTO 42000
42040 IF DROI$="q" THEN B1CH=B1CH-1:LINE(PXQ,110)-(PXQ,110-PYQ),2:BNUM=BNUM+1:B=
B+NPC(B1CH):GOSUB 32000:GOSUB 33000:GOTO 42000
42100 RETURN

43000 REM - roi expansion for region 3
43010 DROI$=INKEY$:IF DROI$ = "" THEN 43010
43015 IF DROI$="0" THEN 43100
43020 PYP=INT(SCALE*NPC(H2CH+1)+.5):PYQ=INT(SCALE*NPC(H1CH-1)+.5)
43025 PXP=H2CH+1-XZERO:PXQ=H1CH-1-XZERO
43030 IF DROI$="p" THEN H2CH=H2CH+1:LINE(PXP,110)-(PXP,110-PYP),3:GNUM=GNUM+1:BN
UM=BNUM-1:B=B-NPC(H2CH):G=G+NPC(H2CH):GOSUB 32000:GOSUB 33000:GOTO 43000
43040 IF DROI$="q" THEN H1CH=H1CH-1:LINE(PXQ,110)-(PXQ,110-PYQ),3:GNUM=GNUM+1:BN
UM=BNUM-1:B=B-NPC(H1CH):G=G+NPC(H1CH):GOSUB 32000:GOSUB 33000:GOTO 43000
43100 RETURN

44000 REM - roi expansion for region 4
44010 DROI$=INKEY$:IF DROI$ = "" THEN 44010
44015 IF DROI$="0" THEN 44100
44020 PYP=INT(SCALE*NPC(B2CH+1)+.5):PYQ=INT(SCALE*NPC(H2CH)+.5)
44025 PXP=B2CH+1-XZERO:PXQ=H2CH-XZERO
44030 IF DROI$="p" THEN B2CH=B2CH+1:LINE(PXP,110)-(PXP,110-PYP),2:BNUM=BNUM+1:B=
B+NPC(B2CH):GOSUB 32000:GOSUB 33000:GOTO 44000
44040 IF DROI$="q" THEN LINE(PXQ,110)-(PXQ,110-PYQ),2:BNUM=BNUM+1:GNUM=GNUM-1:B=
B+NPC(H2CH):G=G-NPC(H2CH):GOSUB 32000:GOSUB 33000:H2CH=H2CH-1:GOTO 44000
44100 RETURN

45000 REM - roi expansion for region 5
45010 DROI$=INKEY$:IF DROI$ = "" THEN 45010
45015 IF DROI$="0" THEN 45100
45020 PYP=INT(SCALE*NPC(HCH+1)+.5):PYQ=INT(SCALE*NPC(B2CH)+.5)
45025 PXP=HCH+1-XZERO:PXQ=B2CH-XZERO
45030 IF DROI$="p" THEN HCH=HCH+1:LINE(PXP,110)-(PXP,110-PYP),1:GOTO 45000
45040 IF DROI$="q" THEN LINE(PXQ,110)-(PXQ,110-PYQ),1:BNUM=BNUM-1:B=B-NPC(B1CH):
GOSUB 32000:GOSUB 33000:B2CH=B2CH+1:GOTO 45000
45100 RETURN

```

```
60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";DETNAME$(DETNAME)
60006 PRINT
60010 PRINT "EN", "EFF"
60011 PRINT"kev", " "
60020 PRINT USING"####.##";88.03;:PRINT USING"###.#####";FNEFF(88.03)
60030 PRINT USING"####.##";122.06;:PRINT USING"###.#####";FNEFF(122.06)
60040 PRINT USING"####.##";165.85;:PRINT USING"###.#####";FNEFF(165.85)
60050 PRINT USING"####.##";279.19;:PRINT USING"###.#####";FNEFF(279.19)
60060 PRINT USING"####.##";391.69;:PRINT USING"###.#####";FNEFF(391.69)
60070 PRINT USING"####.##";514!;:PRINT USING"###.#####";FNEFF(514!)
60080 PRINT USING"####.##";661.64;:PRINT USING"###.#####";FNEFF(661.64)
60090 PRINT USING"####.##";898.02;:PRINT USING"###.#####";FNEFF(898.02)
60100 PRINT USING"####.##";1173.21;:PRINT USING"###.#####";FNEFF(1173.21)
60110 PRINT USING"####.##";1332.56;:PRINT USING"###.#####";FNEFF(1332.56)
60120 PRINT USING"####.##";1836.01;:PRINT USING"###.#####";FNEFF(1836.01)
60130 INPUT"Press return to proceed";ZZ
60140 RETURN
```

PEAKPART: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
1-16/DIM setup	<--- 7000-7999/Gaussian F-function <--- 8000-8140/DATA lines for F
20-140/Multiplet data	<--- Input maxs, mins, FWHM, raw areas
150-180/Peak region Fs	<--- 5000-5999/Calcs per maxs, mins, FWHM <--- 6000-6999/F value interpolation
200-220/New peak areas	<--- 2000-2990/F coeffs & raw areas array 3000-3170/Triangularize array 4000-4990/Solve refined peak areas
300-400/Screen results	
500-680/Printout results	
1000/STOP	

