A Portable Microcomputer for the Analysis of Plutonium Gamma-Ray Spectra

Vol. II. Software Description and Listings

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ABSTRACT

A portable microcomputer has been developed and programmed for the International Atomic Energy Agency (IAEA) to perform in-field analysis of plutonium gamma-ray spectra. The unit includes a 16-bit LSI-11/2 microprocessor, 32-K words of memory, a 20-character display for user prompting, a numeric keyboard for user responses, and a 20-character thermal printer for hard-copy output of results. The unit weights 11 kg and has dimensions of 33.5 x 30.5 x 23.0 cm. This compactness allows the unit to be stored under an airline seat. Only the positions of the 148-keV ^{241}Pu and 208-keV ^{237}U peaks are required for spectral analysis that gives plutonium isotopic ratios and weight percent abundances.

Vol. I of this report provides a detailed description of the data analysis methodology, operation instructions, hardware, and maintenance and troubleshooting. Vol. II describes the software and provides software listings.

1. SOFTWARE DESCRIPTION

The following is a description of the software developed for the portable microcomputer to analyze plutonium gamma-ray spectra for plutonium isotopic abundances. Descriptions of the main program and the various subroutines are given. A flow diagram of the main program is shown in Fig. 1. Listings of the main program and subroutines are provided in Section 2.

The software was developed for a Digital Equipment Corporation (DEC) LSI-11/2 microprocessor with 16K words of PROM and 12K words of RAM. The programs were compiled with DEC's FORTRAN IV V02.1-4 and linked with LINK V05.04A using a V03B-00 RT-11 operating system. (Note that if newer versions of DEC's RT-11 operating systems are used, the program may exceed available memory space because of increased memory requirements for the operating system.) The program was generated for a stand-alone environment in which the only input/output device supported by FORTRAN-level input/output is the terminal. To generate a stand-alone program, several special options must be specified at link time. The /LDA (absolute binary format) switch must be included in the LINK command string (see LINK command file listing in Section 2) to cause an LDA output file to be generated. The /INCLUDE switch must also be given to request the module \$SIMRT from the FORTRAN IV Library. The LDA file must be loaded into PROM by some type of PROM writing device. The final step before starting the program is to load into location 40g of PROM the program transfer address that is given at the end of the LINK map listing (see Section 2).

FIG. 1. Flow diagram of main program--IAEAPU.

(Continued)

(Continued)

a. Main Program - IAEAPU

This program analyzes plutonium and ^{241}Am gamma-ray peaks from 123 keV up to 383 keV for isotopic ratios and weight percent abundances of total plutonium. It can analyze spectra contained in up to 2048 channels. For a complete analysis to occur, the spectrum must start at or below 121.5 keV and include the ^{237}U 208.0-keV peak. The only inputs required to the program are the positions of the ^{241}Pu 148.6-keV and the ^{237}U 208-keV peaks. Input of the ^{242}Pu weight percent abundance is allowed, but not required. The remaining information necessary for analyzing the plutonium spectra is contained in the program.

The program begins by reading the time/date from the clock board with the subroutines CLOCK and YEAR. This information is loaded into the byte array, SND, and sent to the alphanumeric display with the subroutine SEND.

Next, the program monitors the microprocessor keyboard for any input with the subroutine RECV. The value of I returned by subroutine RECV indicates to the main program what action was requested. If I=0, then, the clock board minute register has changed and the main program updates the time/date display. An I=1 indicates that the INIT function key on the keyboard was pressed; this is interpreted as a request for resetting the clock. The subroutine SETCLK is called for this purpose. A value of I>1 indicates that the START key was pressed on the keyboard and the spectral data have been transferred from the analyzer into the data array, ARRAY. The number of channels transferred is given by I. The data transfer is performed by the subroutine SIREAD, which is called by the subroutine RECV.

Once a spectrum has been transferred from the analyzer to the microcomputer memory, the main program sends the current time/date and the spectrum number/livetime to the printer by calling the subroutine SEND. It then prompts the user for the ^{241}Pu 148-keV and the ^{235}U 208-keV peak positions with the queries, 148 PEAK POS and 208 PEAK POS, respectively. The responses are stored in the array NREF. The program next prompts the user for the ^{242}Pu weight percent abundance and the percent error on that value with the queries, WT % PU-242 and PU-242 % ERR. The values entered are stored as P242 and PE242, respectively. If the user enters a zero value for P242, there is no query for the PE242 value. The queries are displayed by calling the subroutine SEND, and the responses are read from the keyboard by the subroutine RECVR. No additional information is required from the user for analysis of the spectrum.

The first step in the data analysis is to determine the gain (GAIN), channel-zero energy (ZERO), and gamma-ray peak shape parameters: SHAPC(1), ATAIL, and BTAIL. In Section 2 of Vol. I, SHAPC(1) is the K_1 parameter in Eq. 3; ATAIL is the A parameter - tail amplitude - in Eq. 1; BTAIL is the B parameter - tail slope - in Eq. 1 times the gain.) Values for these parameters are obtained by analysis of the 148- and 208-keV reference peaks. Approximate values for several parameters are used initially in the analysis of the reference peaks; then the analysis is repeated using the results obtained in the first pass for these parameters.

Approximate gain and zero values are determined from the user-provided reference peak locations. Sixty channels of data centered about the reference peaks are read into a working array, Y. The maximum count in the reference peak and minimum counts on each side of the peak are obtained with the subroutines MAXVAL and MINVAL. A statistical test is performed on this information to determine whether a peak exists at the location given by the user. The test requires that the difference between the

maximum and minimum counts exceed four times the square root of the maximum count. If this condition is not met, the program displays the message BAD PEAK POSITION and the program returns to the beginning. This condition may exist for three reasons: poor counting statistics in the reference peaks, incorrect value entered by the user for the reference peak position, or spectral data improperly transferred from the analyzer.

Before the reference peaks are analyzed for channel positions and shape parameters, the background distributions beneath the peaks are removed. The minimum counts found on either side of the peak are used as the corresponding background levels. The difference (step) between these levels, DBG, is proportioned at each channel beneath the peak by ratioing the partial peak area up to that channel, YS, to the total peak area, YSUM. (See description of the background methodology in Section 2 of Vol. I.)

The peak position, PKPS, and the peak width parameter, ALFA, are determined with the subroutine GFIT2. This subroutine fits a parabola to the natural logarithm of the net counts in the upper half of a peak. In addition to the background corrected data in array Y, inputs to this subroutine are the approximate position of the peak JPK within the array Y and the parameters: ALFA, ATAIL, and BTAIL. ALFA is equal to $-4 \cdot \ln(2) / (\text{FWHM})^2$ where the FWHM is expressed in channels. GFIT2 returns the peak position PKPS, the peak height PKHT, and a redetermined value for ALFA. With this information, the subroutine CTAIL determines the peak tail parameters, ATAIL and BTAIL.

From the more accurate positions of the reference peaks, new gain and channel-zero energy values for the spectrum can be calculated. The tail parameter values are checked to ensure that they fall within some reasonable bounds. Poor counting statistics in the reference peaks or unknown peak interferences could cause these

values to fall outside the bounds. The bounds have been empirically determined and require that the value given by $BTAIL/GAIN$ be greater than 1 and less than 3. If these conditions are not met, $BTAIL$ is set to $2 * GAIN$ and $ATAIL$ is set to $BTAIL/10$. If $BTAIL$ falls within the given bounds, but $ATAIL$ exceeds the value of $BTAIL$, then $ATAIL$ is set to $BTAIL/10$.

The peak width values determined for both reference peaks are used to determine the value of $SHAPC(1)$ for the spectrum. $SHAPC(1)$ is related to the "system" noise and is reevaluated for each measurement, and $SHAPC(2)$ is related to the statistical nature of the charge collection process in the detector. $SHAPC(2)$ is fixed to a constant value of 0.0017 in the program.

The analysis of the reference peaks is repeated with these new parameter values to ensure that the approximations used in the first pass do not distort the final results. After the second pass, the values obtained in the analysis of the reference peaks for the gain, channel-zero energy, and the FWHM of the 208-keV peak are printed out.

Several checks are made on these parameters to verify that an accurate analysis can be completed. The gain and channel-zero energy are checked to determine if the spectral regions required for the isotopic analysis are included in the spectrum. If the gain, channel-zero energy, and maximum channel in the spectrum indicate that the maximum energy in the spectrum is less than 210 keV, the message BAD GAIN; CHECK PEAK POS is flashed on the display. The program cannot do a complete analysis if the 208-keV peak is not included, so the analysis is stopped and the program returns to the beginning. If the energy of channel zero is greater than or equal to 121.5 keV, the message BAD ZERO; CHECK PEAK POS is flashed on the display. Again the data analysis is stopped and the program returns to the beginning. If the peak shape analysis results

in a value of SHAPC(1) less than zero, the message CHECK PEAKS is flashed on the display and the analysis does not continue. A negative SHAPC(1) occurs if either the 148- or the 208-keV reference peak does not have a Gaussian peak shape. This may result from very poor counting statistics, entry of an incorrect peak position, or if either peak has a channel that overflowed. If the FWHM of the 208-keV peak exceeds 15 keV, the message POOR RESOLUTION is flashed on the display. This is to warn the user that the spectral resolution is not good and the results may be questionable. The analysis continues, however.

The next step in the program is to analyze seven or nine peak groupings in the spectrum to determine gamma-ray peak areas. If the spectrum does not contain the 330- or 370-keV regions, only seven groups are analyzed. Each group may contain only one peak or a multiplet of overlapping peaks. The beginning and ending energies of the groups are stored in the arrays ENSTCH and ENECH. The number of channels used to determine the levels on both sides of each group are stored in the arrays NBG1 and NBG2.

The channel location of the region to be analyzed is determined from the gain and channel-zero energy values. Once the starting channel of the group IST and the number of channels NDPTS in the group have been determined, a check is made to ensure that the entire group is contained in the spectrum. A separate check is made to determine if the upper background window overlaps the end of the spectrum. If it does overlap, the program reduces the size of the upper background window, if possible, to allow it to fit within the spectrum. If its size must be reduced to zero width, the analysis is stopped and the message BAD GAIN OR ZERO is displayed. Before locating the 330- and 370-keV groups, the gain must be reevaluated by determining the position of the ^{239}Pu 375-keV peak. This is done in case of nonlinearity in the spectrum.

The next step is to determine the average background levels on both sides of the group with the subroutine AVE. The background distribution beneath the peak(s) is calculated and subtracted channel by channel from the group with the subroutine BKGRD. If the 203.5-keV peak is being analyzed, an additional step is taken to remove any counts from the region caused by the 208-keV peak tail. This is done with the subroutine STRIP.

After removing the background, the reference peak in each grouping is located with the subroutine GFIT2. For the first peak grouping, the 120-keV region, the position of the 129.3-keV peak is checked to ensure that the correct reference peaks were used. If the position of the 129.3-keV peak is found to be incorrect based on the gain and zero-channel energy, the message BAD PEAK POSITION is displayed and the analysis is stopped.

The next step in the analysis of a peak grouping is to load the arrays PKHT and NXFLG with the information needed for fitting the peak grouping to determine individual peak areas. The byte array STR contains the information for how these arrays are to be loaded. This array can be divided into nine parts. Each part applies to one of the nine peak groupings. The first value in each part gives the number of peaks in the grouping. For instance, the first six in the array (see program listing) indicates that there are six peaks in the first grouping. The remaining byte values for each part indicate whether the height (area) of each peak is a free parameter or if it is fixed relative to another peak. These byte values are loaded into the NXFLG array. If a value is zero or is equal to the number of peaks in the group, the corresponding peak height is a free parameter. Any other value indicates that the corresponding peak height is ratioed relative to the free peak height indicated by that value. For instance, in the first grouping the value 3 for the second, third, and fourth peaks indicates that the heights of

these peaks are ratioed to the height of the third free peak, which in this case is the last peak. The corresponding ratios are obtained from the **RATIO** array and loaded into the appropriate locations in the **PKHT** array. The peak that has a value equal to the number of peaks in the grouping is the peak to which the relative positions of all the other peaks are fixed.

Now a set of linear equations is formed and fit simultaneously to the net data channels in the group with the peak heights as the unknowns. The calculational method is to form the matrix (peak response matrix) of linear equations **ALPHA** and to solve it by the method of weighted least-squares. The weights **WT** are the variance of the approximate gross channel counts. The peak heights **PT** are obtained by inverting the matrix **ALPHA** with the subroutine **MATINV** and multiplying the inverted matrix by the matrix **SUM**. The diagonal matrix elements of the inverted matrix of weighted normal equations are used for assigning errors to the results. The peak areas are determined from the peak heights by taking the integrals of the corresponding Gaussians. The errors on the areas are determined by taking the square root of the sum of the square of each peak height error and the square of the statistical uncertainty in the background. The resulting peak energies, areas, and errors are then printed out. For those peaks whose heights are fixed relative to another peak, the error value is replaced by the term **FIXD** in the printout.

When the program determines that there are no more peak groupings to be analyzed, it checks to make sure that at least the first seven groups were analyzed. If fewer than seven groups were found and analyzed, it displays the message **BAD GAIN OR ZERO** and the analysis is stopped.

The peak areas must be corrected for detection efficiency before isotopic ratios can be determined. These corrections require determination of the overall detection efficiency for the gamma rays emitted by the sample. A self-calibration technique is used to obtain the necessary relative detection efficiency corrections from peak areas in each spectrum measured. Areas of the 129.3- and 203.5-keV peaks of ^{239}Pu and the 164.6- and 208-keV peaks of ^{241}Pu are corrected for gamma-ray branching intensities, and the natural logarithm of these values is fitted to a quadratic function of the natural logarithm of the energy (MeV). An additional coefficient is required in the fit to normalize the ^{241}Pu data points to the ^{239}Pu data points. A weighted least-squares technique is used and is done with the subroutine PUFIT. If the 330- and 370-keV peak groupings are included in the spectrum, the 345.0- and 375.0-keV ^{239}Pu peaks are also used in the determination of the relative detection efficiency. In this case, a cubic function is used to fit the data. The results of this analysis allow calculation of the detection efficiency at any energy and therefore the correction of any peak area.

To determine plutonium isotopic ratios, appropriate peak areas from various energy regions are incorporated into a set of linear equations that are solved by the method of least squares (see Eq. 6 in Section 2 of Vol. I). Peak area ratios are the dependent variable, while the isotopic activity ratios are the independent variable. The peak area ratios must be corrected for isotopic branching probabilities and detection efficiencies. The equations are weighted using the peak area errors determined in the peak group fitting process and the relative detection efficiency for each region. If the 330- and 370-keV regions are not in the spectrum, then five equations are developed; if they are, then seven are developed. The matrix ALPHA formed by these equations is inverted by the subroutine MATINV. The plutonium activity ratios are calculated by multiplying the inverted matrix by the matrix BETA. The errors on the ratios are obtained from the diagonal elements of the inverted matrix.

The isotopic activity ratios are multiplied by corresponding half-life (see Table 2 for half-life values) and weight ratios to obtain the plutonium isotopic weight ratios. The plutonium isotopic weight percent abundances are calculated from these ratios. This calculation requires a value for the ^{242}Pu abundance, which cannot be determined by gamma-ray analysis. If the user enters a nonzero value for the ^{242}Pu abundance, then this value is used. If a zero value is entered, the ^{242}Pu abundance is calculated using an empirical algorithm based on the ^{240}Pu and ^{241}Pu abundances. The ^{241}Pu abundance must be corrected for decay since it is large from the reactor. Because this decay information is not always available, the ^{241}Pu abundance is corrected only for decay since separation from ^{241}Am . This period of decay can be determined from the ^{241}Am -to- ^{241}Pu ratio Z5141. The calculated age since chemical separation from ^{241}Am is used to partially correct the ^{241}Pu abundance. The corrected ^{241}Pu -to- ^{239}Pu ratio X4149 and the ^{240}Pu -to- ^{239}Pu ratio Z4049 are used to calculate the weight percent ^{242}Pu abundance P242.

After calculating the weight ratios, weight percent abundances, separation age, and attendant errors, these values are printed out. Once the program finishes printing, it returns to the beginning, updates the time/date display, and waits to start a new analysis.

b. Data Analysis Subroutines

MAXVAL -- This subroutine determines the location L with the maximum value YMAX in an array Y.

MINVAL -- This subroutine determines the location L with the minimum value YMIN in an array Y.

AVE -- This subroutine determines the average value AV of those values contained in array Y from array location NS to NE inclusive. The sum of these values is returned by the subroutine in SUM.

GFIT2 -- This subroutine fits the upper half of a peak with a Gaussian after removing the tailing contribution from the peak. The subroutine returns the peak position PKPOS, the peak height PKHT, and the peak width parameter ALFA. The subroutine must be provided with the position L of the peak within the Y array, an approximate value for ALFA, and values for the peak tail parameters EXP1 (ATAIL) and EXP2 (BTAIL). An error condition is returned if no valid peak exists within an appropriate interval from the location L or if the statistics are poor. The calling program must take appropriate action.

