# A MICROCOMPUTER SOFTWARE SYSTEM FOR THE AUTOMATIC REDUCTION OF GAMMA SPECTRAL DATA

A Thesis

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Dedicated to our baby

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ABSTRACT

Because of technological advances in gamma-ray detection and measuring equipment, gamma-ray spectroscopy has become a more accurate analytical technique; it has also become more complex. Computer aid in gamma spectral analysis is in most cases desirable, and in many cases essential.

A set of computer programs was written to perform automatic reduction of gamma spectral data. The programs were designed to run on a laboratory microcomputer and are written in the BASIC programming language. The programs have met all design requirements such as simplicity, ease of use, ease of modifications, and accuracy. Tests of the programs have shown that they can be easily and correctly used by persons with no computer programming experience and little background in gamma spectroscopy. Users are able to perform automatic qualitative and quantitative sample analyses, and obtain very good results.

The programs in the package were designed to be modified and expanded. Several recommendations concerning the future use and development of these programs were made.

# CHAPTER 1

## INTRODUCTION

When a radioactive material decays, it can emit energy in the form of high-energy electromagnetic radiation, or gamma rays. The number and energy of these emitted gamma rays are unique to the nuclide, hence providing it with a nuclear "fingerprint". Gamma spectral analysis is the technique whereby these emitted gamma rays are counted as a function of energy. Such information can be analyzed to identify radionuclides present in a given sample, and also provide information on the amount of each nuclide present. The samples analyzed can be naturally radioactive, or have their activity induced, such as is the case where stable elements are made radioactive by bombardment with neutrons in the technique known as neutron activation analysis.

Gamma spectral analysis is an extremely powerful and sensitive analytic tool, and has found a place in laboratories around the world, where the techniques in use are being proved and improved constantly. Gamma spectroscopy has applications in virtually every field of physical research and quality control. For a scientist interested in elemental analysis, it is an accurate, precise, specific, non-destructive, fast, and economical technique. Its applications currently include trace element analysis, biological studies, forensic medicine, environmental monitoring, and material accountability systems.

Gamma spectroscopy has been in wide use for the past two decades. In the recent past, however, several things have led to a virtual revolution in the field.

The first of the developments was the development of affordable, large-volume, high resolution lithium-drifted germanium (Ge(Li)) semiconductor detectors. The second was the continuing progress being made in the design and manufacture of multichannel analyzers (MCA's) capable of digitizing gamma spectra into large amounts of data (typically 4096 channels).[1]

By combination of the high resolution of the Ge(Li) detector and the increased capability of the MCA systems in use, it is now possible to examine very complex features of gamma spectra. When this fact is coupled with that of the ever-increasing use of gamma spectroscopy in many fields (implying the acquisition of many gamma spectra), the third major development can be arrived at almost by deduction. Hand analysis of a single complex spectra can be difficult and time consuming. When many spectra must be analyzed, computer aid is desirable, if not absolutely essential to complete the task.

Therefore, the third thing that has a great effect on gamma spectroscopy is the ongoing development of powerful, high-speed digital computers and, more specifically, the recent major advances in microprocessor technology. A new generation of powerful microcomputers, along with a wide variety of excellent hardware and software, is now available at a reasonable cost. Even those establishments on small budgets now have access to computing capabilities

previously out of reach. In addition, the laboratory computer offers a flexability unavailable with large systems. The laboratory computer can be dedicated to a single task or group of tasks, and can act as a controller to other laboratory equipment, while always running in real time but incurring none of the high costs associated with operation under a batch or time sharing mode of a large computer.(2)

Microcomputers used as the basis for automated gamma spectroscopy systems not only free the researcher from the requirement of performing the bulk of the analysis, but perform required calculations much faster and more accurately than can be done by hand. Additionally, the microcomputer can control an entire analysis system, including sample handling and data acquisition, requiring little or no user attention for long periods of time. Microcomputers also provide in most cases the capability of mass storage of large amounts of data in a small volume, the physical storage devices typically being inexpensive magnetic tapes or disks.

Clearly, the use of computer assistance in gamma spectral analysis can offer many advantages to the researcher. The purpose of this research project was to provide a semi-automatic gamma spectroscopy system to augment research capabilities at the Louisiana State University Nuclear Science Center.