```

1 CLS
5 REM PEAKPART.BAS
10 REM Note this and NEQUATNX require all Cii not equal to 0
15 DIM F(80),X(80)
16 GOSUB 7000:REM read in F function values

20 INPUT"Number of Peaks in Multiplet";M:M=M-1
25 PRINT:REM INPUT"Number of data points";N:PRINT
30 DIM A(M),TC(M,M),C(M,M),TD(M),TN(M,M),CHMAX(M),CHLO(M),CHHI(M),AO(M)
90 PRINT
100 PRINT" Input Data":PRINT
104 PRINT
105 INPUT"FWHM for individual multiplet peak (channels)";FWHM:PRINT
106 SIGCH = FWHM/(2*(2*LOG(2))^.5)
110 FOR I=0 TO M
115 PRINT"Input for peak number ";I+1:PRINT
120 INPUT"Channels - lo min";CHLO(I):IF I>0 THEN CHHI(I-1)=CHLO(I)
125 INPUT"    --- peak";CHMAX(I):IF I<M THEN GOTO 135
130 INPUT"    - hi min";CHHI(I):CHHI=CHHI(I)
135 PRINT:INPUT"Min-to-min area of peak";TD(I):AO(I)=TD(I):PRINT:PRINT
140 NEXT I

150 FOR J=0 TO M
155 CHMAX=CHMAX(J)
160 FOR I=0 TO M
165 CHLO=CHLO(I):CHHI=CHHI(I)
170 GOSUB 5000:REM calculate coefficients
175 NEXT I
180 NEXT J
190 CLS

200 GOSUB 2000
204 PRINT
205 INPUT"Is this correct matrix (y-proceed/n-redo data)";YES$:IF YES$="n" THEN CL
S:GOTO 100
210 GOSUB 3000
220 GOSUB 4000

300 REM printout final information
305 CLS
310 PRINT"FWHM (channels) = ";FWHM
315 PRINT:PRINT
320 PRINT"----- Multiplet Peaks -----"
321 PRINT
325 PRINT" No      Min1      Max      Min2      Ao      A      A/Ao"
326 PRINT" #       chn      chn      chn      counts  counts  ratio"
327 PRINT
330 FOR I = 0 TO M
340 PRINT USING"###.###.###.###.###.###.###.###.###.###";I+1,CHL
O(I),CHMAX(I),CHHI(I),AO(I),A(I),A(I)/AO(I)
350 NEXT I
400 REM printout matrix
410 PRINT
420 PRINT"          A1 + A2 + A3 + A4 + A5 + A6 + A7 + A8
+ A9 + A10"
422 PRINT"          Ao(i) =  X      X      X      X      X      X      X      X
X      X "
425 PRINT"          ci1  ci2  ci3  ci4  ci5  ci6  ci7  ci8
ci9  ci10"
430 PRINT
440 FOR I=0 TO M
445 PRINT USING"##### ";AO(I);
450 FOR J=0 TO M
455 IF J=M THEN PRINT USING"#####";C(I,J):GOTO 465
460 PRINT USING"#####";C(I,J);
465 NEXT J
470 NEXT I
480 PRINT

```

```

500 INPUT"Print out hardcopy (y/n)";YES:IF YES="n" OR YES="N" THEN 1000
505 LPRINT:LPRINT
510 LPRINT"FWHM (channels) = ";FWHM
515 LPRINT:LPRINT
520 LPRINT"----- Multiplet Peaks -----"
521 LPRINT
525 LPRINT" No      Min1      Max      Min2      Ao      A      A/Ao"
526 LPRINT" #      chn      chn      chn      counts  counts  ratio"
527 LPRINT
530 FOR I = 0 TO M
540 LPRINT USING"###.###.###.###.###.###.###.###.###.###";I+1,CH
LO(I),CHMAX(I),CHHI(I),AO(I),A(I),A(I)/AO(I)
550 NEXT I
600 REM printout matrix
610 LPRINT
620 LPRINT      "      A1 + A2 + A3 + A4 + A5 + A6 + A7 + A8
+ A9 + A10"
622 LPRINT      " Ao(i) =  X      X      X      X      X      X      X      X
X      X "
625 LPRINT      "      ci1      ci2      ci3      ci4      ci5      ci6      ci7      ci8
ci9      ci10"
630 LPRINT
640 FOR I=0 TO M
645 LPRINT USING"##### ";AO(I);
650 FOR J=0 TO M
655 IF J=M THEN LPRINT USING"#####";C(I,J):GOTO 665
660 LPRINT USING"#####";C(I,J);
665 NEXT J
670 NEXT I
680 LPRINT

1000 STOP

2000 REM display coefficient array
2002 PRINT
2005 FOR IP=0 TO M:PRINT TAB(1+(IP)*10) "a(";IP+1;")";:NEXT IP
2006 PRINT"      "; "Constant"
2010 FOR IP=0 TO M
2020 FOR JP=0 TO M
2030 PRINT TAB(1+(JP)*10) TC(IP,JP);
2040 NEXT JP
2050 PRINT"      = ";TD(IP)
2060 NEXT IP
2990 RETURN