CTAIL -- This subroutine removes the Gaussian component from a peak and analyzes the residual for the tail parameters A and B (see Section 2 of Vol. I for a description of tail parameters). The natural logarithm of the positive residuals is fit to a straight line by least squares to give a tail amplitude value A and a tail slope value B. The peak must have sufficient data in the tail for an accurate analysis.

BKGRD -- This subroutine calculates and subtracts the background distribution channel by channel from data contained in the Y array. NS gives the starting location and NE the ending location of the region within the Y array. The background levels on both sides of this region, AVBG1 and AVBG2, are provided by the calling program. The difference between these two levels is smoothed beneath the specified region and

subtracted from the data in the region. (See the complete description of the background algorithm in Section 2 of Vol. I.) The channel data with the background subtracted are returned by the subroutine in the array YNET. NOTE that the channel data contained in the YNET array is shifted down by NS locations from the corresponding channel data in the Y array.

STRIP -- This subroutine is used to strip a peak or part of a peak from channel data contained in the array Y. The resulting channel data are returned by the subroutine in the array Y.

MATINV - This subroutine was adapted from the matrix inversion subroutine given in Ref. 10 of Vol. I. The subroutine inverts a square matrix in place and calculates its determinant. The input variables are the matrix in ARRAY and the order of the matrix NORDER. The output is the value of the determinant DET and the inverted matrix in ARRAY.

PUFIT -- This subroutine fits a polynomial of order NTERMS to the corrected peak areas as a function of the logarithm of the corresponding energies using a weighted least-squares technique. The peak areas are corrected for gamma-ray branching probabilities. The corrected peak areas give the relative detection efficiency for the measurement at several different energies in the spectrum. Fitting these values to a polynomial gives the detection efficiency as a function of energy and allows calculation of the detection efficiency at any energy. Peak areas from ^{239}Pu and ^{241}Pu gamma rays are used in this analysis; therefore, an additional term must be used in the fit to normalize the activity of the two isotopes.

DPM -- This function routine calculates a psuedo relative detection efficiency value for the isotope specified by the parameter L (^{239}Pu or ^{241}Pu) at the energy (MeV) specified by XX. The calculation uses the polynomial coefficients determined by the log-log fit in the subroutine PUFIT. The ratio of two values calculated by the subroutine DPM at two different energies is equivalent to the ratio of the detection efficiencies at those two energies.

c. Input/Output Subroutines

RECVR -- This subroutine receives the input from the TM-25 keyboard and interprets it. *The input maybe either a numeric entry or a function command to be sent to the Silena MCA.* A function command is interpreted in this subroutine and the appropriate action is carried out by issuing a corresponding command to the MCA over the parallel interface. If the BS 27 MCA is in the wrong state for the requested command, the message COMMAND ERROR is flashed on the display. The function commands work only with the Silena BS 27/N MCA. If the CICERO MCA is being used, the function commands from the portable microprocessor are either ignored or the message COMMAND ERROR is flashed on the display.

A numeric entry is converted into ASCII and stored in the byte array SND. The number of digits received is returned to the calling program by I.

This subroutine may be called to wait for input or to intercept expected input. The value of I when the subroutine is called determines the option used. If I=0, then the subroutine waits for an entry and monitors the clock while waiting. If the clock board minute register changes while waiting, the subroutine returns to the calling program with I=0 to allow the calling program to update the time/date display. If the subroutine

is called with I not equal to zero, the subroutine proceeds immediately to intercept expected input from the keyboard. This is done to avoid having a query on the display being replaced by the time/date display if the clock minute register should change before the user responds to the query.

If the START (analysis) command is entered, the SIREAD subroutine is called by this subroutine to read the data from the Silena MCA byte by byte into the array DATA. Six bytes are stored for each channel transmitted from the MCA. The subroutine RECVR converts this byte array information into floating-point values and stores them in ARRAY. This data array is passed to the calling program by the named common DATA. This array must be located in the RAM part of memory. The number of channels transmitted from the Silena MCA is returned to the calling program by I. NOTE that the maximum number of channels that can be transferred is 2048. The two additional ARRAY locations are for storing the spectrum number and lifetime.

SIREAD -- SIREAD is a subroutine written in MACRO assembly language that performs the transfer of bytes from a Silena MCA to the portable microprocessor. The transfer is through a parallel interface in the MCA and an ADAC 1664 TTL I/O board in the portable microprocessor.

The subroutine begins by obtaining the location of the byte array where the transmitted bytes are to be stored. It clears CHRCTR (byte counter) and then performs a test necessary only for the BS 27 MCA. This test checks to make sure that the BS 27 is in the DISPLAY mode before placing it in the STOP mode. The BS 27 MCA must be in the DISPLAY mode before sending it a STOP command, and it must be in the STOP mode before sending it REMOTE and DATA OUT commands. If the BS 27 is not in the DISPLAY mode, the subroutine returns with CHRCTR equal to zero, which is detected by the

subroutine RECVR as an error condition. This test is not necessary for the CICERO MCA; however, these instructions do not have to be removed for the subroutine to function with the CICERO MCA.

Data transfer from the MCA begins with the subroutine setting the MCA to REMOTE and then issuing a DATA OUT command. The subroutine then waits for the DATA READY FLAG to be set. Once the flag is set, the subroutine reads the byte (character) at the input data register and then resets the DATA READY FLAG. The byte is compared against seven possible control characters. If it is any one of these characters, the input byte is discarded and the subroutine calls an internal subroutine that tests whether the DATA READY FLAG is cleared. When the DATA READY FLAG is cleared, the subroutine returns to the beginning and issues a new DATA OUT command and then waits for the next byte from the MCA. If a legitimate character is found, the upper four bits are cleared to give the correct octal value of the decimal digit transmitted. The result is stored in the byte buffer and the byte is counted by incrementing CHRCTR. Eight bytes are transmitted by the MCA for each channel; two of these are control characters that are discarded.

When the end-of-spectrum character is detected, the subroutine reads the 40 trailing control characters (subouts) at the end of the spectrum transfer and discards them. The subroutine then returns to the calling program with the number of bytes stored in the byte array.

SEND -- This subroutine sends the ASCII characters contained in the array SND to either the 20-character display or the printer. The first character in the array indicates the device to be used and the type of output. (See subroutine listing for these characters and their interpretations.)

A short time delay must be inserted between sending each character to the printer in order to give the printer time to check and load the character into its buffer. If the delay is insufficient, characters will be lost. A carriage return character sent to the printer will cause the printer to print out its buffer. Another time delay is necessary after this command to allow the printer time to empty its buffer.

SETCLK -- This subroutine sets the TCU-50DYR clock registers from the information given by the user on the TM-25 keyboard. The subroutine uses the subroutines **SEND** and **RECV** to interrogate the user for the time/date information. The information is read in ASCII from the TM-25 keyboard and stored in the array **NBR**. The **DECODE** function is used to convert the ASCII array to an integer value, and the function **IBNBCD** is used to convert the integer binary value to BCD, which is required to set the clock registers.

CLOCK -- This subroutine reads the day **IDAY**, month **IMO**, hour **IHR**, and minute **IMIN** from the TCU-50DYR clock board in the portable microprocessor unit.

YEAR -- This subroutine reads the year from the TCU-50DYR clock board CMOS RAM. This subroutine is also responsible for maintaining the pseudo year counter in the TCU-50DYR's battery-supported CMOS RAM. It is necessary to run this routine at least once a year to ensure that the year value is updated. Each time this subroutine is used, the current month is also stored in the CMOS RAM. This allows the subroutine to determine when a new year has started.

PORDR -- PORDR is a MACRO-11 source file that contains PSECT directives. To build a PROM-based application, certain program sections (PSECTS) must be included in the read-only memory (PROM) area. The order in which the declarations appear in the file will be the order in which the sections will be allocated in the executable program. The MACRO-11 source file containing the desired ordering must be assembled and used as the first input file in the LINK command.

2. SOFTWARE LISTINGS

```

C
C*****
C
C      PROGRAM INCHPU
C      -----
C
C      Author: Wayne D. Rueter
C
C      Date: 1-NOV-80
C
C      Update: 22-JUL-83
C
C      This program analyzes Plutonium gamma-ray spectra for
C      plutonium isotopic ratios and weight percents of total
C      plutonium. The program analyzes gamma-ray peaks beginning
C      at 123-KeV up to 383-KeV. For a complete analysis to occur
C      the spectrum must start at or below 121.5-KeV and include the
C      U-237 208.0-KeV peak. The only input required to the program
C      is the positions of the Pu-241 148-KeV and the U-237 208-KeV
C      peaks. The program uses these peaks to establish the gain,
C      zero, and gamma-ray peak shapes for the spectrum being analyzed.
C      The peak shape information is used to generate peak response
C      profiles which are fitted to peaks or peak groupings to determine
C      peak areas. An internal self-calibration technique is used to
C      establish the relative detection efficiency for the measurement.
C      From the peak areas and the efficiency information, a set of
C      equations are formed and solved by least squares to give
C      the plutonium isotopic ratios.
C
C*****
C
C      LOGICAL*1 STR(46),SND(13),NMBR(9),ICRLF(4),FCRLF(4),I(2)
C      EQUIVALENCE(I(1),SND(12))
C
C      COMMON X,Y,ALPHA,SUM,ERROR,YFIT,SIGMAA
C
C      COMMON/DATA/ARRAY(2050) !SPECTRAL DATA LOADED INTO THIS ARRAY
C      ARRAY(1)=SPECTRUM #;ARRAY(2)=LIVETIME + UPTO 2048 DATA CHANNELS
C
C      THE NAMED COMMON BELOW IS NECESSARY SO THAT THE ARRAYS MAY
C      BE FORCED INTO THE PROM AREA DURING THE LINKING OPERATION.
C      THIS MUST BE DONE SINCE THE ARRAY VALUES ARE LOADED USING
C      DATA STATEMENTS.
C
C      COMMON/PURE/STR,ICRLF,FCRLF,ENG,ENSTCH,ENECH,NBG1,NBG2
C
C      DIMENSION ENSTCH(9),ENECH(9),NBG1(9),NBG2(9),NXFLG(8),STB(2),
C      1  RATIO(13),SHAPC(2),NREF(2),REFCH(2),ENG(37),PKPOS(8),PKHT(8),
C      2  PT(5),AX(5),SUM(6),ALPHA(6,6),C(2),AREA(37),YFIT(6),SIGMAA(6),
C      3  ERR(37),X(6),Y(210),P(7,4),WTF(7),BETA(4),RAT(4),ERROR(6)
C
C      NOTE THE 'Y' ARRAY WHICH STORES THE DATA FOR A PARTICULAR
C      WINDOW DURING ANALYSIS MUST BE BIG ENOUGH TO HANDLE 18.7/GAIN
C      + 10 DATA CHANNELS.

```

```

EQUIVALENCE (AREA(5),A125),(AREA(6),A129),(AREA(11),A148),
1 (AREA(13),A152),(AREA(17),A160),(AREA(19),A165),
2 (AREA(22),A203),(AREA(23),A208),(AREA(24),A332),
3 (AREA(29),A345),(AREA(33),A370),(AREA(34),A375),
4 (AREA(21),A185),
5 (ERR(5),ER125),(ERR(6),ER129),(ERR(11),ER148),
6 (ERR(13),ER152),(ERR(17),ER160),(ERR(19),ER165),
7 (ERR(22),ER203),(ERR(23),ER208),(ERR(24),ER332),
8 (ERR(29),ER345),(ERR(33),ER370),(ERR(34),ER375),
9 (ERR(21),ER185)

```

```

DOUBLE PRECISION SUM,ALPHA

```

```

THE BYTE STRING BELOW CONTAINS INFORMATION NEEDED IN FITTING
EACH PEAK OR PEAK GROUPING. THE FIRST VALUE ON EACH LINE
INDICATES THE NUMBER OF PEAKS IN THE GROUP. FOR INSTANCE
THE FIRST 6 ON THE FIRST LINE INDICATES THERE ARE 6 PEAKS
IN THE FIRST GROUP. THE REMAINING VALUES IN THE LINE INDICATE
WHETHER THE PEAK HEIGHT IS A FREE PARAMETER FOR THAT PEAK
OR IF IT IS FIXED RELATIVE TO ANOTHER PEAK. IF THE VALUE IS 0
OR IS EQUAL TO THE NUMBER OF PEAKS IN THE GROUP, THE PEAK
HEIGHT IS A FREE PARAMETER. ANY OTHER VALUE INDICATES THAT
PEAK IS FIXED RELATIVE TO THE FREE PEAK INDICATED BY THAT VALUE.
FOR INSTANCE, IN THE FIRST LINE THE VALUE 3 FOR THE SECOND,THIRD,
AND FOURTH PEAK INDICATES THAT THESE PEAKS ARE FIXED RELATIVE
TO THE THIRD FREE PEAK IN THE GROUP WHICH IN THIS CASE IS
THE LAST PEAK. THE PEAK WHICH HAS A VALUE EQUAL TO THE NUMBER
OF PEAKS IN THE GROUP IS THE PEAK TO WHICH THE POSITIONS OF
ALL THE OTHER PEAKS ARE FIXED TO, i.e., IT IS THE POSITION
REFERENCE FOR ALL OF THE OTHER PEAKS IN THE GROUP.

```

```

DATA STR/'6','0','3','3','3','0','6',
1 '6','0','0','2','0','6','3',
2 '2','2','0',
3 '6','0','3','0','0','6','0',
4 '1','1',
5 '1','1',
6 '1','1',
7 '6','0','3','0','3','3','6',
8 '8','3','3','0','0','8','0','3','3'/

```

```

THE STRINGS BELOW GENERATE A CARRIAGE RETURN AND LINE FEED
ON THE DEVICES INDICATED.

```

```

DATA DCRLF/'104','15','12','40/      !DISPLAY
DATA PCRLF/'40','15','12','40/      !PRINTER

```

```

ENERGIES (KeV) OF PEAKS TO BE ANALYZED

```

DATA ENG/122.926,123.62,124.51,125.21,125.293,129.294,
 1 141.567,144.211,146.077,146.557,148.567,150.11,
 2 152.68,154.2,
 3 159.955,160.19,160.308,161.482,164.597,165.93,
 4 185.72,
 5 203.537,
 6 208.,
 7 332.385,332.853,335.43,336.104,341.517,345.011,
 8 367.050,368.546,368.603,370.933,375.042,376.59,
 9 380.166,382.74/

START POSITIONS FOR EACH PEAK OR PEAK GROUPING IN KeV

DATA ENSTCH/121.9,141.,151.7,159.2,184.,202.7,206.3,
 1 331.,366./

ENDING POSITIONS FOR EACH PEAK OR PEAK GROUPING IN KeV

DATA ENECH/130.6,150.8,154.7,166.4,187.,204.7,211.,
 1 347.14,384.68/

NUMBER OF CHANNELS USED TO DETERMINE THE BACKGROUND IN
 FRONT OF EACH GROUP.

DATA NBG1/3,3,5,4,5,5,4,5,5/

NUMBER OF CHANNELS USED TO DETERMINE THE BACKGROUND
 BEHIND EACH GROUP.