# CHAPTER 2

## PROGRAM DESIGN CRITERIA

A great deal of gamma spectroscopy work is done at the Louisiana State University Nuclear Science Center; in fact, gamma spectroscopy is probably the most versatile and widely used analytic technique available in the department, applications for its use being found in virtually all activities.

Regardless of the particular application, the basic data analysis is always the same: the MCA used must be calibrated to yield accurate peak energy information; spectra must be searched for peaks and these peaks must be assigned energies; data must be output to some device in order for a record of the data to be obtained; in the case of a qualitative analysis, peaks found in a spectrum must be compared to compilations of data to make nuclide identifications; and in the case of a quantitative analysis, peak heights or areas of an unknown sample must be compared to those of a standard (comparator technique).

The design of a computer program or system of programs depends on three basic things:

1. the type of computer equipment available,
2. the background and skills of the programmer, and
3. the requirements of the programs at the institution where they are designed.[1]

In addition, a useful computer program should keep requirements of the user to a minimum. A detailed instruction set should not have to be referenced for routine use; the programs should be operated easily and correctly by users with little experience; no knowledge of computer programming should be required of the user; and finally, the program should be modified easily so that special or more advanced algorithms can be added as necessary.(3)

Many computer codes have been written to perform some type of gamma spectral analysis. The codes range from the very complex to the very simple. A large amount of information has been published in this field; unfortunately, the majority of the literature reviewed contained little that could be directly applied to this project. The reasons for this can be explained by the following.

The codes described in this paper were designed to be most effectively used at the Nuclear Science Center. The main objective of the program system was not to achieve results dramatically more accurate than previously achievable; excellent results have been obtained by hand for many years. The programs were designed to replace the researcher in making calculations and comparisons rather than improve on him. The computer equipment used, while being very good in its class, is limited by available memory and speed of program execution. These limitations preclude the possibility of effectively using the most accurate and powerful algorithms being developed by the scientific community today. While it is fairly certain that many of these algorithms could be success-

fully modified to run on the small system in use here, the execution times encountered would be intolerably long. Fortunately, the work performed at the Nuclear Science Center does not warrant the use of these sophisticated algorithms. Only very simple mathematical relations are necessary for our analyses. The computer performs its greatest service to us by the speed and accuracy with which it can manipulate large amounts of data. Note that two very powerful gamma spectral analysis codes are currently operational at LSU through the efforts of members of the Department of Physics.[4, 5] These codes are designed to run on the IBM 370-3033 computer which serves the university community, and they may be accessed via a remote terminal at the Nuclear Science Center. Despite their availability, these codes have never been used in any way at the Nuclear Science Center; their function does not suit the needs of the users here.

The major requirements of the programs described in this report were to allow the user to:

1. transfer data easily from the MCA in use to the computer's mass storage for retention and eventual analysis;
2. perform an accurate, rapid MCA calibration;
3. easily maintain files of spectral data;
4. perform a sensitive peak search on a spectrum, either automatically or under user control;

5. obtain both graphical and alphanumerical output for evaluation and reporting;
6. perform an automatic qualitative analysis on a selected sample;
7. custom build and tailor libraries to be used for qualitative analysis; and
8. perform a quantitative analysis of a selected set of samples using the comparator (standard) technique.

A microcomputer based system can easily handle the requirements outlined above, and has many advantages over larger systems. Programs are run locally on demand in a real time environment, minimizing the time that must pass between initiation of a program run and the time the results of this run are available to the user; no charges for computer time are incurred; programs that terminate abnormally because of an error can be corrected and restarted with little loss of time; and programs may be addressed easily and modified if necessary.

The programs described in this report were designed on the basis or the requirements outlined above. Every effort was made to incorporate the advantages offered by the use of the microcomputer system into the programs where possible.

Before the design philosophy of the programs is further discussed, we will describe the equipment comprising our gamma spectral system. As stated previously, the available equipment sets constraints on the final form of the programs.

The basic gamma spectroscopy system consists of an ORTEC 85 $cm^3$ coaxial Ge(Li) detector with a measured resolution of 1.86 KeV at FWHM for a 1.33 MeV $^{60}$Cobalt gamma ray. High voltage is supplied to the detector by an ORTEC Model 459 0-5 kV bias supply in line with an ORTEC Model 119 high voltage filter. Detector output is processed by an ORTEC Model 120-4 preamplifier, the output of which is processed by an ORTEC Model 571 amplifier. The MCA in use is an ORTEC Model 6240B with 4096 channels addressable. The MCA contains several options, including a serial I/O EIA-RS-232-C general purpose interface. This interface provides a port for data transfer from the MCA to the microcomputer.