3000 REM -triangulation of equations
3010 FOR J=0 TO M
3015 REM - set first non zero coeff =1
3020 FOR K=J TO M
3025 TN(K,J)=TC(K,J):IF TN(K,J)=0 THEN GOTO 3070
3030 FOR L=J TO M
3040 TC(K,L)=TC(K,L)/TN(K,J)
3050 NEXT L
3060 TD(K)=TD(K)/TN(K,J)
3070 NEXT K
3075 GOSUB 2000
3080 REM - subtract out first non zero coefficients
3085 IF J+1 > M THEN GOTO 3150
3090 FOR K=J+1 TO M
3095 IF TC(K,J)=0 THEN GOTO 3140
3100 FOR L=J TO M
3110 TC(K,L)=TC(J,L)-TC(K,L)
3120 NEXT L
3130 TD(K)=TD(J)-TD(K)
3140 NEXT K
3145 GOSUB 2000
3150 NEXT J
3170 RETURN

4000 REM final results
4002 PRINT:PRINT
4005 PRINT "values of a(i) listed below":PRINT
4010 FOR L=M TO 0 STEP -1
4020 A(L)=TD(L):IF L=M THEN GOTO 4060
4030 FOR J=L+1 TO M
4040 A(L)=A(L)-TC(L,J)*A(J)
4050 NEXT J
4060 NEXT L
4080 FOR L=0 TO M:PRINT"a(";L+1;") = ";A(L):NEXT L
4090 PRINT
4990 RETURN

```

```

5000 REM subroutine for coefficients for peak
5010 X1=(CHLO-CHMAX)/SIGCH:IF I=0 THEN X1 = -100
5015 X=X1:GOSUB 6000:F1=F:REM lower integral limit
5020 X2=(CHHI-CHMAX)/SIGCH:IF I=M THEN X2=100
5025 X=X2:GOSUB 6000:F2=F:REM upper integral limit
5030 TC(I,J)=F2-F1
5035 C(I,J)=F2-F1
5999 RETURN

6000 REM error function (erf) calculation F
6010 IF X => 3.9 THEN F=1:GOTO 6999
6020 IF X <= -3.9 THEN F=0:GOTO 6999
6030 IXL = INT(X/.05): IXH = IXL+1:X=X/.05
6040 F = .5 + SGN(X)*(F(ABS(IXL)) + (X-IXL)*(F(ABS(IXH))-F(ABS(IXL)))) )
6999 RETURN

7000 REM sub to read in F(x) function
7010 FOR IX=0 TO 80:X(IX)=.05*IX:NEXT
7015 F(0)=0
7020 FOR IX=1 TO 80:READ F(IX):NEXT
7999 RETURN

8000 REM Data for F(x)
8010 REM n.05 n.10 n.15 n.20 n.25 n.30 n.35 n.40 n.45 n.50
8020 REM n.55 n.60 n.65 n.70 n.75 n.80 n.85 n.90 n.95 m.00
8030 REM n=0 m=1
8040 DATA 0.0199,0.0398,0.0596,0.0793,0.0987,0.1179,0.1368,0.1554,0.1736,0.1915
8050 DATA 0.2088,0.2258,0.2422,0.2580,0.2734,0.2881,0.3023,0.3159,0.3289,0.3413
8060 REM n=1 m=2
8070 DATA 0.3531,0.3643,0.3749,0.3849,0.3944,0.4032,0.4115,0.4192,0.4265,0.4332
8080 DATA 0.4394,0.4452,0.4505,0.4554,0.4599,0.4641,0.4678,0.4713,0.4744,0.4773
8090 REM n=2 m=3
8100 DATA 0.4798,0.4821,0.4842,0.4861,0.4878,0.4893,0.4906,0.4918,0.4929,0.4938
8110 DATA 0.4946,0.4953,0.4960,0.4965,0.4970,0.4974,0.4978,0.4981,0.4984,0.4987
8120 REM n=3 m=4
8130 DATA 0.4989,0.4990,0.4992,0.4993,0.4994,0.4995,0.4996,0.4996,0.4997,0.4998
8140 DATA 0.4998,0.4998,0.4999,0.4999,0.4999,0.4999,0.4999,0.5000,0.5000,0.500

```

BDATRANS: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
5-28/DIM setup	
30-35/Input data	<--- 1000-1100/Miscellaneous data <--- B:DATAMISC.DAT <--- 2000-2200/Efficiency data <--- B:DATAALB.DAT
41-65/Eff Formula	<--- 60000-60140/Eff vs E for calibs
70-95/Input data	<--- 3000-3100/Gamma peaks <--- B:DATAPEAK.DAT <--- 4000-4100/Gamma spectrum <--- B:DATASPEC.DAT <--- 5000-5080/Isotope data <--- B:DATAISOS.DAT <--- 6000-6100/Existing background <--- <u>backgnd</u> .BKG <--- 7000-7200/Efficiency parameters <--- B:DETLIBRY.LIB
980-990/Continue/STOP	<--- 9000-9100/Supplementary analysis menu

Lines not used in execution

8000-8100/Isotope library of B:DETLIBRY.LIB

13000-13100/Energy to channel transformer