DATA NBG2/10,3,3,7,5,3,10,5,5/

INTENSITY RATIOS FOR INDICATED PEAKS

RATIO(1)=0.00315	!123.62/129.294
RATIO(2)=0.00993	!124.51/129.294
RATIO(3)=0.00923	!125.21/129.294
RATIO(4)=.42	!146.1/144.2
RATIO(5)=.1605	!150.1/146.6
RATIO(6)=.0517	!160.2/161.5
RATIO(7)=0.905	!332.838/345.01
RATIO(8)=0.203	!336.107/345.01
RATIO(9)=0.1184	!341.51/345.014
RATIO(10)=.055095	!367.050/375.042
RATIO(11)=.057515	!368.55/375.042
RATIO(12)=.19426	!380.166/375.042
RATIO(13)=.16496	!382.751/375.042

REFERENCE PEAK ENERGIES TO ESTABLISH GAIN, ZERO, AND
 PEAK SHAPES

STD(1)=148.567
 STD(2)=208.

```

C
C      DISPLAY DATE AND TIME FROM TCU-50BYR CLOCK BOARD
C      ALLOW USER TO CHANGE IF REQUIRED; THIS IS DONE
C      BY USING INIT KEY ON TM25 TERMINAL.
C
      CALL IPOKE('164104,*77) !INITIALIZE SILENA COMMAND LINES
1      CALL YEAR(IYR)          !GET YEAR FROM CLOCK RAM
      CALL CLOCK(IDAY,IMO,IHR,IMIN)          !GET TIME
      ENCODE(20,700,SND)IHR,IMIN,IDAY,IMO,IYR !DISP Y TIME
700    FORMAT('C ',I2,':',I2,' ',I2,'/',I2,'/',I2,' ')
      CALL SEND(ICRLF)
      CALL SEND(SND)
3      I=0                      !UPDATE TIME DISPLAY FLAG
5      CALL RECUR(SND,I)        !WAIT FOR TM25 ENTRY
      IF(I.EQ.0)GOTO 1          !UPDATE TIME DISPLAY
      IF(I.NE.1)GOTO 7
      CALL SETCLK              !SET CLOCK
      CALL CLOCK(IDAY,IMO,IHR,IMIN)
      ENCODE(20,700,SND)IHR,IMIN,IDAY,IMO,IYR
      CALL SEND(SND)
      GOTO 3
C
C      SPECTRAL DATA WAS TRANSFERRED FROM THE SILENA MCA TO THE
C      MICROCOMPUTER. PRINT THE CURRENT TIME AND DATE AND REQUEST
C      THE INFORMATION NEEDED FOR THE ANALYSIS.
C
7      CALL INSERT(' ',SND,1,1)!SYSLIB ROUTINE
      CALL SEND(SND)          !PRINT TIME AND DATE OF ANALYSIS
C
C      NCHNS =I                !NUMBER OF CHANNELS IN SPECTRUM
C
C      PRINT OUT THE SPECTRUM NUMBER AND LIVETIME
C
10     ENCODE(22,750,SND)ARRAY(1),ARRAY(2)
750    FORMAT('SPEC #',F4.0,';LT=',F6.0,' S')
C
C      REMOVE DECIMAL FROM FLOATING POINT NUMBER
C
      JJ = 1
      DO 12 J = 1,22
      IF(SND(J).EQ.'.')GOTO 12
      SND(JJ)=SND(J)
      JJ = JJ + 1
12    CONTINUE
      CALL SEND(SND)
      CALL SEND(ICRLF)
C
C      GET APPROXIMATE CHANNEL POSITIONS FOR REFERENCE PEAKS
C
      CALL SCOPY('D148 PEAK POS',SND)
      CALL SEND(ICRLF)
      CALL SEND(SND)
      CALL SCOPY(' ',NMBR)
      CALL RECUR(NMBR,I)          !GET 148-KeV PEAK POSITION
800    DECODE(I,800,NMBR)NREF(1)
      FORMAT(I5)
      CALL INSERT('E=',D,1,2)
      CALL SEND(D)              !DISPLAY ENTRY
      CALL SCOPY('D208 PEAK POS',SND)
      CALL SEND(ICRLF)

```

```

CALL SEND(SND)
CALL RECV(NMBR,I)                                !GET 208-KeV PEAK POSITION
DECODE(I,800,NMBR)NREF(2)
CALL INSERT('E=',D,1,2)
CALL SEND(D)                                    !DISPLAY ENTRY

C
C GET PU-242 WT. % AND ERROR FROM OPERATOR. IF OPERATOR
C ENTERS A ZERO VALUE FOR PU-242, THE PU-242 WT. % IS CALCULATED.
C
CALL SCOPY('DWT % PU-242 ',SND)
CALL SEND(DCRLF)
CALL SEND(SND)
CALL SCOPY(' ',NMBR)
CALL RECV(NMBR,I)                                !GET PU-242 WT. %
803 DECODE(I,803,NMBR)P242
FORMAT(G5.0)
CALL INSERT('E=',D,1,2)
CALL SEND(D)                                    !DISPLAY ENTRY
IF(P242.EQ.0)GOTO 15
CALL SCOPY('DFU-242 % ERR',SND)
CALL SEND(DCRLF)
CALL SEND(SND)
CALL SCOPY(' ',NMBR)
CALL RECV(NMBR,I)                                !GET % ERROR ON PU-242 WT.
804 DECODE(I,803,NMBR)PE242
ENCODE(7,804,D)PE242
FORMAT('E=',F5.2)
CALL SEND(D)                                    !DISPLAY ENTRY
PE242 = PE242 * P242 /100.

C
C CALCULATE APPROXIMATE GAIN AND ZERO FROM PEAK POSITIONS
C ENTERED BY THE OPERATOR.
C
15 GAIN=(STD(2)-STD(1))/(NREF(2)-NREF(1)) !APPROXIMATE GAIN
ZERO=STD(2)-NREF(2)*GAIN !APPROXIMATE ZERO VALUE

C
C APPROXIMATE SHAPE CONSTANTS FOR FWHM AND TAIL PARAMETERS
C
SHAFC(1)=0.2 !PEAK SHAPE PARAMETERS FOR FULL-WIDTH
SHAFC(2)=0.0017 !THIS VALUE IS FIXED
ATAIL=.058
BTAIL=2.*GAIN !THIS IS AN APPROXIMATE VALUE FOR GAIN

C
C INITIALIZE COUNTERS AND POINTERS
C
NGRP=9 !NUMBER OF GROUPS
NPKS=0 !PEAK COUNTER
NSTRPT=1 !STRING POINTER
NRATPT=1 !RATIO POINTER
A345=0. !INITIALIZE ; USED FOR FLAG LATER

C
C USING REFERENCE PEAKS ESTABLISH GAIN, ZERO, AND PEAK SHAPE
C PARAMETERS FOR GIVEN SPECTRUM. TWO PASSES ARE MADE BECAUSE
C OF THE APPROXIMATE ESTIMATES OF PARAMETERS USED ON THE FIRST PASS.
C
DO 40 JJ=1,2 !DO THIS TWICE
DO 30 J=1,2
IST=NREF(J)-30 !STARTING CHANNEL FOR REFERENCE PEAK REGION
ST=IST

```

```

20      DO 20 K=1,60      !TRANSFER DATA INTO WORKING ARRAY
      Y(K)=ARRAY(IST+K)
C
C      GET MAXIMUM AND MINIMUM VALUES IN PEAK REGION AND CHECK TO MAKE
C      SURE VALID PEAK EXISTS IN REGION.
C
      IST=1
      CALL MAXVAL(IST,60,JPK,YMAX,Y)
      CALL MINVAL(1,JPK,MS,C1,Y)
      CALL MINVAL(JPK,58,ME,C2,Y)
      CALL AVE(MS,ME,YSUM,AV,Y)
C
C      YSUM IS THE GROSS NUMBER OF COUNTS IN THE REFERENCE PEAK
C
C
C      IS DATA IN THE SPECIFIED REGION STATISTICALLY SIGNIFICANT?
C
      IF((YMAX-C1).GT.4.*SQRT(YMAX))GOTO 22
      CALL SCOPY('FBAD PEAK POSITION ',SND)
      CALL SEND(DCRLF)
      CALL SEND(SND) !SEND MESSAGE THAT A VALID PEAK WAS NOT FOUND
      GOTO 5
C
C      SUBTRACT OUT BACKGROUND FROM REFERENCE PEAKS USING A
C      SMOOTHED STEP BENEATH THE PEAK.
C
22      YS=0.
      DBG=C2-C1      !DIFFERENCE BETWEEN THE FRONT AND BACK BKGS.
      DO 25 I=MS,ME
      YS=YS+Y(I)      !PARTIAL SUM OF PEAK
25      Y(I)=Y(I)-C1-DBG*YS/YSUM
C
C      DETERMINE THE PEAK CHANNEL LOCATIONS AND SHAPES OF THE
C      REFERENCE PEAKS
C
      GSQ=GAIN*GAIN
      SG=SHAPC(1)/GSQ + SHAPC(2)*(ST/GAIN + ZERO/GSQ) + 0.462
C
C      SG = THE (FULL-WIDTH-HALF-MAXIMUM IN CHANNELS)**2
C
      ALFA=-2.7726/SG !APPROXIMATE PEAK WIDTH PARAMETER
C
C      GET PEAK CHANNEL POSITION AND WIDTH PARAMETER ALFA
C      TEST ERROR FLAG: IT WILL BE SET TO -1 IF PEAK IS NOT
C      FOUND OR DOES NOT APPEAR TO BE GAUSSIAN.
C
      CALL GFIT2(JPK,ALFA,ATAIL,BTAIL,PKPS,PXT,ERRP,Y)
      IF(ERRP.EQ.-1)GOTO 21
      C(J)=ALFA
      REFCH(J)=ST+PKPS
C
C      GET PEAK TAILING PARAMETERS ATAIL AND BTAIL. AN
C      APPROXIMATE VALUE MUST BE SENT FOR ATAIL IN THE CALL.
C
      CALL CTAIL(MS,ME,PKPS,PXT,ALFA,ATAIL,BTAIL,Y)
30      CONTINUE
C
C      CALCULATE NEW GAIN AND ZERO FROM DETERMINED REFERENCE PEAK
C      POSITIONS
C

```



```

GAIN=(STD(2)-STD(1))/(REFCH(2)-REFCH(1))
ZERO=STD(2)-GAIN*REFCH(2)
SZERO=ZERO
GSQ=GAIN*GAIN
NREF(1)=(STD(1)-ZERO)/GAIN
NREF(2)=(STD(2)-ZERO)/GAIN

C
C
C
C
CHECK ATAIL AND BTAIL PARAMETERS; IF OUT OF RANGE,
USE DEFAULT VALUES.

FACT=BTAIL/GAIN
IF((FACT,LT.1.).OR.(FACT,GT.3.))BTAIL=2.*GAIN
IF(BTAIL,EQ.GAIN)ATAIL=BTAIL/10.
IF(ATAIL,GT.BTAIL)ATAIL=BTAIL/10.

C
C
C
REEVALUATE PEAK WIDTH PARAMETER SHAPC(1)

C(2)=(-2.7726/C(2)-0.462)*GSQ
SHAPC(1)=C(2)-STD(2)*SHAPC(2)
CONTINUE

40
C
C
C
OUTPUT RESULTS TO PRINTER

ENCODE(20,805,SND)GAIN
805
FORMAT('GAIN =',F7.4,' KEV/CH')
CALL SEND(SND) !PRINT GAIN
CALL SEND(PCRLF)

C
C
C
C
RECALCULATE THE ZERO BECAUSE OF THREE CHANNEL OFFSET IN THE DATA
ARRAY. THIS IS BECAUSE SPECTRUM # AND LIVETIME ARE STORED IN
ARRAY(1) AND ARRAY(2). ARRAY(3) = FIRST REAL DATA CHANNEL IN
THE SPECTRUM; CHANNEL ZERO.

C
ZERO=ZERO+3.*GAIN
ENCODE(20,806,SND)ZERO
806
FORMAT(' CHNL ZERO E=',F7.3)
CALL SEND(SND) !PRINT CHANNEL ZERO ENERGY
CALL SEND(PCRLF)
HT208 = PKT !SAVE 208 PEAK HEIGHT
ZERO=SZERO
FWHM=GAIN*SQRT(-2.7726/ALFA)
ENCODE(20,807,SND)FWHM
807
FORMAT(' FWHM(208 KEV)=',F5.3)
CALL SEND(SND) !PRINT 208-KeV RESOLUTION

C
C
C
C
CHECK GAIN,ZERO, AND FWHM. IF INVALID, WARN USER.
IF BAD GAIN AND ZERO VALUES ARE DETECTED, RETURN TO
THE BEGINNING - DO NOT COMPLETE THE ANALYSIS.
IF THE 208-KeV RESOLUTION IS GREATER THAN 1.15 KeV,
WARN THE USER BUT CONTINUE THE ANALYSIS.

C
C
C
C
CHECK TO MAKE SURE THE GAIN AND ZERO OF THE SPECTRUM
* ALLOW THE 208-KEV PEAK TO BE INCLUDED IN THE SPECTRUM.

IF(GAIN*NCHNS+ZERO,GT.210.)GOTO 50
CALL SCOPY('BAD GAIN; CHECK POS',SND)
CALL SEND(PCRLF)
CALL SEND(SND) !SEND BAD GAIN MESSAGE
GOTO 5

```

```

C
C CHECK ZERO - SEE IF 120-KeV REGION IS INCLUDED IN THE
C SPECTRUM.
50 IF(ZERO.LT.121.5)GOTO 60
CALL SCOPY('FBAD ZERO; CHECK POS',SND)
CALL SEND(DCRLF)
CALL SEND(SND) !SEND BAD ZERO MESSAGE
GOTO 5

C
C CHECK SHAPC(1 , IF LESS THAN ZERO THIS INDICATES SOMETHING
C WRONG WITH THE 208-KeV PEAK. THE MOST LIKELY PROBLEM IS
C OVERFLOW OF A CHANNEL IN THE 208-KeV PEAK.
60 IF(SHAPC(1).GT.0)GOTO 70
CALL SCOPY('CHECK PEAKS ',SND)
CALL SEND(DCRLF)
CALL SEND(SND)
GOTO 5

C
C CHECK THE PEAK RESOLUTION OF THE 208-KeV PEAK. IF GREATER
C THAN 1.15 KeV, WARN THE USER BUT CONTINUE THE ANALYSIS.
C POOR RESOLUTION INDICATES HIGH COUNT RATE OR BAD POLE ZERO
C ADJUSTMENT - ACTION SHOULD BE TAKEN TO IMPROVE. POOR
C RESOLUTION WILL DEGRADE THE RESULTS OF THE ANALYSIS.
70 IF(FWHM.LT.1.15)GOTO 80
CALL SCOPY('FPOOR RESOLUTION ',SND)
CALL SEND(DCRLF)
CALL SEND(SND)

C
C BEGIN FITTING EACH PEAK GROUPING
80 DO 200 K=1,NGRP

C
C IF THE SPECTRUM INCLUDES THE 300-KeV REGIONS ADJUST GAIN
C FOR ANY NONLINEARITY BEFORE CONTINUING THE ANALYSIS
C
IF(K.NE.8)GOTO 100
STD(2)=375.04
IST=(STD(2)-ZERO)/GAIN-30
IF(IST+60.GT.NCHNS)GOTO 200
DO 90 J=1,60
90 Y(J)=ARRAY(IST+J)
ST=IST
IST=1
CALL MAXVAL(IST,60,JP,K,YMAX,Y)
CALL GFIT2(JPK,ALFA,ATAIL,BTAIL,PKPS,ALFA,ERRF,Y)
GAIN=(STD(2)-208.)/(PKPS+ST-REFCH(2))
REFCH(2)=PKPS+ST
ZERO=STD(2)-GAIN*REFCH(2)
100 IST=(ENSTCH(K)-ZERO)/GAIN
IF(IST.LT.0)GOTO 250
IEND=(ENECH(K)-ZERO)/GAIN+1
SG=SHAPC(1)/GSQ + SHAPC(2)*{IST/GAIN+ZERO/GSQ} + 0.462
ALFA= -2.7726/SG
ST=FLOAT(IST)
START=ST-1.
NUMS=NRG1(K)
IF(NUMS.GT.IST)NUMS=IST-2

```

```

NUME=NBG2(K)
NDPTS=IEND-IST+1

C
C CHECK WHETHER WINDOW IS CONTAINED WITHIN THE SPECTRUM.
C
IF(IST+NDPTS.GT.NCHNS)GOTO 200

C
C CHECK TO MAKE SURE UPPER BACKGROUND WINDOW DOES NOT GO
C BEYOND THE END OF THE SPECTRUM. STRANGE RESULTS WILL BE
C OBTAINED IF ALLOWED TO HAPPEN. IF POSSIBLE READJUST UPPER
C BACKGROUND WINDOW.
C
IEND = IST + NDPTS + NUME + NUMS - NCHNS
IF(IEND.LE.0)GOTO 105 !NO PROBLEM
IF(IEND.GE.10)GOTO 250 !REPORT PROBLEM
NUME = 10 - IEND
NDATA=NDPTS+NUMS+NUME
IST=IST-NUMS-2

105
C
C THE 2 IN THE ABOVE STATEMENT IS REQUIRED BECAUSE THE DATA
C IN THE DATA ARRAY 'ARRAY' IS OFFSET BY TWO CHANNELS FROM
C THAT IN THE ANALYZER MEMORY.
C
NE1=NDPTS+NUMS
DO 110 J=1,NDATA
110 Y(J)=ARRAY(I*IST+J)
C
C STRIP 208-KeV TAIL FROM THE 203-KeV PEAK REGION
C
IF(K.NE.6)GOTO 115
PKLC = (208. - ZERO)/GAIN - IST
EXP1 = ATAIL
EXP2 = BTAIL
CALL STRIP(1,NDATA,PKLC,HT208,ALFA,EXP1,EXP2,Y)

C
C DETERMINE BACKGROUND BEFORE AND AFTER PEAK GROUPING
C
115 CALL AVE(1,NUMS,BGD,AVBG1,Y)
CALL AVE(NE1+1,NDATA,YSUM,AVBG2,Y)

C
C GET LOW-ENERGY BACKGROUND FOR 125-129 GROUP BETWEEN PEAKS
C
IF(K.NE.1)GOTO 120
NEST=2.1/GAIN
FACT=.3/GAIN
NUMSE=FACT*NUMS
CALL AVE(NEST,NEST+NUMSE,BGD,AVBG1,Y)
NUME=(126.6-ZERO)/GAIN-IST+NUMS-2
CALL AVE(NUME,NUME+NUMSE+1,BGD,AVBG3,Y)
IF(AVBG1.GT.AVBG3)AVBG1=AVBG3

C
C REMOVE BACKGROUND FROM PEAK GROUPING
C
120 CALL BKGRD(NUMS+1,NE1,AVBG1,AVBG2,NDPTS,Y,Y)
AVBG=0.5*(AVBG1+AVBG2)
AVBG1=SQRT(AVBG1/NBG1(K)) !BKG ERROR
AVBG2=SQRT(AVBG2/NBG2(K)) !BKG ERROR

C
C GET POSITION OF GROUP REFERENCE PEAK
C BE SURE TO BEGIN SEARCH IN CORRECT POSITION