The computer equipment used with this system is all supplied by Tektronix. The computer is a Model 4051 microcomputer. It is programmable in the BASIC computer language. The computer has 32 kilobytes of random access memory and an internal 300 kilobyte magnetic tape drive for mass storage. The 4051 has a display screen consisting of a cathode-ray storage tube that is capable of both alphanumeric display and high-resolution screen graphics. The 4051 is fitted with an RS-232-C data communications interface, which provides the port for reception of data from the MCA by the computer. Additional equipment includes a Model 4924 tape drive which provides an additional port for 300 kilobytes of on-line mass storage at all times, and a Model 4631 thermal hardcopy unit, which serves as an output device for both alphanumeric and graphical data.

While the basic ORTEC and Tektronix instruments were not designed, as some systems are, to be operated together for the

specific purpose of automated gamma spectral analysis, the system developed using them in conjunction satisfies the requirements at the Nuclear Science Center very well, in some cases offering definite advantages over currently available commercial systems. Nonetheless, there are several basic limitations of the computer/MCA interface that cannot be easily overcome; these limitations affected the final design of the software. For example, there is currently a one-way data transfer capability only: from the MCA to the computer. No MCA functions are addressable under computer control.

Next we describe the basic design considerations of the programs. Detailed program descriptions are given in the next chapter.

The system for automated analysis consists not of a single program, but of a series of programs, each one performing a specific set of functions. This modular program design offers many advantages, some of them being:

1. All available RAM (random access memory) need not be filled during program execution. This allows for moderate expansion of programs without a complete program restructuring.
2. Errors are detected more easily. If an error occurs, only the module that was executing at the time of the error need to inspected (in most cases).

3. New modules may be added to the system as necessary, and the basic package will remain intact and operational throughout the writing and testing of the new module.

All programs are written in the BASIC computer language supported by the Tektronix 4051 computer. BASIC is a high-level, user-oriented language designed to be used by both advanced programmers and those with limited programming experience. The language is powerful and flexible, and almost as universal as the well-known FORTRAN computer language.

The programs comprising this system were written to run in a highly interactive mode with the user. A dedicated microcomputer operating in real time lends itself to this type of operation as do few other instruments. Such interactivity allows the user to exercise maximum control over the execution flow of the programs, enabling him to treat the data as his requirements dictate. This interactivity also provides in some cases, automatic checking of user-input data, preventing the loss of time occurring when a program executes using incorrect data; allows for easy program termination at any time for any reason; and allows for equally easy program restarts. The graphics capability of the 4051 allows the use not only of alphanumerical computer prompts and user responses, but also of graphic data editing on the display screen during program execution. The use of this capability in these programs makes the system much more flexible.

When these programs were designed, the inexperienced or occasional user was foremost in mind. The user is not required to have an in-depth knowledge of gamma spectroscopy, though some knowledge is essential to assure the proper interpretation of the results of the programs. The user is not required to have any knowledge of computer programming whatsoever. When a user response is required by a program, the program provides a message to that effect. In cases where more than one valid response is possible, the program informs the user of his choices and in some cases provides recommendations. The user is never required during routine operation to address the computer on any level below the program level. There are two known cases where a user might need to address the computer while it is not under program control; these cases are: 1) when a new data tape must be initialized, and 2) the case where a tape used for scratch data must be reformatted. Detailed instructions on how to accomplish these two functions are given in an appendix to this paper. Both actions are simple and fast to accomplish.

Throughout the execution of these programs, detailed instructions are provided to the user which tell him exactly what is expected of him. In several cases the program executing will automatically halt to allow the user to make necessary calculations or to gather data which he will need later in the program. The user is then allowed to restart the program at the point that he left off.

Due to the design of the programs, the characteristics of the computer central processing unit, and the limited RAM available,

there are occasions where several minutes will be required for the computer to finish processing a given set of instructions. These cases have been kept to a minimum, but in some cases where these delays cannot be avoided, the user is given the opportunity to select an alternate method of execution. While the input to and the results of these alternate choices vary, the user can select the option which will give him the results he desires in a minimum amount of time.