```

5 REM file BDATRANS.BAS
21 DIM H1(100),H2(100),RATERR(100)
22 DIM GOEFF(5,3),HOEFF(5,3),AOEFF(5,3),BOEFF(5,3),KOEFF(5,3)
23 DIM CEOH0(5,3),CE1H0(5,3),CEOH1(5,3),CE2H0(5,3),CE1H1(5,3),CEOH2(5,3)
24 DIM CE3H0(5,3),CE2H1(5,3),CE1H2(5,3),CEOH3(5,3)
25 DIM YLOC(20),DETNAM$(10),BENERGY(100),BRATE(100),BERR(100),DETLAB$(10)
26 DIM ISOTH(100),MDA(100),ACTRAT(100),LIBEN(100),SBRATE(100),SBERR(100)
27 DIM RATE(100),ENERGY(100),ISOEN(100),ISOIDS(100),ISO$(100),ISOGAM(100)
28 DIM NPC(4096),AREA(100),EAREA(100),LOCH(100),FWHM(100),TAIL(100),CENT(100)

30 GOSUB 1000:REM read file B:DATAMISC.DAT
35 GOSUB 2000:REM read file B:DATACALB.DAT

41 DEF FNENC(CHAN)=COENC+CIENC*CHAN
44 DEF FNFWMH(CHAN)=SQR(COFWWM + C1FWHM*CHAN)
58 DEF FNEFFA(EN)=GOEFF*EXP(AOEFF*SQR(BOEFF^2+UOEFF*(LOG(EN)-KOEFF)^2)*(COEFF+C1
EFF*LOG(EN)+C2EFF*LOG(EN)^2+C3EFF*LOG(EN)^3)+.5*(1+SGN(EN-ENX))*(DOEFF+D1EFF*LOG
(EN)+D2EFF*LOG(EN)^2+D3EFF*LOG(EN)^3))
59 DEF FNEFFB(EN)=1+POEFF+P1EFF*LOG(EN)+P2EFF*LOG(EN)^2+P3EFF*LOG(EN)^3
60 DEF FNEFF(EN)=FNEFFA(EN)*FNEFFB(EN)
61 INPUT"Do you wish to see EFF vs EN data for standard energies (y/n)";EFFVEN$:
CLS:IF EFFVEN$ <> "y" THEN GOTO 65
62 GOSUB 6000:REM check on efficiency data EFF vs EN
65 REM - temporary continue

70 GOSUB 3000:REM read file B:DATAPEAK.DAT
75 GOSUB 4000:REM read file B:DATASPEC.DAT
80 GOSUB 5000:REM read file B:DATAISOS.DAT
85 GOSUB 6000:REM read file DETFILE$.BKG
90 GOSUB 7000:REM read file B:DETLIBRY.LIB
95 REM gosub 8000:rem read file B:ISOLIBRY.LIB (when needed for B:DATAISOS.DAT)

980 GOSUB 9000:REM - continuation menu
990 STOP

1000 REM - subroutine to read miscellaneous parameters file B:MISCDAT.DAT
1010 OPEN "B:DATAMISC.DAT" FOR INPUT AS #3
1020 INPUT #3,LTIME,STCH,ENCH,AUNIT$,UNUM,UDEM,TDAYS,DETN,DETNAM$(DETN),DETLAB$(
DETN),STDATE$
1030 CLOSE #3
1100 RETURN

2000 REM - subroutine to read data calib file B:DATACALB.DAT
2100 OPEN "B:DATACALB.DAT" FOR INPUT AS #3
2110 INPUT #3,COENC,CIENC,COFWHM,C1FWHM,GOEFF,AOEFF,BOEFF,UOEFF,KOEFF,CQEFF,C1EF
F,C2EFF,C3EFF,ENX,DOEFF,D1EFF,D2EFF,D3EFF,POEFF,P1EFF,P2EFF,P3EFF
2160 CLOSE #3
2200 RETURN

3000 REM - subroutine to read data peak file B:DATAPEAK.DAT
3010 OPEN "B:DATAPEAK.DAT" FOR INPUT AS #3
3015 KP=1
3020 IF EOF(3) THEN MPMAX=KP-1:GOTO 3060
3040 INPUT #3,CENT(KP),ENERGY(KP),FWHM(KP),TAIL(KP),AREA(KP),RATE(KP),SBRATE(KP)
,ISOIDS(KP),ACTRAT(KP),LIBEN(KP),RATERR(KP),SBERR(KP),H1(KP),H2(KP)
3050 KP=KP+1:GOTO 3020
3060 CLOSE #3
3100 RETURN

4000 REM -subroutine to read in spectrum file B:DATASPEC.DAT
4010 OPEN "B:DATASPEC.DAT" FOR INPUT AS #3
4020 FOR I=STCH TO ENCH
4030 INPUT #3, NPC(I)
4040 NEXT I
4050 CLOSE #3
4100 RETURN

5000 REM - subroutine to read in isotope library file B:DATAISOS.DAT
5010 OPEN "B:DATAISOS.DAT" FOR INPUT AS #3
5020 L=0
5030 L=L+1
5040 INPUT #3, ISO$(L),ISOTH(L),ISOEN(L),ISOGAM(L),MDA(L)
5050 IF ISO$(L)="limit " THEN 5070
5060 GOTO 5030
5070 CLOSE #3
5080 RETURN

```