```

```

C
IST = 1
IF(K,EQ,1)IST=5.35/GAIN
IF(K,EQ,8)IST=7.0/GAIN
CALL MAXVAL(IST,NDPTS,JPK,YMAX,Y)
CALL GFIT2(JPK,ALFA,ATAIL,BTAIL,FKPS,PKT,ERRP,Y)

C
C CHECK THE POSITION OF THE 129.3-KeV PEAK. MAKE SURE THE
C CORRECT REFERENCE PEAK POSITIONS WERE USED.
C
IF(K,NE,1)GOTO 123
REFEN = (START + FKPS)*GAIN + ZERO - ENG(6)
IF(REFEN,LT,0)REFEN = -REFEN
IF(REFEN,GT,1.)GOTO 21

C
C SETUP PEAK REFERENCE FLAGS FOR FITTING
C
123 NF=STR(NSTRPT)-48
DO 130 J=1,NF
NXFLG(J)=STR(NSTRPT+J)-48
PKHT(J)=1.
IF(NXFLG(J),NE,NP)GOTO 125
REFEN=ENG(J+NPKS)
NXFLG(J)=0
125 IF(NXFLG(J),EQ,0)GOTO 130
PKHT(J)=RATIO(NRATPT)
NRATPT=NRATPT + 1
130 CONTINUE
NSTRPT=NSTRPT+NF+1

C
DO 140 I=1,5
SUM(I)=0.
DO 140 J=1,5
ALPHA(I,J)=0.
140

C
C HAVING DETERMINED POSITION OF REFERENCE PEAK FRP GROUPING
C RECALCULATE THE GAIN IN ITS LOCAL REGION BASED ON ITS
C POSITION RELATIVE TO THE 208-KeV PEAK
C
IF((K,EQ,7).OR.(K,EQ,9))GOTO 145
SGAIN=(REFEN-STD(2))/(FKPS+START-1.-REFCH(2))

C
C CALCULATE THE POSITIONS OF ALL PEAKS IN THE GROUPING
C RELATIVE TO THE REFERENCE PEAK FOR THE GROUP.
C
145 DO 150 J=1,NF
PKPOS(J)=(ENG(J+NPKS)-REFEN)/SGAIN+FKPS
150

C
C GENERATE PEAK RESPONSE PROFILE FOR PEAK GROUPING AND STORE
C IN THE 'AX' ARRAY.
C
DO 170 I=1,NDPTS
WT=1.0/(Y(I)+AVEBG)
XI=I
L=1
DO 152 J =1,5
AX(J) = 0.
DO 160 JJ=1,NF
DLTAX=XI-PKPOS(JJ)
DLXSQ=DLTAX*DLTAX
152

```

```

ALFA=-2.7726/(SHAPC(2)*PKPOS(JJ)/GAIN + SG)
EXPNT =ALFA*DLXSQ
CB=0.
IF(DLTAX,GE,0)GOTO 154
EXPNT=BTAIL*DLTAX
153 IF(EXPNT+10.)154,153,153
EXPNT2=EXP(EXPNT)
EXPNT3=EXP(0.4*EXPNT)
CB=ATAIL*EXPNT2*(1.-EXPNT3)
154 IF(NXFLG(JJ).LE,0)GOTO 155
AX(NXFLG(JJ))=AX(NXFLG(JJ))+PKHT(JJ)*(EXP(EXPNT)+CB)
GOTO 160
155 AX(L)=AX(L)+PKHT(JJ)*(EXP(EXPNT)+CB)
L=L+1
160 CONTINUE
NFREE=L-1
DO 165 KK=1,NFREE
SUM(KK)=SUM(KK)+AX(KK)*Y(I)*WT
DO 165 KL=1,NFREE
ALPHA(KK,KL)=ALPHA(KK,KL)+AX(KK)*AX(KL)*WT
165 CONTINUE
170 CONTINUE
C
C INVERT MATRIX TO GET PEAK HEIGHTS
C
CALL MATINV(ALPHA,NFREE,DET)
C
C CALCULATE PEAK HEIGHTS FROM INVERTED MATRIX ELEMENTS
C
DO 180 L=1,NFREE
PT(L)=0.
DO 180 J=1,NFREE
PT(L)=PT(L)+SUM(J)*ALPHA(L,J)
180 CONTINUE
C
C PRINT OUT COLUMN HEADING
C
CALL SEND(PCRLF)
CALL SCOPY('PEAK EN. COUNTS %ER',SND)
CALL SEND(SMD)
C
C CALCULATE PEAK ENERGIES, AREAS, AND ASSOCIATED ERRORS
C
L=1
DO 190 J=1,NP
NPKS=NPKS+1
ERR(NPKS)=0.
ALFA = -2.7726/(SHAPC(2)*PKPOS(J)/GAIN + SG)
NDPTS=SQRT( -2.7726/ALFA)
CB = (AVBG1*NDPTS)**2 + (AVBG2*NDPTS)**2
IF(NXFLG(J).GT,0)GOTO 192
PKHT(J)=PKHT(J)*PT(L)
IF(PKHT(J).EQ,0)PKHT(J)=1.
ERR(NPKS)=SQRT(ALPHA(L,L)*3.1416 * -1./ALFA + CB)
L=L+1
GOTO 193
192 PKHT(J)*PKHT(J)*PT(NXFLG(J))
193 CHAN = PKPOS(J)+START
PKE=(PKPOS(J)-PKPS)*GAIN+REFEN
AREA(NPKS) = PKHT(J)*(1.7724*SQRT(-1./ALFA))

```

```

      IF(ERR(NPKS).EQ.0)GOTO 195
      IF(AREA(NPKS).LE.0)GOTO 194
      ERR(NPKS)=100. * ERR(NPKS)/AREA(NPKS)
194      IF(AREA(NPKS).LE.3.*SQRT(CB))AREA(NPKS)=0.
      C
      C      PRINT OUT PEAK ENERGIES, AREAS AND ERRORS
      C
195      ENCODE(20,930,SND)PKE,AREA(NPKS),ERR(NPKS)
      C
      C      IF PEAK HEIGHT WAS FIXED RELATIVE TO ANOTHER PEAK IN THE
      C      GROUP LABEL IT AS SUCH
      C
      IF(ERR(NPKS).EQ.0)CALL INSERT('FIXD',SND,17,4)
1930      FORMAT(F6.2,1X,F8.0,F5.1)
190      CALL SEND(SND)
200      CONTINUE
      C
      C      DETERMINE IF THE FIRST 7 PEAKS/PEAK GROUPINGS WERE ANALYZED.
      C      IF NOT,REPORT PROBLEM AND STOP THE ANALYSIS.
      C
      IF(K.BE.7)GOTO 251
250      CALL SCOPY('FBAD GAIN OR ZERO ',SND)
      CALL SEND(DCRLF)
      CALL SEND(SND)
      GOTO 5
      C
      C      DIVIDE SELECTED PEAK AREAS BY APPROPRIATE BRANCHING RATIOS
      C      TO GIVE DISINTEGRATIONS. USE THIS INFORMATION TO DETERMINE
      C      RELATIVE DETECTION EFFICIENCY FOR SAMPLE.
      C
251      NGRF = 4          !# OF PEAKS TO BE USED
      NP = 4             !# OF PARAMETERS TO USE IN THE FIT
      YS =.001          !USE TO CONVERT ENERGIES TO MeV
      C
      X(1)=ALOG(ENG(6)*YS)      !FU-239 129.3-KeV
      Y(1)=A129/6.26E-05
      ERROR(1)=ER129
      X(2)=ALOG(ENG(19)*YS)     !FU-241 164.6-KeV
      Y(2)=A165/4.64E-07
      ERROR(2)=ER165
      X(3)=ALOG(ENG(22)*YS)     !FU-239 203.6-KeV
      Y(3)=A203/5.6E-06
      ERROR(3)=ER203
      X(4)=ALOG(ENG(23)*YS)     !FU-241 208.0-KeV
      Y(4)=A208/5.33E-06
      ERROR(4)=ER208
      C
      C      INCLUDE THE 300-KeV PEAK INFORMATION IF GROUPS WERE ANALYZED
      C
      IF(A345.EQ.0)GOTO 255
      X(5)=ALOG(ENG(29)*YS)     !FU-239 345.0-KeV
      Y(5)=A345/5.59E-06
      ERROR(5)=ER345
      X(6)=ALOG(ENG(34)*YS)     !FU-239 375.0-KeV
      Y(6)=A375/1.55E-05
      ERROR(6)=ER375
      C
      NGRF = 6          !#OF PEAKS TO BE USED; A345 NONZERO
      NP = 5            !# OF FREE PARAMETERS TO BE USED IN FIT
      C

```

```

C      CARRY OUT LOG-LOG POLYNOMIAL FIT
C
255    CALL PUFIT(NF,NGRP,IERR)
      IF(IERR.NE.-1)GOTO 257
      CALL SCOPY('FBAD PEAK AREAS',SND)
      CALL SEND(DCRLF)
      CALL SEND(SND)

C
C      RECOMBINE AREAS OF CERTAIN REGIONS FOR COMPLETE ANALYSIS
C
257    AREA(5) = AREA(4) + AREA(5)
      AREA(11) = AREA(11)+AREA(12)
      ERR(17) = SQRT((ERR(15)*AREA(15))**2+(ERR(17)*AREA(17))**2)
      AREA(17) = AREA(15)+AREA(16)+AREA(17)
      ERR(17) = ERR(17)/AREA(17)
      AREA(19) = AREA(19)+AREA(20)

C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      CALCULATE ISOTOPE RATIOS
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      CALCULATE WEIGHTING FACTORS
C
      WTF(1) = DFM(.125,1)/A129
      WTF(1) = (100.*WTF(1)/(A125/A129*SQRT(ER125**2+ER129**2)))**2
      WTF(2) = DFM(.1486,1)/A129
      WTF(2) = (100.*WTF(2)/(A148/A129*SQRT(ER148**2+ER129**2)))**2
      WTF(3) = DFM(.1527,1)/A148
      WTF(3) = (100.*WTF(3)/(A152/A148*SQRT(ER148**2+ER152**2)))**2
      WTF(4) = DFM(.160,1)/A165
      WTF(4) = (100.*WTF(4)/(A160/A165*SQRT(ER160**2+ER165**2)))**2
      WTF(5) = DFM(.204,1)/A208
      WTF(5) = (100.*WTF(5)/(A203/A208*SQRT(ER203**2+ER208**2)))**2

C
C      ZERO ARRAYS
C
      DO 260 J =1,4
        RAT(J) = 0.
        ERR(J) = 0.
        BETA(J) = 0.
      DO 259 JJ =1,4
259    ALPHA(J,JJ) = 0.
      DO 260 K =1,7
        Y(K) = 0.
260    P(K,J) = 0.

C
C      LOAD MATRIX ELEMENTS
C      DFM IS DEFINED AS A FUNCTION WHICH CALCULATES A PSEUDO
C      DISINTEGRATION NUMBER AT THE ENERGY AND FOR THE ISOTOPE
C      SPECIFIED. A RATIO OF THESE VALUES IS EQUIVALENT TO
C      THE RATIO OF THE RELATIVE DETECTION EFFICIENCIES AT THE
C      ENERGIES INDICATED.
C
C      EQUATION FOR THE 125- AND 129-KeV PEAKS
C
      FACT=A129 * DFM(.12529,1)/(A125*DFM(.12929,1))
      P(1,4)= FACT * 4.08E-5
      Y(1) =6.26E-5 -FACT*7.11E-7

C
C      EQUATION FOR THE 148- AND 129-KEV PEAKS

```

```

C
P(2,3)= 1.9E-6 * A129 * DPM(.1486,2)/(A148 * DPM(.12929,2))
Y(2)=6.25E-5
C
C
EQUATION FOR THE 148- AND 152-KeV PEAKS
C
P(3,1)= 9.32E-6
FACT = A152 * DPM(.14857,2)/(A148 * DPM(.1527,2))
P(3,3)= -FACT * 1.90E-6
P(3,4)= -FACT * 7.40E-7
C
C
EQUATION FOR THE 160-KeV PEAK GROUPING AND THE 165-KeV PEAK
C
P(4,2)= -4.02E-6
FACT=A160 * DPM(.1646,2)/(A165 * DPM(.160,2))
P(4,3)=FACT * 4.63E-7 - 6.4E-8
P(4,4)=FACT * 8.99E-7 - 16.67E-7 + 2.32E-7
Y(4) = 7.0E-3
C
C
EQUATION FOR THE 203- AND 208-KeV PEAKS
C
P(5,3)=A203 * DPM(.208,2)/(A208 * DPM(.2036,2))
P(5,4)=P(5,3) * 7.91E-6
P(5,3)=P(5,3) * 5.33E-6
Y(5) = 5.6E-6
C
C
INCLUDE INFORMATION FROM THE 300-KeV PEAKS IF THEY ARE
C
PRESENT IN THE SPECTRUM.
C
IF(A345.ER.0)GOTO 262
C
C
RECOMBINE AREAS BEFORE ANALYZING
C
AREA(24) = AREA(24)+AREA(25)+AREA(26)+AREA(27)
AREA(29) = AREA(28)+AREA(29)
AREA(33)=AREA(32)+AREA(33)
AREA(34)=AREA(34)+AREA(35)
C
WTF(6) = DPM(.333,1)/A345
WTF(6) =(100.*WTF(6)/(A332/A345*SQRT(ER332**2+ER345**2)))*2
WTF(7) = DPM(.370,1)/A375
WTF(7) =(100.*WTF(7)/(A370/A375*SQRT(ER370**2+ER375**2)))*2
C
C
EQUATION FOR THE 330-KeV PEAK GROUPING
C
FACT = A345 * DPM(.333,2)/(A332 * DPM(.345,2))
P(6,3) = FACT * 3.219E-7 ! 2.98E-7 + 2.39E-8
P(6,4)= FACT * 6.45E-6 ! 1.49E-6 + 4.96E-6
Y(6) = 6.62E-7 + 5.59E-6 - FACT * 6.054E-6
C
C
EQUATION FOR THE 370-KeV PEAK GROUPING
C
FACT = A375 * DPM(.370,1)/(A370 * DPM(.375,1))
P(7,3) = FACT * 3.76E-8 ! 1.05E-8 + 2.71E-8
P(7,4) = FACT * 2.693E-6 - 1.38E-6
Y(7) = 1.55E-5
C
C
SETUP MATRIX FOR ISOTOPIC RATIOS
C
262 DO 265 I=1,NGRP+1

```



```

DO 265 J=1,4
BETA(J) = BETA(J) + P(I,J) * Y(I) * WTF(I)
DO 265 K=1,4
265 ALPHA(J,K) = ALPHA(J,K) + P(I,J)*P(I,K)*WTF(I)
C
C INVERT MATRIX TO GET ISOTOPIC RATIOS
C
CALL MATINV(ALPHA,4,DET)
C
C CALCULATE ISOTOPIC RATIOS AND ERRORS FROM THE INVERTED
C MATRIX ELEMENTS
C
DO 270 J =1,4
DO 270 K =1,4
270 ERR(J) = SQRT(ALPHA(J,J))
RAT(J) = RAT(J) + BETA(K) * ALPHA(J,K)
C
C CORRECT RATIOS FOR HALF-LIVES AND MASS DIFFERENCES
C
Z4849 = RAT(1) * .003628
EZ4849= ERR(1)* .003628
Z4049 = RAT(2) * .27252
EZ4049= ERR(2)* .27252
Z4149 = RAT(3) * .0006009
EZ4149= ERR(3) * .0006009
Z5141 = RAT(4) *1./Z4149 * .018025
EZ5141= ERR(4) *1./Z4149 * .018025
EZ5141=Z5141*SQRT((EZ5141/Z5141)**2+(EZ4149/Z4149)**2)

Z2549= A185 * 7.038E08/((.561*IDPM(.186,1)*24119.)
EZ2549 = SQRT(ER185**2 + ER203**2)*Z2549/100.
C
C CALCULATE TIME SINCE SEPARATION OF AM-241 BASED ON THE
C AM-241/PU-241 RATIO.
C
PUAGE=ALOG(.96694*Z5141+1.)/1.2793E-04
EPUAGE=(.96694*EZ5141)/((1.+96694*Z5141)*1.2793E-04)
C
C DETERMINE PU-242 ABUNDANCE AND CALCULATE WEIGHT
C PERCENT FOR EACH PU ISOTOPE. CORRECT PU-241 ABUNDANCE
C FOR DECAY SINCE SEPARATION. NOTE: THIS CORRECTION IS
C NOT COMPLETE SINCE IT IGNORES COOLING TIME.
C
X4149=Z4149/EXP(-PUAGE * 1.322E-4)
C
C CALCULATE PU-242 ABUNDANCE BASED ON R. GUNNINK ALGORITHM
C
IF(P242,NE.0)GOTO 280
P242 = 52. * Z4049 * X4149
PE242=P242
280 CB=1.+Z4849+Z4049+Z4149
P239 =(100.-P242)/CB
PE239=SQRT(EZ4849**2+EZ4049**2+EZ4149**2)*P239
PE239=SQRT((P239/CB)**2+(PE242/(100.-P242))**2)
CB = (PE239/P239)**2
C
C CALCULATE PLUTONIUM ISOTOPIC WT. % ABUNDANCES
C
C
C PU-238 WT. %