The programs will also notify the user if he has selected to use a routine that could possibly yield inaccurate results if used incorrectly. In these cases, instructions and recommendations are provided the user which, if followed, can assure the user of the most accurate results.

It should be stressed that while these programs were written to aid the user, they were not written to run without supervision. This is because the computer is limited in its abilities; it is very good at making repetitive calculations and comparisons rapidly and accurately. The human operator has available, however, his experience and judgement—qualities that cannot be programmed into any computer, no matter how complex. When the computer and human user are properly interfaced, it is possible to do a larger quantity of high-quality work rapidly, than either could do alone.

An important facet of the program design are the measures that were taken to assure program availability. While the computer is always available and can be called on on demand, the computer

requires an instruction set before it can act. These instruction sets are the programs described in this report. The programs are stored on a magnetic tape and can be loaded into the computer memory to be executed whenever the user desires--provided that the programs are on the tape in a complete, operational form.

There are two ways that a mass storage device, in our case magnetic tapes, can be addressed. The first is to read data from these tapes; the second is to write data to these tapes. Reading data (programs and/or alphanumeric data) from a tape is non-destructive, i.e., when data is transferred from a tape to the computer memory, the data remains on the tape. Writing data to a tape, however, is destructive; any data previously on the tape in the position where writing occurs is destroyed as the data being written replaces it. For this reason, it is always necessary to ensure that data is not written to a tape where important and possibly irreplacable data resides.

Even the most experienced user can make a mistake, and the inexperienced user can be expected to do so as he becomes familiar with the computer. The underlying philosophy was, therefore, to design the system to provide maximum protection for data stored on tape. This was accomplished by classifying data according to its relative importance and replacability, and storing different classes of data on separate tapes as we now describe.

Class 1 data is that data which is essential to system operation and that is the hardest to replace. This class of data

consists of the programs comprising this software system. All Class 1 data is stored on a single tape designated as a Program Tape. This tape is manually write-protected and cannot be written to under any circumstances; it can only be read. This eliminates the possibility of accidental erasure of all or part of the contained programs unless the tape is deliberately write-enabled.

Class 2 data consists of gamma spectra. These spectra are considered important, but not necessarily irreplacable. Spectral data may reside on any tape designated as a Spectrum Data Tape. Since data must be written to these tapes when it is transferred from the MCA, these tapes cannot be manually write-protected at all times. The programs have been designed, however, so that these tapes need only be write-enabled during the execution of the data transfer program. At all other times, the tapes may be write-protected, and will only have to be write-enabled when another spectrum is to be dumped to them. When this is the case, the controlling program automatically finds on the tape the first empty file available for storage. This frees the user from the possibility of data erasure due to improper file selection. There are two possible exceptions to this statement. Both occur in the data receive program and are described in the next chapter and in Appendix D (Operating Instructions).

Class 3 data consists of all easily replacable data such as calibration data and intermediate results of program runs. This data resides on a tape designated Scratch Data Files; this tape

must be write-enabled at all times. If all or part of this data is accidentally erased, it can be easily replaced under program control. In the worst possible case, a complete erasure of the tape--the user need only reformat the tape (instructions on how to do this are given in Appendix C) and rerun the programs that had been run prior to erasure, a process taking only a few minutes.

Additionally, programs that output data to tape files automatically write this data to predetermined (fixed) files or to files selected under program control. This frees the user from the worry of directing data to the wrong file.

Finally, one further precaution was taken. As stated previously, in addition to the 4051 internal tape drive, a second unit, the 4924 tape drive, is on-line at all times to the computer. The programs have been written so that all data to be written to tape is directed to the tape in the 4924 tape drive--and the only tape that ever need be inserted in the 4924 drive is that containing Class 3 data. Again, this makes accidental erasure of important data difficult. There is one exception to this direction of data, however. The program that controls the data transfer from the MCA to the 4051 requires that the write-enabled tape to receive the data be in the 4051 internal tape drive. In this case, the precautions under Class 2 data protect the tape from accidental erasure by the user.