```

6000 REM - subroutine to read in background library
6010 DETFILES$=DETLAB$(DETN)+".BKG"
6020 OPEN DETFILES$ FOR INPUT AS #2
6030 CBACK=1
6040 IF EOF(2) THEN BAMAX=CBACK-1:GOTO 6070
6050 INPUT #2,BENERGY(CBACK),BRATE(CBACK),BERR(CBACK)
6060 CBACK=CBACK+1:GOTO 6040
6070 CLOSE #2
6100 RETURN

7000 REM - subroutine to read in detector library B:DETLIBRY.LIB
7005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
7010 FOR I=1 TO 5
7020 FOR J=1 TO 3
7030 INPUT #3,GOEFF(I,J),AOEFF(I,J),BOEFF(I,J),KOEFF(I,J),HOEFF(I,J)
7040 INPUT #3,CEOH0(I,J)
7050 INPUT #3,CE1H0(I,J),CE0H1(I,J)
7060 INPUT #3,CE2H0(I,J),CE1H1(I,J),CE0H2(I,J)
7070 INPUT #3,CE3H0(I,J),CE2H1(I,J),CE1H2(I,J),CE0H3(I,J)
7080 NEXT J
7090 NEXT I
7095 CLOSE #3
7100 I=0:J=0
7200 RETURN

8000 REM - subroutine to read in isotope library data B:ISOLIBRY.LIB
8001 REM - note that B:DATAISOS.DAT is used instead usually
8005 NMDA=0
8007 OPEN "B:ISOLIBRY.LIB" FOR INPUT AS #3
8010 FOR ISO=1 TO 100
8020 INPUT #3,ISO$(ISO),ISOTH(ISO),ISOEN(ISO),ISOGAM(ISO),MDA(ISO)
8025 ISOGAM(ISO)=ISOGAM(ISO)/100
8027 IF MDA(ISO)=1 THEN NMDA=NMDA+1
8030 IF ISO$(ISO) = "limit " THEN ISO=100
8040 NEXT ISO
8050 CLOSE #3
8100 RETURN

9000 REM- subroutine for supplementary analyses
9005 OPEN "B:DETLIBRY.LIB" FOR INPUT AS #3
9010 CLS
9020 PRINT"Supplementary Analyses - as applicable to current spectrum":PRINT
9030 PRINT"      (1) Background file development (GRABBACK)"
9040 PRINT"      (2) Detector efficiency calibration (GRABCALB)"
9050 PRINT"      (3) Peak/spectrum diagnostics (GRABDIAG)"
9060 PRINT"      (4) Peak/multiplet plot analysis (GRABPLOT)"
9070 PRINT"      (5) Analyses per isotopes (GRABISOS)":PRINT
9080 PRINT"Data files are now being transferred to RAM disk (b:) for analyses"
9090 PRINT:PRINT"Type selected analysis (e.g. GRABBACK) after":PRINT"C-prompt (
C> ) and press enter"
9095 CLOSE #3
9100 RETURN

13000 REM  calc channel from energy
13010 AOEN = FNENC(0)
13020 ALEN = FNENC(1)-FNENC(0)
13030 CHANO = (ENERGY-AOEN)/ALEN
13040 CHAN = CHANO + (ENERGY-FNENC(CHANO))/ALEN
13050 IF ABS(ENERGY-FNENC(CHAN))>.1 THEN CHANO=CHAN:GOTO 13040
13055 RCHAN=CHAN
13060 CHAN=INT(CHAN+.5)
13100 RETURN

60000 REM temp check on eff
60005 PRINT"Efficiency (EFF) per standard energy (EN) for ";DETNAM$(DETN)
60006 PRINT
60010 PRINT "EN","EFF"
60011 PRINT"keV"," # "
60020 PRINT USING"#####";88.03;:PRINT USING"#####";FNEFF(88.03)
60030 PRINT USING"#####";122.06;:PRINT USING"#####";FNEFF(122.06)
60040 PRINT USING"#####";165.85;:PRINT USING"#####";FNEFF(165.85)
60050 PRINT USING"#####";279.19;:PRINT USING"#####";FNEFF(279.19)
60060 PRINT USING"#####";391.69;:PRINT USING"#####";FNEFF(391.69)
60070 PRINT USING"#####";514!;:PRINT USING"#####";FNEFF(514!)
60080 PRINT USING"#####";661.64;:PRINT USING"#####";FNEFF(661.64)
60090 PRINT USING"#####";898.02;:PRINT USING"#####";FNEFF(898.02)
60100 PRINT USING"#####";1173.21;:PRINT USING"#####";FNEFF(1173.21)
60110 PRINT USING"#####";1332.56;:PRINT USING"#####";FNEFF(1332.56)
60120 PRINT USING"#####";1836.01;:PRINT USING"#####";FNEFF(1836.01)
60130 INPUT"Press return to proceed";ZZ
60140 RETURN

```

GEFFCX1: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
1-135/DIM setup	<--- 10000-10011/DATA Effs vs E <--- 6000-6070/Log(eff)-Log(E) trans
140-170/Initialize fit	<--- 1000-1040/Parameter definitions
200-320/Initial funct	<--- 5000-5070/Log-Log hyperbola
500-630/L-S min loop	<--- 4000-4090/Derivitive search sign <--- 5000-5070/Log-Log hyperbola <--- 5000-5070/Log-Log hyperbola

Subcode Options - run from line number 12000

12000-12180/Display Eff vs E of fit over designated range

13000-13110/Display efficiencies for fit vs measurements