```

```

C
P238= Z4849*P239
PE238=SQRT((EZ4849/Z4849)**2+CB)*P238
C
C
PU-240 WT. %
C
P240 =Z4049*P239
PE240=SQRT((EZ4049/Z4049)**2+CB)*P240
C
C
PU-241 WT. %
C
P241 =Z4149*P239
PE241=SQRT((EZ4149/Z4149)**2+CB)*P241
C
C
AM-241 TO TOTAL PLUTONIUM
C
AM241=Z5141*P241
EM241=SQRT((EZ5141/Z5141)**2+(PE241/P241)**2)*AM241
C
C
PRINT OUT THE ISOTOPIC RATIOS AND THE ISOTOPIC
C
C
WEIGHT PERCENTS
C
CALL SEND(PCRLF)
ENCODE(20,900,SND)Z4849
900 FORMAT('238PU/239PU=',F8.6)
CALL SEND(SND)
ENCODE(20,901,SND)EZ4849
901 FORMAT(10X,'+-',F8.6)
CALL SEND(SND)
ENCODE(20,902,SND)Z4049
902 FORMAT('240PU/239PU=',F8.6)
CALL SEND(SND)
ENCODE(20,901,SND)EZ4049
CALL SEND(SND)
ENCODE(20,903,SND)Z4149
903 FORMAT('241PU/239PU=',F8.6)
CALL SEND(SND)
ENCODE(20,901,SND)EZ4149
CALL SEND(SND)
ENCODE(20,904,SND)Z5141
904 FORMAT('241AM/241PU=',F8.6)
CALL SEND(SND)
ENCODE(20,901,SND)EZ5141
CALL SEND(SND)
ENCODE(20,905,SND)Z2549
905 FORMAT('235U/239PU=',F8.6)
CALL SEND(SND)
ENCODE(20,901,SND)EZ2549
CALL SEND(SND)
CALL SCOPY(' TIME SINCE SEP,=',SND)
CALL STRPAD(SND,20)
CALL SEND(SND)
ENCODE(20,906,SND)FUAGE,EFUAGE
906 FORMAT(1X,F7.0,'+-',F4.0,' DAYS')
CALL SEND(SND)
CALL SEND(PCRLF)
C
C
OUTPUT PLUTONIUM WEIGHT PERCENT VALUES
C
ENCODE(20,907,SND)P238,PE238

```

```

907     FORMAT('Z238= ',F6.3,'+-',F5.3)
        CALL SEND(SND)
        ENCODE(20,908,SND)F239,FE239
908     FORMAT('Z239= ',F6.3,'+-',F5.3)
        CALL SEND(SND)
        ENCODE(20,909,SND)F240,FE240
909     FORMAT('Z240= ',F6.3,'+-',F5.3)
        CALL SEND(SND)
        ENCODE(20,910,SND)F241,FE241
910     FORMAT('Z241= ',F6.3,'+-',F5.3)
        CALL SEND(SND)
        IF(F242.NE.FE242)GOTO 285
        ENCODE(20,911,SND)F242
911     FORMAT('Z242= ',F6.3,' CALC. ')
        CALL SEND(SND)
        GOTO 286
285     ENCODE(20,912,SND)F242,FE242
912     FORMAT('Z242= ',F6.3,'+-',F5.3)
        CALL SEND(SND)
286     ENCODE(20,913,SND)AM241,EM241
913     FORMAT('ZAM/PU=',F5.3,'+-',F5.3)
        CALL SEND(SND)
        GOTO 1             !RETURN TO THE BEGINNING
END

```

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
C      VERSION 0 19-JAN-78
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C
C      MAXVAL
C      THIS ROUTINE RETURNS THE POSITION AND VALUE OF THE MAXIMUM VALUE
C      IN A GROUP OF DATA POINTS FROM NS TO NE INCLUSIVE.
      SUBROUTINE MAXVAL (NS,NE,JMAX,YMAX,Y)
      DIMENSION Y(2)
      YMAX = 0.0
      DO 2 I = NS,NE
      IF (Y(I) - YMAX) 2,2,4
4      YMAX = Y(I)
      JMAX = I
2      CONTINUE
      RETURN
      END

```

```

C      MINVAL
C      THIS ROUTINE RETURNS THE POSITION AND VALUE OF THE MINIMUM VALUE
C      IN A GROUP OF DATA POINTS FROM NS TO NE INCLUSIVE.
      SUBROUTINE MINVAL (NS,NE,JMIN,YMIN,Y)
      DIMENSION Y(2)
      YMIN=1.0E38
      DO 4 I=NS,NE
      IF (Y(I)-YMIN)2,4,4
2      JMIN=I
      YMIN=Y(I)
4      CONTINUE
      RETURN
      END

```

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      VERSION 19-JAN-78
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      AVE
C      THIS ROUTINE DETERMINES THE AVERAGE COUNT OF A GROUP OF DATA
C      VALUES FROM NS TO NE INCLUSIVE. IT ALSO RETURNS THE SUM.
      SUBROUTINE AVE (NS,NE,SUM,AV,Y)
      DIMENSION Y(2)
      SUM = 0.0
      SM = NE - NS + 1
      DO 2 I = NS,NE
2      SUM = SUM + Y(I)
      AV = SUM / SM
      RETURN
      END

```

```

C
C*****
C
C      SUBROUTINE GFIT2(L,ALFA,EXP1,EXP2,PKPOS,PKHT,ERR,Y)
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date:   25-MAR-80
C
C      Update: 23-JUL-82
C
C      This subroutine fits the upper half of a peak with a
C      gaussian function after stripping out the tailing contribution.
C      The subroutine returns the peak position, height, and width.
C      An error condition is returned if no valid peak exists within
C      the region indicated or if the statistics are poor. The
C      calling program must then take appropriate action.
C
C      L      = LOCATION WITHIN "Y" ARRAY OF PEAK POSITION
C      ALFA    = PEAK WIDTH PARAMETER; AN APPROXIMATE VALUE SHOULD
C               BE SENT TO THIS ROUTINE. A CALCULATED VALUE IS
C               RETURNED.
C      EXP1    = SHORT-TERM TAIL AMPLITUDE
C      EXP2    = SHORT-TERM TAIL SLOPE
C      PKPOS   = POSITION OF PEAK CALCULATED BY THIS ROUTINE
C      PKHT    = PEAK HEIGHT CALCULATED BY THIS ROUTINE
C      ERR     = ERROR FLAG; SET TO -1 IF AN ERROR CONDITION EXISTS;
C               OTHERWISE THE ERROR ON THE PEAK POSITION
C      Y       = DATA ARRAY
C*****
C
C      DIMENSION Y(2)
C
C      INITIALIZE PARAMETERS
C
C      PKPOS = L           !IN CASE OF EARLY RETURN
C      ERR   = 0           !CLEAR ERROR FLAG
C      I     = SQRT(.693/-ALFA)!EXPECTED CHANNEL HALF-WIDTH
C
C      INITIALIZE SUMS
C
C      SY = 0.0
C      SYY= 0.0
C      SXY= 0.0
C      SXXY= 0.0
C
C      SEARCH FOR THE CHANNEL WITH DATA LESS THAN 1/2 THE
C      MAXIMUM HEIGHT OF THE PEAK.
C
C      Y2=0.5*Y(L)
C      M=1
C      DO 10 J=1,12
C      IF(Y(L+M).LT.Y2)GO TO 11
C      M=M+1
10  CONTINUE
C
C      TEST TO SEE IF A CHANNEL WAS FOUND AND HOW FAR AWAY

```

```

C      IF A CHANNEL WAS NOT FOUND OR IT IS LESS THAN 2 CHANNELS
C      AWAY FROM THE MAXIMUM CHANNEL RETURN WITH AN ERROR CONDITION
C
11     IF(M.GE.I-1.AND.M.LT.12)GOTO 12
      ERR = -1
      RETURN
C
12     C=M*(M+1)/3.
      Y1 = Y(L+1)
      Y2 = Y(L-1)
      TPOS = .5 * (Y2-Y1) / (Y1 - 2. * Y(L) + Y2)
      Y0 = Y(L)
C
C      STRIP OUT THE SHORT-TERM TAIL CONTRIBUTION TO THE PEAK
C
      I=-M
      J=L+I
      XL=I
      DLX = XL - TPOS
      Y1 = Y(J)
      IF (DLX) 20,27,27
      Y1 =Y1-Y0 * EXP1* EXP(EXP2 * DLX) * (1. -EXP(.4*ALFA*DLX*DLX))
27     IF(Y1.LT.0) Y1 = .1
C
C      TAKE THE NATURAL LOGARITHM OF THE NET "Y" DATA; THE RESULT
C      SHOULD BE A PARABOLA. FIT THE RESULTING VALUES TO A PARABOLA
C      TO GET THE PEAK HEIGHT, POSITION, AND WIDTH.
C
      Y1=ALOG(Y1)
      SY=SY+Y1
      SYY=SYY+Y1**2
      SXY=SXY+XL*Y1
      SXXY=SXXY+(XL**2-C)*Y1
99     I=I+1
      IF(I.LE.M)GOTO 100
C
C      COMPUTE THE DIAGONAL ELEMENTS OF X'X
C
      XPX11=2*M+1.
      XPX22=XPX11*C
      XPX33=XPX22*(4*M*(M+1)-3)/15.
C
C      COMPUTE LEAST SQUARES ESTIMATES OF COEFFICIENTS
C
      A0=SY/XPX11
      A1=SXY/XPX22
      ALFA=SXXY/XPX33
C
C      IS THE PARABOLA NEARLY DEGENERATE; IF SO, RETURN WITH ERROR
C
      IF(ABS(A0).GE.1.E-06)GOTO 4
      ERR=-1
      RETURN
C
C      COMPUTE THE COORDINATES OF THE VERTEX
C
4     PKPOS=-0.5*A1/ALFA
      PKHT=A0+0.5*A1*PKPOS-ALFA*C
      ERR=SYY-A0*SY-A1*SXY-ALFA*SXXY
      IF(M.GT.1)ERR=ERR/(2*(M-1))

```



```
PKPOS=PKPOS+L  
PKHT=EXP(PKHT)  
RETURN  
END
```

```

C
C*****
C
C      SUBROUTINE CTAIL(NS,NE,PKPOS,PKHT,ALFA,A,B,Y)
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date:   1-Nov-80
C
C      This subroutine strips the gaussian component from a peak. Any
C      residual remaining at low energies is treated as short-term
C      tailing. The positive data are fit to a straight line by least-
C      squares to give a short-term tail amplitude and slope.
C      NOTE: The peak must have good statistics for this subroutine
C      to give good results.
C
C      NS      = STARTING POSITION OF PEAK IN THE "Y" ARRAY
C      NE      = ENDING POSITION OF PEAK IN THE "Y" ARRAY
C      PKPOS   = PEAK CENTROID IN THE "Y" ARRAY
C      PKHT    = PEAK HEIGHT
C      ALFA    = PEAK WIDTH PARAMETER
C      A       = SHORT-TERM TAIL AMPLITUDE DETERMINED BY THIS ROUTINE
C      B       = SHORT-TERM TAIL SLOPE DETERMINED BY THIS ROUTINE
C               ENTER SUBROUTINE WITH AN INITIAL ESTIMATE FOR THIS
C               PARAMETER
C      Y       = ARRAY OF PEAK DATA
C*****
C
C      DIMENSION Y(2)
C
C      INITIALIZE PARAMETERS
C
C      A       =0.
C      SUMX    =0.
C      SUMX2   =0.
C      SUMY    =0.
C      SUMXY   =0.
C      SUMW    =0.
C
C      CALCULATE POINT AT WHICH THE TAIL SHOULD START TO ROLL-OFF
C      BENEATH THE PEAK BASED ON INITIAL ESTIMATE FOR THE TAIL SLOPE
C
C      XM = B/(0.3*ALFA)
C
C      STRIP OUT THE GAUSSIAN
C
C      K=1
C      DO 10 I=NS,NE
C      XI = I
C      DX = XI -PKPOS
C      IF(DX.GT.XM)GOTO 11
C      DXSQ = DX * DX
C      ADX = ALFA * DXSQ
C      FXX = EXP(ADX)*PKHT      !GAUSSIAN COMPONENT
C      TY = Y(I) - FXX         !RESIDUAL IS TAIL
C      IF(FXX.LT.1.0)GOTO 10
C      IF(TY.LT.1.0)GOTO 10
C      IF(TY.GT.B)GOTO 9       !IS RESIDUAL STILL SIGNIFICANT

```

```

      IF(K.LE.6)GOTO 10
      GOTO 11
9      B=TY-3.*SQRT(TY)
C
C      PERFORM LEAST-SQUARES FIT TO DATA WITH A STRAIGHT LINE
C
      ALY=ALOG(TY)
      SUMX=SUMX+DX/TY
      SUMX2=SUMX2+DX*DX/TY
      SUMY=SUMY+ALY/TY
      SUMXY=SUMXY+DX*ALY/TY
      SUMW=SUMW+1./TY
      K=K+1
10     CONTINUE
C
C      IF LESS THAN 4 POINTS ARE INVOLVED RETURN AND USE  DEFAULT VALUES
C
11     IF(K.LT.4)RETURN
C
      GET DETERMINANT.  IF DETERMINANT IS EQUAL TO ZERO, RETURN WITHOUT
      FURTHER CALCULATION.
C
      DEL =SUMW*SUMX2-SUMX*SUMX
      IF(DEL.EQ.0)RETURN
      A=(SUMX2*SUMY-SUMX*SUMXY)/DEL
      A=EXP(A)/PKHT      !SHORT-TERM TAIL AMPLITUDE
      B=(SUMW*SUMXY-SUMX*SUMY)/DEL      !SHORT-TERM TAIL SLOPE
C
      RETURN
      END

```

```

C      SUBROUTINE BKGRD
C
C*****
C
C      SUBROUTINE BKGRD(NS,NE,AVBG1,AVBG2,L,Y,YNET)
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date: 22-Jul-82
C
C      This subroutine calculates the background distribution
C      beneath the region in the array Y given by NS and NE. The
C      background is a smoothed step function beneath each peak in
C      the region.
C
C      NS      = STARTING CHANNEL OF THE REGION
C      NE      = ENDING CHANNEL OF THE REGION
C      AVBG1   = AVERAGE BACKGROUND IN FRONT OF THE REGION
C      AVBG2   = AVERAGE BACKGROUND IN BACK OF THE REGION
C      L       = NUMBER OF POINTS IN REGION
C      Y       = ARRAY OF DATA FROM WHICH BACKGROUND IS
C               SUBTRACTED
C      YNET    = ARRAY OF DATA WITH BACKGROUND REMOVED
C               NOTE THAT THIS ARRAY IS SHIFTED DOWN FROM
C               THE "Y" ARRAY
C*****
C
C      DIMENSION Y(2),YNET(2)
C
C      XPTS = NE - NS + 1
C      DBG = (AVBG2 - AVBG1) !BACKGROUND STEP
C      SM = 0.0
C      YS = 0.0
C      L = 0
C
C      DO 2 I = NS,NE
C      SM = SM + Y(I)
C      AVEBG=AVBG1+DBG*0.5
C
C      SM= SM - AVEBG*XPTS !APPROXIMATE NET AREA OF REGION
C
C      DO 10 I = NS,NE
C          L = L + 1
C          YS = YS + Y(I) - AVEBG !PARTIAL SUM
C          XBG = AVBG1 + DBG * YS/SM
C
C      IF (DBG.GE.0) XBG = AVBG1 + DBG * L /XPTS
C      YNET(L) = Y(I) - XBG
C
C      RETURN
C      END
10

```

```

C
C*****
C
C      SUBROUTINE STRIP(NS,NE,PKPOS,PKHT,ALFA,EXP1,EXP2,Y)
C      -----
C
C      Author: Ray Gunnink
C
C      Date:   April, 1974
C
C      This subroutine is used to strip a peak or part of a peak from
C      a continuum.
C
C      NS      = STARTING CHANNEL IN Y ARRAY
C      NE      = ENDING CHANNEL IN Y ARRAY
C      PKPOS   = POSITION OF PEAK
C      PKHT    = HEIGHT OF PEAK BEING REMOVED
C      ALFA    = WIDTH PARAMETER OF PEAK
C      EXP1    = SHORT-TERM TAIL AMPLITUDE OF PEAK
C      EXP2    = SHORT-TERM TAIL SLOPE OF PEAK
C      Y       = ARRAY CONTAINING THE DATA ON WHICH COMPUTATION
C               IS PERFORMED
C
C*****
C
C      DIMENSION Y(2)
C
C      DO 10 I =NS,NE
C      XI = I
C      DX = XI - PKPOS
C      DDX= DX * DX
C      ADX=ALFA * DDX
C      FXX = EXP(ADX)
C      EXPN3 = EXP(0.4 * ADX)
C      IF(DX) 2,4,4
C2   EXPN2 = EXP(EXP2 * DX)
C      FXX = FXX + EXP1 * EXPN2 * (1. - EXPN3)
C4   Y(I) = Y(I) - PKHT * FXX
C10  CONTINUE
C      RETURN
C      END