From the above the user can see that the system programs and the data acquired on tape are inherently secure. There are times, however, when a user might wish to access Class 1 and 2 data

tapes in a write-enabled mode, such as during a program modification. Regardless of the precautions taken, an error will eventually occur. For this reason, a complete backup tape containing the programs is always maintained. This backup ensures uninterrupted program availability in the event of an error causing accidental erasure. For safety's sake, no two Class 1 tapes should ever be write-enabled at any time and no Class 1 data tape should be used for program runs until the user is sure that a complete, operational backup tape is available. Following these procedures has allowed for rapid recovery from errors made during the development of these programs. In any event, complete listings of all programs in this package at the time of this writing are included as an appendix to this report; the programs can be replaced by hand if necessary.

Finally, the programs in this system have been written to accomodate the user who might wish to modify the programs at a later time. All programs contain Remark statements (equivalent to the FORTRAN comment card) in profusion. These statements provide the programmer with information on exactly what function a series of statements performs. Between these Remark statements and the simplicity of the BASIC language, modifications to the programs by the somewhat experienced programmer should be effected with a minimum of difficulty. The user who is not familiar with the BASIC language or the operation of the 4051 computer should not attempt to make modifications to the programs; this would likely lead to a costly mistake.

Summarizing, it is believed that the program system written satisfies the requirements of the users at the Nuclear Science Center. Detailed descriptions of the programs are given in the next chapter, and the results obtained by their use during tests are shown in Chapter 4.

# CHAPTER 3

## PROGRAM DESCRIPTIONS

The software for automated spectral analysis consists of ten separate programs. In this chapter we give descriptions of the operation of each program; detailed operating instructions are given in an appendix.

Three computer tapes are required to run these programs:

1. "Program Tape" - This tape contains the programs described in this chapter.
2. "Spectrum Data Tape" - This tape is used to store spectral data transferred from the MCA. Data is recalled from this tape for analysis. Note that additional tapes may be added to the system as the ones in use are filled.
3. "Scratch Data Files" - This tape holds intermediate results of program runs.

The system allows processing of 1024, 2048, or 4096 channel spectra. All programs may be run at one sitting or as time allows. In several cases, programs must be run in a specific order to yield correct results. This is because only the results of the most recent run of a particular program are stored on the scratch data tape. This stored data is then recalled for use by the next program in the series. For example, a run of the "List Results of Peak Search" program will not yield the correct peak energies unless the

the user has first run the "Calibration Routine" program, entering to it the calibration data associated with the spectrum being analyzed. Figure 3-1 shows the order in which the programs may be called. Solid lines indicate the order in which programs must be called from the directory to yield the proper results. Dotted lines indicate that any program may be called from the directory, as long as the results of the previous program in the series are present on the scratch data tape.

Note that while the programs were written to run interactively with the user, the user need not always be present during execution. If the user is not present when the computer sends a prompt for information, the program will wait for a user response before continuing with program execution.

The following lists the programs in the order that they are stored on the Program Tape. The descriptions given in this chapter in this same order.

File Number

1. "Directory"
   - allows the user to request a program to be run.
2. "Receive Spectrum from Ortec"
   - allows the user to transfer spectral data from the Ortec MCA to the Spectrum Data Tape.
3. "Calibration Routine"
   - allows the user to enter calibration data to be used to calculate peak energies.