```

1 CLS
5 REM GEFFCX1.BAS
100 REM-input section
110 INPUT"number of data points";N:PRINT
111 INPUT"Log of data to be taken (y/n)";YES:PRINT
115 DIM X(N),Y(N),SY(N)
120 FOR J=1 TO N:READ X(J),Y(J),SY(J):NEXT J
125 IF YES="y" THEN GOSUB 6000
130 INPUT"number of parameters";NP
135 DIM V(NP),VO(NP),VS(NP),SN(NP),VT(NP)

140 PRINT"Initial estimates of parameters"
145 GOSUB 1000
150 FOR I=1 TO NP
160 PRINT VS(I);" = ";;INPUT VO(I):V(I)=VO(I)
170 NEXT I

200 GOSUB 5000
210 SA=S
300 PRINT:PRINT
310 FOR I=1 TO NP:PRINT VS(I),:NEXT I
320 PRINT "S"

500 REM-test minimum routine
510 FOR I=1 TO NP
520 K=0
530 GOSUB 4000
535 SN(I)=-SN
540 K=K+1
545 IF K>15 THEN GOTO 610
550 AV=VO(I)*(.5)^K:AV=ABS(AV)
555 VT(I)=V(I)
560 V(I)=V(I)+AV*SN(I)
565 GOSUB 4000
566 IF SN <> -SN(I) THEN V(I)=VT(I)
567 IF SN <> -SN(I) THEN 540
570 SB=SA
580 GOSUB 5000
590 SA=S
600 IF ABS((SA-SB)/SA) > .001 THEN GOTO 540
610 PRINT V(I),
620 NEXT I
625 PRINT SA
630 GOTO 500

1000 REM parameter definitions
1010 VS(1)="A"
1020 VS(2)="B"
1030 VS(3)="C"
1040 VS(4)="D"
1100 RETURN

4000 REM-test the derivative sign
4010 GOSUB 5000
4020 S0=S
4030 V(I)=V(I)+.001*ABS(VO(I))
4040 GOSUB 5000
4050 S1=S
4060 V(I)=V(I)-.001*ABS(VO(I))
4080 SN=SGN(S1-S0)
4090 RETURN

5000 REM S calculation and function definition
5010 A=V(1):B=V(2):C=V(3):D=V(4)
5020 S=0
5030 FOR J=1 TO N
5040 FY=A*SQR(B^2+(X(J)-C)^2)+D
5050 S=S+(Y(J)-FY)^2/SY(J)^2
5060 NEXT J
5070 RETURN

6000 REM SUB FOR LOG DATA
6005 INPUT"Equal weights (y) or individual (n)";YES
6010 FOR J=1 TO N
6017 SY(J)=SY(J)/Y(J)
6020 X(J)=LOG(X(J)):Y(J)=LOG(Y(J))
6030 IF YES="y" THEN SY(J)=1
6035 NEXT J
6040 PRINT"logx","logy","error/wt"
6050 FOR J=1 TO N
6060 PRINT X(J),Y(J),SY(J)
6065 NEXT J
6070 RETURN

```

```

10000 REM data x(i),y(i),sy(i)
10001 DATA 88, 0.1206, 1
10002 DATA 122, 0.1354, 1
10003 DATA 166, 0.1060, 1
10004 DATA 279, 0.0700, 1
10005 DATA 393, 0.0476, 1
10006 DATA 514, 0.0353, 1
10007 DATA 662, 0.0280, 1
10008 DATA 898, 0.0201, 1
10009 DATA 1173, 0.0158, 1
10010 DATA 1333, 0.0138, 1
10011 DATA 1836, 0.01005, 1

```

```

12000 REM calc curve with parameters

```

```

12010 CLS
12020 INPUT "a = ";A
12030 INPUT "b = ";B
12040 INPUT "c = ";C
12050 INPUT "d = ";D
12060 PRINT
12062 INPUT "compare with data (d) or calc range (r)";DR$:IF DR$="d" THEN GOSUB 1
3000
12063 IF DR$="d" THEN 12062
12070 INPUT "start energy";ES
12080 INPUT "end energy";EE
12090 INPUT "energy step";ET
12100 PRINT
12110 PRINT "energy", "efficiency"
12120 FOR EN=ES TO EE STEP ET
12130 X=LOG(EN)
12140 Y=A*SQR(B^2+(X-C)^2)+D
12150 EFF=EXP(Y)
12155 PRINT EN,EFF
12160 NEXT EN
12170 PRINT
12180 GOTO 12070

```