```

```

C
C
C*****
C
C
C      SUBROUTINE MATINV(ARRAY,NORDER,DET)
C      -----
C
C      This subroutine was adapted from the matrix inversion subroutine
C      given in the book, "Data Reduction and Error Analysis for the
C      Physical Sciences" by Philip R. Bevington. This subroutine
C      inverts a square symmetric matrix and calculates its determinant.
C      The input variables are ARRAY and NORDER, and the output variable
C      is DET. The inverted matrix is returned in ARRAY.
C
C      ARRAY  = MATRIX WHOSE INVERSE IS TO BE EVALUATED
C      NORDER = DEGREE OF THE MATRIX
C      DET    = VALUE OF THE DETERMINANT
C
C*****
C
C      DIMENSION IK(6),JK(6)
C      DOUBLE PRECISION ARRAY(6,6),AMAX,SAVE
C
C      DET = 1.
C      DO 100 K =1,NORDER
C
C      FIND LARGEST ELEMENT ARRAY(I,J) IN REST OF MATRIX
C
C      AMAX = 0.
C      DO 30 I =K,NORDER
C      DO 30 J =K,NORDER
C      IF (ABS(AMAX)-ABS(ARRAY(I,J)))24,24,30
C      AMAX = ARRAY(I,J)
C      IK(K) = I
C      JK(K) = J
C      CONTINUE
C
C      INTERCHANGE ROWS AND COLUMNS TO PUT AMAX IN ARRAY(K,K)
C
C      IF (AMAX)41,32,41
C      DET = 0.
C      GOTO 140
C      I = IK(K)
C      IF (I-K)21,51,43
C      DO 50 J =1,NORDER
C      SAVE = ARRAY(K,J)
C      ARRAY(K,J) = ARRAY(I,J)
C      ARRAY(I,J) = -SAVE
C      J = JK(K)
C      IF (J-K) 21,61,53
C      DO 60 I = 1,NORDER
C      SAVE = ARRAY(I,K)
C      ARRAY(I,K) = ARRAY(I,J)
C      ARRAY(I,J) = -SAVE
C
C      ACCUMULATE ELEMENTS OF INVERSE MATRIX
C
C      DO 70 I =1,NORDER
C      IF (I-K)63,70,63

```

```

63     ARRAY(I,K) = -ARRAY(I,K)/AMAX
70     CONTINUE
71     DO 80 I =1,NORDER
        DO 80 J =1,NORDER
            IF(I-K)74,80,74
74         IF(J-K)75,80,75
75         ARRAY(I,J)= ARRAY(I,J) + ARRAY(I,K) * ARRAY(K,J)
80         CONTINUE
81         DO 90 J =1,NORDER
            IF(J-K)83,90,83
83         ARRAY(K,J) = ARRAY(K,J)/AMAX
90         CONTINUE
            ARRAY(K,K) = 1. / AMAX
            DET = DET * AMAX
100        C
        C     RESTORE ORDERING OF MATRIX
        C
101        DO 130 L =1,NORDER
            K = NORDER - L + 1
            J = IK(K)
            IF(J-K)111,111,105
105         DO 110 I =1,NORDER
            SAVE = ARRAY(I,K)
            ARRAY(I,K) = -ARRAY(I,J)
110         ARRAY(I,J) = SAVE
111         I = JK(K)
            IF(I-K)130,130,113
113         DO 120 J =1,NORDER
            SAVE = ARRAY(K,J)
            ARRAY(K,J) = -ARRAY(I,J)
120         ARRAY(I,J) = SAVE
130         CONTINUE
140         RETURN
        END

```

```

C
C
C*****
C
SUBROUTINE PUFIT(NTERMS,NDPTS,IERR)
-----
C
C      Author: Wayne D. Rueter
C
C      Date:   1-NOV-80
C
C      Update: 28-JUL-82
C
C      This subroutine fits a polynomial of order NTERMS to the
C      logarithm of the corrected peak areas as a function
C      of the logarithm of energy using a weighted least-squares
C      technique. The peak areas are corrected for gamma-ray branching
C      ratios. These values give the "relative detection" efficiency
C      for the measurement as a function of energy. Fitting these values
C      to a polynomial allows calculation of the "relative detection"
C      efficiency at any energy. Peak areas from Pu-239 and Pu-241
C      are used in this analysis, therefore, an additional term must
C      be used in the fit to normalize the areas of the two isotopes.
C
C      EFF      = THE CORRECTED PEAK AREAS
C      ERROR     = THE UNCERTAINTY ASSOCIATED WITH EACH PEAK AREA
C      E         = THE ENERGY OF EACH PEAK IN MeV
C      A         = THE POLYNOMIAL COEFFICIENTS DETERMINED BY THE FIT
C      SIGMAA    = THE DIAGONAL TERMS OF THE INVERTED MATRIX WHICH ARE
C                  RELATED TO THE UNCERTAINTY OF EACH COEFFICIENT.
C                  HOWEVER, THE OFF-DIAGONAL MATRIX ELEMENTS ARE NON-ZERO
C                  AND MUST BE INCLUDED IN ANY ERROR ANALYSIS.
C      NDPTS     = THE NUMBER OF DATA POINTS TO BE FITTED
C      NTERMS    = THE NUMBER OF COEFFICIENTS TO USE IN THE FIT
C
C*****
C
COMMON E,EFF,ALPHA,A,ERROR,YFIT,SIGMAA
DIMENSION E(6),EFF(210),ERROR(6),SIGMAA(6),YFIT(6)
DOUBLE PRECISION WEIGHT(6),P(6,6),BETA(6),ALPHA(6,6),
1  A(6),Y(6)
C
C      INITIALIZE ERROR FLAG
C      IERR = -1
C
C      INITIALIZE COEFFICIENTS
C
DO 10 J=1,NDPTS
DO 10 K=1,NTERMS
A(K)=0.
10  P(J,K)=0.
P(1,1)=1.      !PU-239 129.3 KEV
P(2,2)=1.      !PU-241 164.6 KEV
P(3,1)=1.      !PU-239 203.6 KEV
P(4,2)=1.      !PU-241 203.0 KEV
P(5,1)=1.      !PU-239 345.0 KEV
P(6,1)=1.      !PU-239 375.0 KEV
C
C      CALCULATE WEIGHTS AND TAKE LOGARITHM OF CORRECTED PEAK AREAS
C

```



```

20      DO 40 I=1,NDPTS
      SIGMAA(I)=ERROR(I)/100.
      WEIGHT(I)=1./SIGMAA(I)**2
C
C      IF A PEAK AREA IS ZERO, RETURN WITH ERROR FLAG SET
C
      IF(EFF(I),LE.0)RETURN
      Y(I)=DLOG(EFF(I))
C
      P(I,3)=E(I)
      P(I,4)=E(I)**2
      P(I,5)=E(I)**3
40     CONTINUE
C
C      ACCUMULATE MATRICES ALPHA AND BETA
C
      DO 54 J=1,NTERMS
      BETA(J)=0.
      DO 54 K=1,NTERMS
54     ALPHA(J,K)=0.
      DO 66 I=1,NDPTS
      DO 66 J=1,NTERMS
      BETA(J)=BETA(J)+P(I,J)*Y(I)*WEIGHT(I)
      DO 66 K=J,NTERMS
      ALPHA(J,K)=ALPHA(J,K)+P(I,J)*P(I,K)*WEIGHT(I)
66     ALPHA(K,J)=ALPHA(J,K)
C
C      INVERT CURVATURE MATRIX
C
101    CALL MATINV(ALPHA,NTERMS,DET)
C
C      CALCULATE COEFFICIENTS AND THEIR UNCERTAINTIES
C
111    DO 113 J=1,NTERMS
      DO 113 K=1,NTERMS
113    A(J)=A(J)+BETA(K)*ALPHA(J,K)
      DO 124 J=1,5
124    SIGMAA(J)=DSORT(ALPHA(J,J))
      IERR = 0      !CLEAR ERROR FLAG
      RETURN
      END

```

```

C
C
C*****
C
      DOUBLE PRECISION FUNCTION DPM(XX,L)
      -----
C
C      Author: Wayne D. Ruhter
C
C      Date:   1-NOV-80
C
C      This function routine calculates a psuedo "relative detection"
C      efficiency value for the isotope specified by the parameter L at
C      the energy (MeV) specified by XX.  The calculation uses the
C      polynomial coefficients determined by the log-log fit in PUFIT.
C*****
C
      COMMON E,EFF,ALPHA,ANS,ERROR,YFIT,SIGMAA
      DIMENSION E(6),EFF(210),ERROR(6),YFIT(6),SIGMAA(6)
      DOUBLE PRECISION ALPHA(6,6),ANS(6)
C
C
C      DPM = ANS(L)+ANS(3)*DLOG(XX)+ANS(4)*DLOG(XX)**2
C      DPM = DPM + ANS(5) * DLOG(XX)**3
C      DPM = DEXP(DPM)
C
C
C      RETURN
C      END

```

```

C
C*****
C
C      SUBROUTINE RECVR(SND,I)
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date:   1-Nov-80
C
C      Update: 28-Jun-83
C
C      This subroutine receives input from the TM25 terminal and interprets
C      it. The input may either be a numeric entry or a function command
C      to be sent to the Silena MCA.
C
C      A numeric entry is converted to an ASCII array and returned
C      to the calling program in the array SND along with the number
C      of characters entered.
C
C      A function command entry is interpreted in this subroutine and the
C      appropriate action is carried out by this subroutine through the
C      parallel interface. If the START command is entered this subroutine
C      calls the subroutine SIREAD which reads the data from the Silena
C      MCA byte by byte into the array DATA. The subroutine RECVR converts
C      this byte array information into floating-point values and stores
C      them in the array ARRA7. This data array is returned to the calling
C      program through a common statement. The number of channels
C      read from the Silena MCA is returned by I in the call statement.
C
C*****
C
C      LOGICAL*1 SND(2),DATA(12300),STR(46),DCRLF(4),PCRLF(4)
C      COMMON/DATA/ARRAY(2050)
C      COMMON/PURE/STR,DCRLF,PCRLF,ENG,ENSTCH,ENECH,NBG1,NBG2
C      EQUIVALENCE (ARRAY(1),DATA(1))
C
C      IF THIS SUBROUTINE IS CALLED WITH I NOT EQUAL ZERO, THIS IS A
C      FLAG INDICATING THAT AN ENTRY IS TO OCCUR SO PROCEED TO INTERCEPT
C      IT. IF I=0, THEN WAIT FOR AN ENTRY. WHILE WAITING MONITOR THE
C      CLOCK AND IF A MINUTE ELAPSES UPDATE THE DISPLAYED TIME.
C
C      IST=61                                !INITIALIZE TO MONITOR CLOCK
C      IF(I.NE.0)GOTO 9                      !GET READY TO RECEIVE
C      CALL CLOCK(IDAY,IMO,IHR,IST)          !GET TIME TO BEGIN MONITOR
C      I=0                                    !INITIALIZE BYTE COUNTER
C
C      IF(IPEEK("176500).EQ."200)GOTO 11!TM25 HAS CHARACTER?
C      CALL CLOCK(IDAY,IMO,IHR,IMIN)        !GET NEW TIME
C      IF(IMIN.EQ.0.AND. IST.EQ.59)IST=-1!RETURN ON THE HOUR
C      IF(IMIN.GT. IST)RETURN                !IF MINUTE ELAPSES RETURN TO
C      GOTO 10                               !DISPLAY; OTHERWISE KEEP LOOKING
C      ISND=IPEEK("176502)                  !YES, GET CHARACTER
C      IF(ISND.EQ."215)GOTO 19               !CARRIAGE RETURN -END OF NUMERIC INPUT
C      SND(I+1)=ISND--"200                  !STRIP EXTRA BITS
C      IF(SND(I+1).EQ."12)GOTO 10            !EXTRA CHARACTER GO BACK
C      I=I+1                                 !COUNT BYTE
C      GOTO 10                               !LOOK FOR MORE CHARACTERS
C      IF(I.EQ.1)GOTO 200                    !NO NUMERIC ENTRY; LOOK FOR COMMAND

```

```

200      RETURN                                !NUMERIC ENTRY; RETURN
20      I=0                                    !GET CONTROL CHARACTER
      IF(IPEEK("176500).NE."200)GOTO 20!TM25 HAS CHARACTER?
      ISND=IPEEK("176502)                  !YES, READ IT
      I=I+1                                  !COUNT BYTE
      IF(I.EQ.9)GOTO 9
      IF(I.EQ.5)GOTO 25                      !NO MORE; GO BACK AND WAIT
      IF (ISND.GT."320)GOTO 320             !A COMMAND ENTRY; DECIDE WHICH ONE
      IF (ISND.GT."300)GOTO 300
      GOTO 20
25      I=1
      RETURN
320      ISND=ISND-"322
      I = I +4
      IF (ISND)321,322,324

C      A "DATA IN" COMMAND REQUESTED. THE "DATA IN" COMMAND EITHER READS
C      DATA FROM THE TAPE OR BEGINS ACQUISITION OF DATA. MAKE SURE MCA
C      IS IN THE STOP MODE. IF NOT, ISSUE AN ERROR WARNING.
C
C      "164100 IS THE SILENA STATUS REGISTER ADDRESS
C      "164104 IS THE SILENA COMMAND REGISTER ADDRESS
321      ISND="76                                !DATA IN COMMAND
      IF(IPEEK("164100).NE."177760)GOTO 100 !CHECK FOR STOP
      CALL IPOKE("164104,ISND)                !OK, ISSUE COMMAND
      ISND="77                                  !THIS CLEARS ALL COMMAND LINES TO
      CALL IPOKE("164104,ISND)                !RELEASE MCA
      GOTO 20

C      THE "DATA OUT" COMMAND CAUSES THE DATA IN THE MCA MEMORY TO BE
C      WRITTEN ONTO THE CASSETTE TAPE. THE MCA MUST BE IN THE STOP
C      MODE BEFORE STARTING OTHERWISE ISSUE A WARNING.
322      ISND="75                                !DATA OUT COMMAND
      IF(IPEEK("164100).NE."177760)GOTO 100!CHECK FOR STOP
      CALL IPOKE("164104,ISND)                !OK, ISSUE COMMAND

C      WAIT FOR MCA TO COMPLETE WRITING TO TAPE
C
21      IF(IPEEK("164100).NE."177764)GOTO 21
      GOTO 20

C      NO COMMAND FOUND. MAKE SURE MCA IS RELEASED FROM PROCESSOR
C      BY CLEARING ALL COMMAND LINES.
C
324      ISND="77                                !FREE ANALYZER FROM PROCESSOR
      CALL IPOKE("164104,ISND)
      I=1
      RETURN

C
300      IF(I.GT.2)GOTO 20
      I = I + 4
      IF (ISND.NE."301)GOTO 301

C      THE "START" COMMAND WAS ENTERED. READ IN DATA FROM THE SILENA
C      MCA AND RETURN TO MAIN PROGRAM FOR DATA ANALYSIS.
C
      CALL SIREAD(DATA,IER)                  !START COMMAND
C

```

```

C      IF AN ERROR IS FOUND IN THE READING PROCESS THE SUBROUTINE
C      SIREAD RETURNS WITH IER=0 OTHERWISE IT RETURNS WITH IER=
C      THE NUMBER OF BYTES TRANSFERRED FROM THE MCA.
C
C      IF(IER.EQ.0)GOTO 100
C
C      CONVERT BYTE ARRAY "DATA" INTO FLOATING-POINT VALUES AND STORE
C      IN THE ARRAY "ARRAY". RETURN WITH THE NUMBER OF CHANNELS IN
C      THE ARRAY.
C
C      K=0
C      DO 350 J=1,IER,6
C      K=K+1
350 1  ARRAY(K)=DATA(J)*100000.+DATA(J+1)*10000.+DATA(J+2)*1000.
C      +DATA(J+3)*100.+DATA(J+4)*10.+DATA(J+5)
C      I=IER/6
C      RETURN
C
C      ISND=ISND-"304
301  IF(ISND)302,304,310
C
C      DISPLAY COMMAND REQUESTED
C
C      ISND="73
302  CALL IPOKE("164104,ISND)      !DISPLAY COMMAND
C      GOTO 20                      !ISSUE COMMAND
C
C      STOP COMMAND REQUESTED
C
C      ISND="57
304  CALL IPOKE("164104,ISND)      !STOP COMMAND
C      GOTO 20                      !ISSUE COMMAND
C
C      ERASE DATA COMMAND REQUESTED. THE MCA MUST BE IN DISPLAY
C      MODE OTHERWISE ISSUE WARNING.
C
C      ISND="67
310  IF(IPEEK("164100).NE."177764)GOTO 100      !ERASE COMMAND
C      CALL IPOKE("164104,ISND)      !OK, ISSUE COMMAND
C      GOTO 20
C
C      INCORRECT COMMAND OR FAILURE TO READ DATA HAS OCCURRED--
C      ISSUE WARNING TO USER ON THE DISPLAY.
C      CALL SEND(DCRLF)
100  CALL SCOPY('FCOMMAND ERROR',DATA)
C      CALL SEND(DATA)
C      GOTO 9                      !RETURN FOR NEW ENTRY FROM TM25
C      END