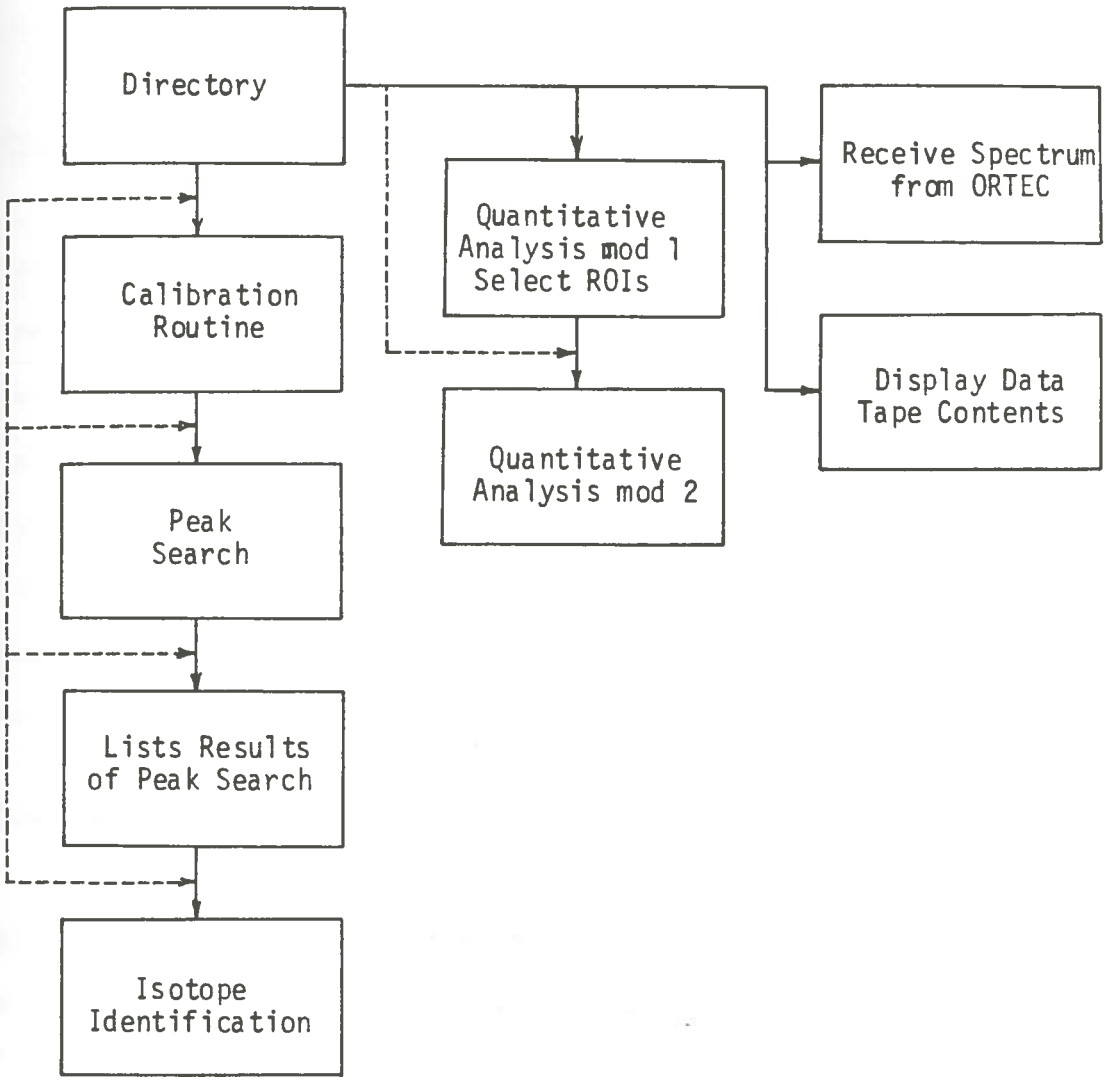


Figure 3-1

Program Calling Sequence

File Number

4. "Peak Search"

- allows the user to search a spectrum for peaks either automatically or under user control.

5. "List of Results of Peak Search"

- uses the results of the most recent peak search and the most recent calibration to calculate peak energies and produce a table of results.

6. "Isotope Library"

- a library of nuclides and associated gamma-ray energies that is used by the isotope identification program. This module is not an operating program in itself.

7. "Isotope Identification"

- uses the results of the peak search and the isotope library to perform a qualitative analysis on the sample being analyzed.

8. "Quantitative Analysis 1: Select ROIs"

- allows the user to manually select beginning and ending channels for a peak region-of-interest to be used for quantitative analysis.

9. "Quantitative Analysis Module 2"

- uses the ROIs entered in program 8 to do a comparator type quantitative analysis on a group of selected samples.

File Number

10. "Display Data Tape Contents"

- allows the user to scan a spectrum data tape and produce a printout of descriptive information about the spectra on that tape.

We will now describe each program individually.

Program Descriptions: "Directory" Program

The directory program is the first program on the program tape, stored in tape file number 1. This program is initialized by inserting the program tape in the 4051 and pressing the AUTO LOAD button. A list of the available programs on the tape is displayed in the format of a "menu" and the user is asked if he would like to run a program. A "yes" response causes the program to prompt the user for the file number of the desired program. Entering the correct number causes the desired program to be located, loaded into the computer memory, and executed.

Program Descriptions: "Receive Spectrum from Ortec" Program

This program resides in file 2 of the Program Tape. It allows the user to transfer data from the memory of the Ortec MCA to a file of a Spectrum Data Tape in the 4051 internal tape drive.