```

13000 REM compare calc to data

```

```

13010 DIM X(11),Y(11),SY(11)
13020 FOR J=1 TO 11 :READ X(J),Y(J),SY(J):NEXT J
13025 PRINT
13030 PRINT "energy","meas eff","calc eff","%-diff"
13040 FOR J=1 TO 11
13050 X=LOG(X(J))
13060 Y=A*SQR(B^2+(X-C)^2)+D
13070 EFF=EXP(Y)
13080 PD=100*(Y(J)-EFF)/EFF
13090 PRINT X(J),Y(J),EFF,PD
13100 NEXT J
13110 RETURN

```

TEFFPERF: Program Structure Reference

<u>Main</u>	<u><--- Subroutines and [files]</u>
5-110/Data set info	<--- 10000-10011/DATA Effs vs E
120-180/Read eff data	<--- 12200-12610/DATA hypbla, h0, eff vs h
200-290/Basis norm eff	<--- 1000-1100/Efficiency calculation
300-396/Meas-fit effs	
400-429/Print basis eff	
431/GOTO 440 if need perturb analysis	
433-439/Print perturbation polynomial coeffs	
440-640/Print meas vs fit	
650/GOTO exit if anal perturbation done	
660-830/L-S perturb terms	
840-910/Solve perturb polynom coeffs	<--- 2000-2990/Display coefficient matrix <--- 3000-3170/Triangularize matrix <--- 2000-2990/Display matrix status <--- 4000-4490/Calc perturb polynom coeffs
920/GOTO 200 to output results	
999/STOP	

```

5 CLS
8 DEFDBL T
20 PFLAG = 0
90 INPUT "Description of Data Set";DS$
100 INPUT "number of energies";NE
110 INPUT "number of heights";NH

120 READ A,B,C,H0
130 DIM H(NH),EN(NE),EFF(NE,NH),PERDV(NE,NH),X(NE),C(10,10),D(10)
135 DIM K(10),L(10),TC(10,10),TD(10),A(10),TN(10,10)
140 FOR J=1 TO NH:READ H(J):NEXT J
150 FOR I=1 TO NE
160 READ EN(I)
170 FOR J=1 TO NH:READ EFF(I,J):NEXT J
180 NEXT I

200 REM calculations for normalization factor
210 G=0
220 FOR I=1 TO NE
230 FOR J=1 TO NH
240 X=LOG(EN(I))
245 H=H(J)
250 GOSUB 1000
255 GCAL=EFF(I,J)/EFFUN
260 G=G + GCAL
270 NEXT J
280 NEXT I
290 G=G/(NE*NH)

300 REM calculate efficiencies and compare with experimental values
302 PRINT:PRINT:PRINT "Results for : ";DS$:PRINT
305 AVEDEV=0
310 FOR I=1 TO NE
320 FOR J=1 TO NH
322 X=LOG(EN(I))
324 H=H(J)
330 GOSUB 1000
340 EFFCAL = G*EFFUN
350 PERDEV = 100*(EFF(I,J)/EFFCAL - 1)
355 AVEDEV=PERDEV^2 + AVEDEV
360 PRINT USING"####.##";PERDEV;
365 PERDV(I,J) = PERDEV
370 NEXT J
380 PRINT
390 NEXT I
392 AVEDEV=SQR(AVEDEV/(NE*NH-1))
394 PRINT:PRINT"G = ";G
396 PRINT "ave deviation = ";AVEDEV

400 REM list calculated efficiencies
410 PRINT:PRINT:PRINT "Results for : ";DS$
420 PRINT:PRINT"Parameters for eff = G*EXP(A*SQR(B^2+(X-C)^2))/(H+H0)^2"
421 PRINT"          with X=LOG(gamma energy)":PRINT
425 PRINT"G = ";G
426 PRINT"A = ";A
427 PRINT"B = ";B
428 PRINT"C = ";C
429 PRINT"H0 = ";H0:PRINT:PRINT:PRINT

431 IF PFLAG=0 THEN GOTO 440

433 PRINT "Efficiency includes perturbation correction factor below"
434 PRINT "      1 + A(0,0) + A(1,0)*X + A(0,1)*H + ..... + A(0,3)*H^3"
435 PRINT:PRINT"above coefficients below":PRINT
437 FOR IA=1 TO 10:PRINT"A(";K(IA);",";L(IA);") = ";A(IA)/100:NEXT IA
439 PRINT

```

```

440 PRINT"Comparison of experimental/calculated efficiencies below"
450 PRINT:PRINT
460 PRINT"          sample height (cm)"
470 PRINT"energy(KeV)";
480 FOR J=1 TO NH:PRINT USING"####.###";H(J);:NEXT J
490 PRINT:PRINT
500 FOR I=1 TO NE
510 PRINT USING"####.###";EN(I);:PRINT"  ";
520 FOR J=1 TO NH
530 PRINT USING"###.####";EFF(I,J);
540 NEXT J
550 PRINT
560 PRINT"          ";
570 X=LOG(EN(I))
580 FOR J=1 TO NH
590 H=H(J)
600 GOSUB 1000
610 PRINT USING"###.####";G*EFFUN;
620 NEXT J
630 PRINT:PRINT
640 NEXT I

650 IF PFLAG = 1 THEN GOTO 999

660 PFLAG = 1
700 REM fit to perturbation array PERDV(I,J)
710 FOR I=1 TO NE: X(I)=LOG(EN(I)):NEXT I
715 K(1)=0:K(2)=1:K(3)=0:K(4)=2:K(5)=1:K(6)=3:K(8)=2:K(9)=1:K(10)=0
720 L(1)=0:L(2)=0:L(3)=1:L(4)=0:L(5)=1:L(6)=2:L(7)=0:L(8)=1:L(9)=2:L(10)=3
730 FOR IA=1 TO 10
735 FOR JA=1 TO 10
740 C(IA,JA)=0:REM coefficient of expansion constant a(k(ia),l(ja))
750 FOR I=1 TO NE
760 FOR J=1 TO NH
770 C(IA,JA)=C(IA,JA) + X(I)^(K(JA)+K(IA))*H(J)^(L(JA)+L(IA))
775 NEXT J
780 NEXT I
785 PRINT IA,JA,C(IA,JA)
790 NEXT JA
795 D(IA)=0
800 FOR I=1 TO NE
805 FOR J=1 TO NH
810 D(IA)=D(IA)+PERDV(I,J)*X(I)^K(IA)*H(J)^L(IA)
815 NEXT J
820 NEXT I
825 PRINT IA,"d",D(IA):PRINT
830 NEXT IA