```

```

;
; .TITLE SIREAD
; *****
;
; .GLOBL SIREAD
; -----
; .PSECT USER$I RW,I,LCL,REL,CON
;
; Author: Wayne D. Ruhter
;
; Date: 22-JUN-83
;
; This MACRO subroutine carries out the transfer of eight-bit
; bytes from a Silena MCA to the Portable microcomputer. The
; transfer is through a Parallel interface in the Silena and an
; ADAC TTL I/O board in the Portable microcomputer.
;
; *****
;
;
; DEVICE REGISTERS
;
STR= 164100 ;SILENA STATUS REGISTER ADDRESS
DAR= 164102 ;DATA REGISTER ADDRESS
SIC= 164104 ;SILENA COMMAND REGISTER ADDRESS
;
;
;
;
SIREAD: MOV (R5)+,R0 ;GET NO. OF ARGS
        MOV (R5)+,R4 ;BUFFER POINTER
        CLR CHRCTR ;SET COUNTER TO 0
        BITB #4,STR ;ANALYZER IN DISPLAY?
        BEQ ERROR ;NO, REPORT ERROR
        MOVB #57,SIC ;YES, PUT ANALYZER IN STOP
WAIT1: BITB #4,STR
        BNE WAIT1 ;WAIT FOR STOP
        MOVB #37,SIC ;SET TO REMOTE
OUT: MOVB #275,SIC ;START DATA OUT
READY: BITB #10,STR ;TEST DATA READY
        BEQ READY ;NOT READY
        MOVB DAR,R1 ;READ DATA REGISTER
        MOVB #175,SIC ;RESET DATA READY
        CMPB #377,R1 ;INTENSIFICATION CHARACTER?
                     ;IF YES, GET NEXT CHARACTER
        BEQ TEST1 ;LOOK FOR CONTROL CHARACTER
        CMPB #12,R1
        BEQ TEST1 ;LOOK FOR CONTROL CHARACTER
        CMPB #215,R1
        BEQ TEST1 ;LOOK FOR CONTROL CHARACTER
        CMPB #240,R1
        BEQ TEST1 ;LOOK FOR CONTROL CHARACTER
        CMPB #33,R1
        BEQ TEST1 ;LOOK FOR CONTROL CHARACTER
        CMPB #333,R1 ;END OF SPECTRUM CHAR?
        BEQ DONE ;YES-TAKE ACTION
        BICB #360,R1 ;NO, REMOVE EXTRA BITS
        MOVB R1,(R4)+ ;STORE IN BUFFER
        INC CHRCTR ;COUNT IT
TEST1: JSR PC,TEST ;TEST IF MCA IS READ FOR NEW REQUEST

```

```

BR OUT
DONE:  MOVW #50,R3      ;READ REMAINING CHARACTERS
      JSR PC,TEST      ;TEST IF MCA IS READ FOR NEW REQUEST
OUT1:  MOVW #275,SIC    ;THERE ARE 40 TRAILING CHARACTERS AT THE END
RDY2:  BITB #10,STR
      BEQ RDY2
      MOVW #175,SIC
      JSR PC,TEST      ;TEST IF MCA IS READ FOR NEW REQUEST
      SOB R3,OUT1
      MOVW #275,SIC
      MOVW #77,SIC
ERROR: MOV CHRCTR,@(R5);SEND BACK THE # OF CHARACTERS
      RTS PC
;
;      TEST WHETHER MCA DATA READY STATUS IS CLEARED
;
TEST:  BITB #10,STR
      RNE TEST
      RTS PC
;
;
;      THIS PSECT DEFINITION FORCES THE VARIABLE "CHRCTR" INTO
;      THE RAM MEMORY. "CHRCTR" COUNTS THE NUMBER OF VALID CHARACTERS
;      TRANSMITTED FROM THE SILENA MCA.
;
.PSECT USER$D          RW,D,LCL,REL,CON
CHRCTR: .WORD 0.
.END

```

```

C
C
C*****
C
C      SUBROUTINE SEND(SND)
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date: 1-NOV-80
C
C      This subroutine sends the ASCII characters contained in the
C      array SND to either the alphanumeric display or the printer.
C      The first character in the array determines the device and
C      the type of output. If the first character is one of the
C      following the indicated action is taken.
C
C      "C"- 20 CHARACTERS TO DISPLAY
C      "D"- 13 CHARACTERS TO DISPLAY
C      "E"- 7 NUMERIC CHARACTERS TO DISPLAY
C      "F"- 20 CHARACTERS TO DISPLAY IN A FLASHING MODE
C              THIS IS USED FOR ERROR MESSAGES
C
C      If the first character is other than those above the output
C      is to the 20-character thermal printer.
C
C*****
C      LOGICAL*1 SND(1),PSND(1)
C
C      I=2                                !START WITH SECOND CHARACTER
C      NSND="0"                            !INITIALIZE FLASHING FLAG
C      NCHR = 7                            !INITIALIZE TO 7 CHARACTERS
C      IF(SND(1).EQ."103")GOTO 9           !DISPLAY 20 CHARACTERS
C      IF(SND(1).EQ."105")GOTO 10          !DISPLAY NUMBER
C      IF(SND(1).EQ."106")GOTO 8          !DISPLAY FLASHING MESS.
C      NCHR=13                             !13 CHARACTERS FOR MESSAGE
C      IF(SND(1).EQ."104")GOTO 10          !DISPLAY MESSAGE
C      GOTO 20                             !PRINT MESSAGE
C
C      IF THE FIRST CHARACTER WAS AN "F" SET NSND="200. THIS SETS
C      THE EIGHTH BIT IN THE OUTPUT CHARACTER WHICH FLAGS THE DISPLAY
C      THAT THE CHARACTER IS TO BE FLASHED.
C
C      8      NSND="200"                    !FLASH CHARACTERS
C      9      NCHR=20                        !20 CHARACTERS
C      10     IF(IPEEK("176514").NE."200")GOTO 10!DISPLAY READY?
C      ISND=SND(1)+NSND                    !YES, PREPARE CHARACTER
C      CALL IPOKE("176516,ISND)            !SEND CHARACTER
C      IF(SND(1).EQ."12")GOTO 40           !IF LINE FEED, RETURN
C      IF(I.EQ.NCHR)GOTO 40                !ALL CHARACTERS-RETURN
C      I=I+1                               !COUNT CHARACTER
C      GOTO 10                             !LOOK FOR MORE
C
C      OUTPUT TO PRINTER
C
C      20     I=1                          !START WITH FIRST CHARACTER
C      21     IF(IPEEK("176524").NE."200")GOTO 20!PRINTER READY?
C      ISND=SND(I)                          !YES, PREPARE CHARACTER
C      IF(ISND.EQ."12")GOTO 40             !IF LINE FEED-RETURN

```



```

C
C      A SHORT DELAY BETWEEN SENDING EACH CHARACTER TO THE PRINTER
C      TO GIVE THE PRINTER TIME TO TEST AND LOAD THE CHARACTER INTO
C      THE PRINTER BUFFER.
C
      DO 1000 K=1,10                !DELAY FOR CHARACTER
1000  CONTINUE
      CALL IPoke("17&526,ISND)      !SEND CHARACTER TO PRINTER BUFFER
      IF(I.EQ.20)GOTO 30             !BUFFER FULL-GOTO 30
      I=I+1                          !COUNT CHARACTER
      GOTO 21                        !GO BACK FOR MORE

C
C
30      ISND="15                     !CARRIAGE RETURN IS FLAG TO PRINTER
      DO 1001 K=1,30                 !TO PRINT BUFFER
1001  CONTINUE
      CALL IPoke("17&526,ISND)      !SEND OUT BUFFER

C
C      A DELAY IS NECESSARY HERE TO WAIT FOR PRINTER TO PRINT THE
C      BUFFER.
40      DO 1002 KK=1,15000           !WAIT FOR BUFFER TO EMPTY
1002  CONTINUE
C
      RETURN
      END

```

```

C
C
C*****G*****:*****
C
C      SUBROUTINE SETCLK
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date:   28-May-82
C
C      Update: 29-Jul-83
C
C      This subroutine sets the TCU-50BYR clock registers from the
C      information given by the user on the TM-25 terminal. The
C      subroutine uses the routines SEND and RECV to interrogate
C      the user for the time information. The information is read
C      in ASCII from the TM-25 terminal and stored in the array NBR.
C      The function IBNCD converts a binary byte into two BCD integers.
C
C*****G*****:***
C
C      LOGICAL*1 NBR(20),STR(46),DCRLF(4),PCRLF(4)
C      COMMON/PURE/STR,DCRLF,PCRLF,ENG,ENSTCH,ENECH,NBG1,NBG2
C
C      GET THE HOUR AND MINUTE FROM THE TM-25 TERMINAL.
C
C      CALL SCOPY('CENTER TIME(HH.MM) ',NBR)
C      CALL SEND(DCRLF)
C      CALL SEND(NBR)
C      CALL RECV(NBR,1)
C      CALL INDEX(NBR,'.',ICHR)
C      DECODE(ICHR-1,2,NBR)IHR
C      DECODE(1-ICHR,2,NBR(ICHR+1))IMN
C      FORMAT(I2)
C
C      SET TCU-50BYR CONTROL WORD FOR UPDATE OF THE SECONDS REGISTER
C      AND ENABLE WRITE.
C      THE SECONDS REGISTER IS SET TO ZERO
C
C      CALL IPOKE("160772","4002")
C      CALL IPOKE("160770","0")
C
C      SET MINUTE CLOCK REGISTER
C      CONVERT BINARY MINUTES TO BCD FIRST
C
C      IVL = IBNCD(IMN)
C      CALL IPOKE("160772","4003")
C      CALL IPOKE("160770,IVL)
C
C      SET HOUR CLOCK REGISTER
C
C      IVL = IBNCD(IHR)
C      CALL IPOKE("160772","4004")
C      CALL IPOKE("160770,IVL)
C
C      GET DAY OF MONTH AND MONTH FROM TM-25 TERMINAL
C
C      CALL SCOPY('CENTER DATE(DD.MM) ',NBR)
C      CALL SEND(DCRLF)

```

```

CALL SEND(NBR)
CALL RECV(NBR,I)
CALL INDEX(NBR,'.',,ICHR)
DECODE(ICHR-1,2,NBR)IDAY
DECODE(I-ICHR,2,NBR(ICHR+1))IMO

C
C   SET TCU-50DYR CONTROL WORD FOR DAY OF MONTH UPDATE
C
C   CALL IPOKE("160772,"4006)
C
C   SET DAY OF MONTH CLOCK REGISTER
C
C   IVL = IBNBCD(IDAY)
C   CALL IPOKE("160770,IVL)
C
C   SET MONTH CLOCK REGISTER
C
C   IVL = IBNBCD(IMO)
C   CALL IPOKE("160772,"4007)
C   CALL IPOKE("160770,IVL)
C
C   GET YEAR FROM TM-25 TERMINAL AND STORE IN TCU-50DYR CMOS
C   RAM. THE YEAR IS UPDATED BY SOFTWARE (SEE THE SUBROUTINE YEAR)
C   RATHER THAN HARDWARE. THIS NECESSITATES THAT THE CURRENT
C   MONTH ALSO BE STORED IN RAM.
C
C   CALL SCOPY(/CENTER YEAR(YY) ',NBR)
C   CALL SEND(DCRLF)
C   CALL SEND(NBR)
C   CALL RECV(NBR,I)
C   DECODE(I,2,NBR)IYR
C   CALL SEND(DCRLF)
C
C   PUT YEAR IN CMOS RAM
C
C   CALL IPOKE("160772,"7777)      !SELECT clock RAM ADDRESS
C   IVL =IBNBCD(IYR)                !AND ENABLE WRITE
C   CALL IPOKE("160770,IVL)
C
C   SET CURRENT MONTH ALSO
C
C   CALL IPOKE("160772,"7776)
C   IVL =IBNBCD(IMO)
C   CALL IPOKE("160770,IVL)
C
C   RETURN
C   END
C
C*)*****
C
C   FUNCTION TO CONVERT A BINARY VALUE TO TWO BCD INTEGERS
C   CONTAINED IN ONE BYTE.
C
C*****
C
C   FUNCTION IBNBCD(IVL)
C
C   IONE = MOD(IVL,10)
C   ITEN = (IVL-IONE)/10

```

```
C      IBNBCD = 16*ITEN + IONE  
      RETURN  
      END
```

```

*****
SUBROUTINE CLOCK(IDAY,IMO,IHR,IMIN)
-----
Author: Wayne D. Ruten
Date: 28-May-1982
Update: 29-JUN-83

Subroutine to read the day,month,hour, and minute from the
Digital Pathways Inc. TCU-50DYR clock board.

IDAY = INTEGER VALUE OF DAY
IMO = INTEGER VALUE OF MONTH
IHR = INTEGER VALUE OF HOUR
IMIN = INTEGER VALUE OF MINUTE
*****

GET MINUTE VALUE FIRST; SET CONTROL REGISTER FOR AUTO INCREMENT
"160772 IS THE ADDRESS OF THE TCU-50DYR CONTROL WORD
"160770 IS THE ADDRESS OF THE TCU-50DYR DATA REGISTER
CALL IPoke("160772,"3)
IMIN = IPeek("160770)
IMIN = IBcDBN(IMIN)
CALL IPoke("160772,"4)
IHR = IPeek("160770)
IHR = IBcDBN(IHR)
GET DAY OF MONTH
CALL IPoke("160772,"6)
IVL = IPeek("160770)
IDAY = IBcDBN(IVL)
GET MONTH
CALL IPoke("160772,"7)
IVL = IPeek("160770)
IMO = IBcDBN(IVL)
RETURN
END
*****

```

```

C
C      FUNCTION TO CONVERT 2 BCD DIGITS CONTAINED IN ONE BYTE
C      TO A BINARY NUMBER.
C
C*****
C
C      FUNCTION IBCDBN(IVAL)
C      -----
C
C      ITEN = (IVAL.AND."360)
C      ITEN = ITEN/16
C      IONE = (IVAL.AND."17)
C      IBCDBN = IONE + 10 * ITEN
C
C      RETURN
C      END

```

```

C
C
C*****
C
C      SUBROUTINE YEAR(IYR)
C      -----
C
C      Author: Wayne D. Ruhter
C
C      Date:   28-May-82
C
C      Update: 29-Jul-83
C
C      This subroutine reads the year from the TCU-50DYR CMOS RAM.
C      This subroutine is responsible for maintaining the psuedo year
C      counter in the TCU-50DYR's battery supported CMOS RAM. It is
C      necessary to run this routine at least once per year to ensure
C      that year counter is bumped appropriately. Each time this
C      routine is used the current month is stored in the CMOS RAM.
C*****
C
C      GET YEAR FROM CMOS RAM
C      "160772 IS THE ADDRESS OF THE TCU-50DYR CONTROL WORD
C      "160770 IS THE ADDRESS OF THE TCU-50DYR DATA REGISTER
C      "3777 SELECTS THE YEAR FROM THE CMOS RAM
C
C      THE FUNCTION IBCDBN CONVERTS A BCD NUMBER TO BINARY
C      (See listing for CLOCK subroutine.)
C
C      CALL IPOKE("160772","3777")
C      IVL = IPEEK("160770")
C      IYR = IBCDBN(IVL)
C
C      GET LAST MONTH FROM CMOS RAM
C
C      CALL IPOKE("160772","3776")
C      LMO = IPEEK("160770")
C
C      GET CURRENT MONTH FROM TCU-50DYR CLOCK
C
C      CALL IPOKE("160772","7")
C      IMO = IPEEK("160770")
C
C      STORE CURRENT MONTH IN CMOS RAM
C
C      CALL IPOKE("160772","7776")
C      CALL IPOKE("160770,IMO)
C
C      COMPARE LAST MONTH AGAINST CURRENT MONTH
C      IF CURRENT MONTH IS LESS THAN LAST MONTH, INCREMENT
C      THE YEAR AND STORE THE RESULT IN THE CMOS RAM.
C
C      IF(IMO.GE.LMO)RETURN
C
C      INCREMENT YEAR
C
C      IYR = IYR + 1

```

```

C      "7777 LOADED INTO THE CONTROL WORD ENABLES WRITING INTO
C      THE YEAR ADDRESS OF THE CMOS RAM.
C
C      CALL IPOKE("160772,"7777)
C
C      THE FUNCTION IBNBCD CONVERTS A BINARY NUMBER TO A BCD NUMBER
C
C      IVL = IBNBCD(IYR)
C      CALL IPOKE("160770,IVL)
C      RETURN
C      END

```



```

;      MACRO CODE TO ORDER PSECTS WITH PURE CODE FIRST
;      IMPURE CODE AND DATA LAST
;      PURE CODE AND DATA SECTIONS FOLLOW
;
      .PSECT  OTS$I                      RW,I,LCL,REL,CON
      .PSECT  OTS$P                      RW,D,GBL,REL,OVR
      .PSECT  SYS$I      RW,I,LCL,REL,CON
      .PSECT  USER$I    RW,I,LCL,REL,CON
      .PSECT  $CODE      RW,I,LCL,REL,CON
      .PSECT  OTS$D      RW,I,LCL,REL,CON
      .PSECT  SYS$D      RW,I,LCL,REL,CON
      .PSECT  $DATAP     RW,D,LCL,REL,CON
      .PSECT  PURE       RW,D,GBL,REL,OVR
      .PSECT  OTS$D      RW,D,LCL,REL,CON
;
;      IMPURE CODE AND DATA PSECTS FOLLOW
;
      .PSECT  OTS$S      RW,D,LCL,REL,CON
      .PSECT  SYS$S      RW,D,LCL,REL,CON
      .PSECT  $DATA      RW,D,LCL,REL,CON
      .PSECT  USER$D     RW,D,LCL,REL,CON
      .PSECT  .$$$$.     RW,D,GBL,REL,OVR
      .PSECT  DATA      RW,D,GBL,REL,OVR
      .PSECT  $STACK     RW,D,LCL,REL,CON
      .PSECT  $STKST     RW,D,LCL,REL,CON
;
.END

```

```

!This is a command file for linking the IAEAPU program for PROM
!application.  The program is linked with stand-alone RT-11 SIMRT.
!A LDA format file is produced as the output file to be loaded
!into PROM.  PULIB is a library file containing the subroutines
!AVE, MAXVAL, and MINVAL.
LINK/MAP:MAP.OUT/EXECUTE:IAEAPU.LDA/BOUNDARY:100000/LDA/INCLUDE
PORDR,IAEAPU,PULIB/PROMPT
MATINV,GFIT2,BKGRD
PUFIT,CTAIL,STRIP,DFM
SEND,RECVR,SIREAD
SETCLK,CLOCK,YEAR
//
OTS$D
$SIMRT

```

RT-11 LINK V05.04A Load Map
XIAEAP.LDA Title: .MAIN. Ident: FORV02

Section	Addr	Size	Global	Value	Global	Value	Global	Value
. ABS.	000000	001000	(RW,I,GBL,ABS,OVR)					
			\$USRSW	000000	\$RF2A1	000000	\$NLCHN	000006
			\$HRDWR	000006	\$SYSV\$	000011	\$WASIZ	000152
			\$LRECL	000210	\$TRACE	004737		
OTS\$I	001000	026642	(RW,I,LCL,REL,CON)					
			\$\$OTSI	001000	ADF\$IM	001000	ADF\$PM	001006
			ADF\$MM	001012	ADF\$SM	001022	SUF\$IM	001042
			SUF\$SM	001050	SUF\$PM	001100	SUF\$MM	001104
			ADF\$IP	001134	ADF\$PP	001142	ADF\$MP	001146
			ADF\$SP	001156	SUF\$IP	001176	SUF\$SP	001204
			SUF\$PP	001234	SUF\$MP	001240	ALOG10	001266
			ALOG	001272	\$CVTFC	001646	\$CVTFD	001646
			CCF\$	001660	CCF\$	001660	\$RC	001660
			\$RD	001660	\$CVTFB	001676	\$CVTFI	001676
			\$CVTCB	001712	\$CVTCI	001712	\$CVTDB	001712
			\$CVTDI	001712	CIC\$	001724	CID\$	001724
			CLC\$	001724	CLD\$	001724	\$DI	001724
			CIF\$	001734	CLF\$	001734	\$RI	001734
			CLL\$	002042	CLI\$	002046	\$CVTIF	002050
			\$CVTIC	002064	\$CVTID	002064	CCI\$	002076
			CID\$	002076	\$IC	002076	\$ID	002076
			CFI\$	002112	\$IR	002112	\$CVTDF	002176
			CFD\$	002210	\$DR	002210	RCI\$	002242
			GC0\$	003256	FC0\$	003264	EC0\$	003270
			DC0\$	003276	SUD\$PS	004220	SUD\$MS	004224
			ADD\$PS	004244	ADD\$MS	004250	ADD\$IS	004270
			SUD\$IS	004302	\$ADD	004314	\$SUBD	004330
			SUD\$SS	004342	\$SD	004342	ADD\$SS	004346
			\$ADD	004346	DID\$PS	005426	DID\$MS	005432
			DID\$IS	005452	\$DIVD	005464	DID\$SS	005476
			\$DVD	005476	DEXP	006404	DLOG10	007310
			DLOG	007314	MUD\$PS	010114	MUD\$MS	010120
			MUD\$IS	010140	\$MULD	010152	MUD\$SS	010164
			\$MLD	010164	DSQRT	011216	EXP	011422
			ADF\$IS	011762	\$ADDF	011770	ADF\$SS	012002
			\$ADR	012002	ADF\$PS	012006	ADF\$MS	012012
			SUF\$IS	012026	\$SUBF	012034	SUF\$SS	012046
			\$SBR	012046	SUF\$PS	012052	SUF\$MS	012056
			DIF\$PS	012072	DIF\$MS	012076	DIF\$IS	012110
			\$DIVF	012116	DIF\$SS	012130	\$DVR	012130
			MUF\$PS	012134	MUF\$MS	012140	MUF\$IS	012152
			\$MULF	012160	MUF\$SS	012172	\$MLR	012172
			DII\$PS	012176	DII\$MS	012204	DII\$IS	012210
			DII\$SS	012212	\$DVI	012212	MUI\$PS	012234
			MUI\$MS	012242	MUI\$IS	012246	MUI\$SS	012250
			\$MLI	012250	\$OTI	012316	\$\$OTI	012320
			\$\$SET	014200	SQRT	014474	\$XDI	014624
			XDI\$	014636	\$PWDI	014636	\$XFI	015234
			XFI\$	015246	\$PWRI	015246	ABS	015524
			AIF\$	015542	IOR\$	015556	AND\$	015562
			EQV\$	015570	XOR\$	015572	NMI\$1M	015606
			NMI\$1I	015620	BLE\$	015630	BEQ\$	015632
			BGT\$	015640	BGE\$	015642	BRA\$	015644
			BNE\$	015650	BLT\$	015652	CAI\$	015662
			CAL\$	015670	CMF\$PS	015720	CMF\$MS	015724

CMF\$IS	015740	\$CMPF	015746	CMF\$SS	015760
\$CMR	015760	CMF\$PI	015772	CMF\$MI	015776
CMF\$II	016006	CMF\$SI	016012	CMF\$PP	016024
CMF\$MP	016030	CMF\$IP	016040	CMF\$SP	016044
CMF\$FM	016054	CMF\$MM	016060	CMF\$IM	016070
CMF\$SM	016074	\$CVTBC	016126	\$CVTBD	016126
CCL\$	016140	CDL\$	016140	\$CVTBF	016150
CFL\$	016162	OCI\$	016172	ICI\$	016200
\$ECI	016214	OCO\$	016374	ICO\$	016402
CPL\$SM	016600	CPI\$SM	016604	CPF\$SM	016610
CPD\$SM	016622	MOD\$IS	016634	MOD\$OM	016646
MOD\$OP	016652	MOD\$OA	016654	MOD\$IP	016662
MOD\$IM	016670	MOD\$IA	016700	MOD\$SA	016714
MOD\$SS	016734	MOD\$PS	016740	MOD\$MS	016744
MOD\$VS	016746	MOD\$PP	016764	MOD\$MP	016770
MOD\$PM	016776	MOD\$MM	017002	MOD\$FA	017010
MOD\$MA	017014	MOD\$SP	017032	MOD\$SM	017036
MOD\$RS	017052	MOD\$RM	017064	MOD\$RA	017066
MOD\$RP	017106	ENC\$	017112	\$ENC	017116
DEC\$	017124	\$DEC	017130	\$CHKR	017314
\$IOEXI	017340	\$EOL	017366	EOL\$	017370
MOF\$SS	017504	MOF\$IS	017516	MOF\$OS	017524
MOF\$MS	017532	MOF\$PS	017544	MOF\$SA	017550
MOF\$SM	017564	MOF\$SP	017574	MOF\$IM	017600
MOF\$IP	017612	MOF\$OM	017620	MOF\$OA	017630
MOF\$OP	017634	MOF\$MM	017640	MOF\$MA	017652
MOF\$MP	017660	MOF\$PM	017666	MOF\$PA	017672
MOF\$PP	017676	MOF\$RS	017702	MOF\$RM	017710
MOF\$RA	017720	MOF\$RP	017724	\$SIMRT	020116
\$TKS	020746	\$TKB	020750	\$TPS	020752
\$TPB	020754	\$ERRTB	022012	\$SHORT	022012
\$ERRS	022117	\$FIO	023176	\$FIO	023202
NGD\$S	024332	NGF\$S	024332	NGD\$M	024344
NGF\$M	024344	NGD\$P	024360	NGF\$P	024360
NGD\$A	024364	NGF\$A	024364	ADI\$SS	024370
ADI\$SA	024374	ADI\$SM	024400	ADI\$IS	024404
ADI\$IA	024410	ADI\$IM	024414	ADI\$MS	024420
ADI\$MA	024424	ADI\$MM	024430	CMI\$SS	024434
CMI\$SI	024440	CMI\$SM	024444	CMI\$IS	024450
CMI\$II	024454	CMI\$IM	024460	CMI\$MS	024464
CMI\$MI	024470	CMI\$MM	024474	MOI\$RS	024500
MOI\$RS	024500	MOI\$RM	024504	MOI\$RP	024510
MOI\$RA	024512	MOI\$SS	024516	MOI\$SS	024516
MOI\$SM	024522	MOI\$SA	024526	MOI\$IS	024532
MOI\$IS	024532	REL\$	024532	MOI\$IM	024536
MOI\$IA	024542	MOI\$MS	024546	MOI\$MM	024552
MOI\$MA	024556	MOI\$OS	024562	MOI\$OM	024566
MOI\$OA	024572	MOI\$IS	024576	MOI\$IN	024604
MOI\$IA	024612	ICI\$S	024620	ICI\$M	024624
ICI\$P	024630	ICI\$A	024632	DCI\$S	024636
DCI\$M	024642	DCI\$P	024646	DCI\$A	024650
NGI\$S	024654	NGI\$M	024660	NGI\$P	024664
NGI\$A	024666	ADI\$IP	024672	ADI\$SP	024674
ADI\$PP	024702	ADI\$MF	024706	ADI\$PS	024716
ADI\$PM	024724	ADI\$FA	024732	CMI\$IP	024740
CMI\$SP	024742	CMI\$MP	024750	CMI\$PP	024760
CMI\$PS	024764	CMI\$PI	024772	CMI\$PM	025000
MOI\$IP	025006	MOI\$SP	025010	MOI\$PP	025016
MOI\$MP	025022	MOI\$PS	025032	MOI\$PM	025040
MOI\$PA	025046	MOI\$OP	025054	MOI\$IP	025062

SUI\$IP	025072	SUI\$SP	025074	SUI\$PP	025102
SUI\$MP	025106	SUI\$PS	025116	SUI\$PM	025124
SUI\$PA	025132	ISN\$	025140	\$ISNTR	025144
LSN\$	025140	\$LSNTR	025144	SUI\$SS	025320
SUI\$SA	025324	SUI\$SM	025330	SUI\$IS	025334
SUI\$IA	025340	SUI\$IM	025344	SUI\$MS	025350
SUI\$MA	025354	SUI\$MM	025360	CML\$MI	025364
CML\$SI	025366	MOL\$SM	025374	MOL\$SA	025400
MOL\$MS	025404	MOL\$MM	025414	MOL\$MA	025420
MOL\$SP	025424	MOL\$PP	025432	MOL\$MP	025436
MOL\$PM	025446	MOL\$PS	025454	MOL\$PA	025460
MOL\$IM	025466	MOL\$IA	025474	MOL\$IP	025502
LLE\$	025512	LEQ\$	025514	LGT\$	025522
LOE\$	025524	LNE\$	025534	LLT\$	025536
CML\$PS	025542	CML\$PI	025550	CML\$PM	025560
TSL\$S	025566	TSL\$M	025572	TSL\$I	025576
TSL\$P	025604	MOD	025612	NMI\$IM	025650
NMI\$MM	025706	NMI\$PM	025714	NPI\$IM	025724
NPI\$MM	025730	NPI\$PM	025734	NMI\$IP	025740
NPI\$IP	025756	NPI\$II	025762	NPI\$IM	025776
\$PQPR4	026020	\$PQPR5	026020	\$PQPR3	026032
RET\$D	026040	RET\$L	026106	RET\$F	026112
RET\$I	026120	RET\$	026122	SAVRG\$	026156
THRD\$	026334	\$STPS	026336	STP\$	026344
\$STP	026344	FOO\$	026350	\$EXIT	026370
\$OTIS	026514	\$OTIS	026516	TSI\$S	026636
TSD\$S	026642	TSF\$S	026646	TSD\$M	026652
TSF\$M	026652	TSI\$M	026652	TSD\$I	026656
TSF\$I	026656	TSI\$I	026656	TSD\$P	026662
TSF\$P	026662	TSI\$P	026662	TVL\$	026670
\$TVL	026670	TVF\$	026676	\$TVF	026676
TVD\$	026704	\$TVD	026704	TVQ\$	026712
\$TVQ	026712	TVP\$	026720	\$TVP	026720
TVI\$	026726	\$TVI	026726	\$VRINT	027062
SAD\$PM	027064	SVD\$PM	027104	SAD\$PP	027124
SVD\$PP	027144	SAD\$IM	027164	SAD\$SM	027166
SVD\$IM	027202	SVD\$SM	027204	SAD\$MM	027222
SVD\$MM	027226	SAD\$IP	027232	SAD\$SP	027234
SVD\$IP	027250	SVD\$SF	027252	SAD\$MP	027270
SVD\$MP	027274	SAF\$PM	027300	SVF\$PM	027316
SAF\$PP	027340	SVF\$PP	027356	SAF\$IM	027372
SAF\$SM	027374	SVF\$IM	027406	SVF\$SM	027410
SAF\$MM	027430	SVF\$MM	027434	SAF\$IP	027440
SAF\$SP	027442	SVF\$IP	027454	SVF\$SP	027456
SAF\$MP	027476	SVF\$MP	027502	SAI\$IM	027506
SAI\$SM	027510	\$BOUND	027514	SVI\$IM	027540
SVI\$SM	027542	SAI\$MM	027552	SVI\$MM	027556
SAL\$IM	027562	SAL\$SM	027564	SVL\$IM	027572
SVL\$SM	027574	SAL\$MM	027602	SVL\$MM	027606
SAL\$IP	027612	SAL\$SP	027614	SVL\$IP	027622
SVL\$SP	027624	SAL\$MP	027632	SVL\$MP	027636
OTS\$P	027642	000050	(RW, D, GBL, REL, QVR)		
SYS\$I	027712	000362	(RW, I, LCL, REL, CON)		
			INDEX	027712	INSRT
			IPQKE	030132	SCOPY
USER\$I	030274	000260	(RW, I, LCL, REL, CON)		
			SIREAD	030274	
			(RW, I, LCL, REL, CON)		
\$CODE	030554	042056	\$BOTSC	030554	MATINV
			BKGRD	060232	PUFIT
				054224	GFIT2
				060672	CTAIL
					056370
					062610

			STRIP	063664	DPM	064244	SEND	064432
			RECVR	065324	SETCLK	067500	IBNBCD	071046
			CLOCK	071156	IBCDBN	071500	YEAR	071616
			AVE	072172	MAXVAL	072332	MINVAL	072476
OTS#D	072632	000000	(RW, I, LCL, REL, CON)					
			*\$OTS0 072632					
SYS#D	072632	000000	(RW, I, LCL, REL, CON)					
\$DATA#	072632	002634	(RW, D, LCL, REL, CON)					
PURE	075466	002312	(RW, D, GBL, REL, OVR)					
OTS#D	100000	000006	(RW, D, LCL, REL, CON)					
OTS#\$	100006	000304	(RW, D, LCL, REL, CON)					
			*\$OTS 100310					
SYS#\$	100312	000004	(RW, D, LCL, REL, CON)					
			*\$SYSLB 100312 \$LOCK 100314 \$CRASH 100315					
\$DATA	100316	004504	(RW, D, LCL, REL, CON)					
USER#D	105022	000002	(RW, D, LCL, REL, CON)					
.\$\$\$\$.	105024	002370	(RW, D, GBL, REL, OVR)					
DATA	107414	030014	(RW, D, GBL, REL, OVR)					
\$STACK	137430	000200	(RW, D, LCL, REL, CON)					
\$STKST	137630	000000	(RW, D, LCL, REL, CON)					
			\$\$\$STK 137630					

Transfer address = 030554 High limit = 137630 = 24524. words

**This address must be loaded into
location 40₆ of PROM.**