840 REM - solve for constants a(k,l) of expansion
845 M=10
850 FOR IA=1 TO 10
855 FOR JA=1 TO 10
860 TC(IA,JA)=C(IA,JA)
865 NEXT JA
870 TD(IA)=D(IA)
875 NEXT IA
890 GOSUB 2000:REM display matrix
900 GOSUB 3000:REM triangularize matrix
910 GOSUB 4000:REM print solution of a

920 GOTO 200:REM go do original calculation with perturbation fixup

999 STOP

1000 REM sub for uncal efficiency calculation
1010 Z=A*SQR(B^2+(X-C)^2)
1020 EFFUN=EXP(Z)*(H+H0)^-2
1030 IF PFLAG = 0 THEN GOTO 1100
1040 PERT = 0
1050 FOR IA=1 TO 10
1060 PERT = PERT + A(IA)*X^K(IA)*H^L(IA)
1070 NEXT IA
1080 PERT=1 + PERT/100
1090 EFFUN = EFFUN*PERT
1100 RETURN

```

```

2000 REM display coefficient array
2002 PRINT
2005 FOR IP=1 TO M:PRINT TAB(1+(IP-1)*7) " a(";IP;")";:NEXT IP
2006 PRINT " "; "Constant" :PRINT
2010 FOR IP=1 TO M
2020 FOR JP=1 TO M
2030 PRINT USING"#####";TC(IP,JP);
2040 NEXT JP
2050 PRINT" = ";:PRINT USING"#####.##";TD(IP)
2060 NEXT IP
2070 PRINT
2990 RETURN

3000 REM -triangulation of equations
3010 FOR J=1 TO M
3015 REM - set first non zero coeff =1
3020 FOR K=J TO M
3025 TN(K,J)=TC(K,J):IF TN(K,J)=0 THEN GOTO 3070
3030 FOR L=J TO M
3040 TC(K,L)=TC(K,L)/TN(K,J)
3050 NEXT L
3060 TD(K)=TD(K)/TN(K,J)
3070 NEXT K
3075 GOSUB 2000
3080 REM - subtract out first non zero coefficients
3085 IF J+1 > 10 THEN GOTO 3150
3090 FOR K=J+1 TO M
3095 IF TC(K,J)=0 THEN GOTO 3140
3100 FOR L=J TO M
3110 TC(K,L)=TC(J,L)-TC(K,L)
3120 NEXT L
3130 TD(K)=TD(J)-TD(K)
3140 NEXT K
3145 GOSUB 2000
3150 NEXT J
3160 GOSUB 2000
3170 RETURN

4000 REM final results
4002 PRINT
4005 PRINT "values of a(i) listed below"
4010 FOR L=M TO 1 STEP -1
4020 A(L)=TD(L):IF L=M THEN GOTO 4060
4030 FOR J=L+1 TO M
4040 A(L)=A(L)-TC(L,J)*A(J)
4050 NEXT J
4060 NEXT L
4080 FOR L=1 TO M:PRINT"a(";L;") = ";A(L):NEXT L
4990 RETURN

12200 REM data for well det - medium vials
12300 REM hyperbola inverse square parameters A,B,C,H0
12350 DATA -1.038801,.3110960,4.711060,6.330
12370 REM
12400 REM experimental efficiencies below
12450 DATA .268, .518, .963, 1.538, 1.999, 2.399, 2.959
12500 REM en h1 h2 h3 h4 h5 h6 h7
12510 DATA 88,0.1664,0.1512,0.1361,0.1149,0.1028,0.0938,0.0791
12520 DATA 122,0.1869,0.1737,0.1519,0.1290,0.1169,0.1015,0.0879
12530 DATA 166,0.1405,0.1341,0.1195,0.1003,0.0896,0.0842,0.0740
12540 DATA 279,0.0945,0.0869,0.0795,0.0653,0.0613,0.0537,0.0490
12550 DATA 393,0.0637,0.0598,0.0535,0.0451,0.0412,0.0373,0.0326
12560 DATA 514,0.0468,0.0443,0.0391,0.0330,0.0305,0.0283,0.0254
12570 DATA 662,0.0372,0.0351,0.0308,0.0268,0.0238,0.0221,0.0200
12580 DATA 898,0.0266,0.0247,0.0214,0.0193,0.0176,0.0165,0.0146
12590 DATA 1173,0.0206,0.0197,0.0175,0.0152,0.0136,0.0130,0.0110
12600 DATA 1332,0.0186,0.0169,0.0154,0.0135,0.0117,0.0109,.00984
12610 DATA 1836,0.0128,0.0126,0.0111,.00977,.00874,.00784,.00750

```