This program offers the user three methods for selection of a file on the Spectrum Data Tape to receive the data. The first is an automatic mode in which the first available file for storage is located under computer control. The second mode allows the user to reuse an existing file containing no longer needed data; the third

allows the user to erase all or part of the tape for reuse. These three modes allow the most efficient use of the storage space available on a tape. Note that the use of the second two modes should be made with caution to avoid accidental erasure of irreplacable data. Warning messages to the user are delivered by the program when either of these modes is selected.

The Spectrum Data Tape to be used for storage is formatted in the following manner. Even number files are used to contain the gamma spectra; the size of these files depends on the length of the spectra stored in them. Preceding each file containing spectral data is a file of fixed length containing descriptive information on the following spectrum; this file contains a spectrum label, initials of the user transferring the data to the tape, date and time of the transfer, the number of channels in the spectrum, and a decay time for the sample, in seconds. This information is requested of the user by the program before a transfer of data is allowed.

The program allows the transfer of full spectra only; these spectra may be 1024, 2048, or 4096 channels in length. The front panel controls on the MCA must be properly set in order to have a complete data transfer take place. Instructions on the proper settings are provided the user by the program. A special note of caution is included here regarding one of the requirements: before a complete data transfer can be affected it is necessary that all regions-of-interest in all memory locations be cleared on the MCA. Failure to do this will cause an incomplete data transfer that will

go undetected by the computer and likely the user. It is also possible that this error could remain undetected by the programs throughout a complete qualitative analysis. The results of the program runs would therefore be erroneous, but no indication of this would be provided the user by the programs.

The user will eventually receive a Magnetic Tape Error #54 error message during a run of this program. This error is expected and is an integral part of the program, indicating that the Spectrum Data Tape in use is filled and can store no more spectra, unless, of course, the tape is recycled or an existing file is reused. A single tape can hold up to 8 - 4096 channel spectra if only 4096 channel spectra are stored on the tape; likewise, the tape can hold up to 16 - 2048 channel spectra or 32 - 1024 channel spectra. The actual number of spectra the tape can hold will depend on the mixture of these lengths present.

When the program has finished executing, it remains in the computer memory. This is so because the user may wish to transfer several spectra in succession. In this case, the user saves time by not having to reload the program into memory for each transfer. This program is written to receive data only from the Ortec 6240B MCA. It is possible to modify the program to allow other MCAs to be used with the system. However, the modifications made will depend on the MCA selected. These modifications should be made only by a user familiar with the operation of the 4051 computer and the Tektronix Data Communications Interface.

Program Descriptions: "Calibration Routine" Program

This program resides in file 3 on the Program Tape. Its function is to allow the user to enter calibration data to be used by a subsequent program for peak channel to energy conversions.

Calibration data is obtained by the user directly from the display screen of the Ortec MCA. The program prompts the user to enter this data; i.e., peak channels and associated energies. This method of data entry and acquisition was selected because it offered the advantage of being considerably faster than any alternative method.

The program will also request the user to enter a reference label to describe the calibration data, the initials of the user performing the calibration, and the date and time that the calibration was performed. Once all data has been entered, it is fitted by the linear least squares method. A calibration equation is then printed out for the user's records, and the coefficients of this equation, as well as the descriptive information entered, is written to a scratch data file.

Up to 20 calibration peaks may be entered to the program. The linear fit performed on the data provides a very accurate calibration, partially due to the extreme linearity and stability of the MCA and associated electronics. The more peaks entered to the program, the more accurate the resulting calibration; however, satisfactory calibrations can be obtained by entering as few as 2 or 3 peaks. If possible, peaks from the low, middle, and high

energy range of the MCA should be entered to the program to obtain the most accurate peak energy determinations at the low- and high-energy extremes.

The programs in the system work with gamma energies in KeV only. For this reason, it is necessary to enter all peak energies to the program in KeV.

Note that only one, the most recent, calibration is available on the scratch data tape at any time. Before a spectrum is searched for peaks, the user must ensure that the calibration information on this tape is the correct information to be used for the spectrum being analyzed. For this reason, the user should always keep a record of calibration data used, and the labels of the spectra acquired under this calibration. This calibration information can then be entered via this program prior to the analysis of any of these spectra. Of course, if several spectra analyzed in succession were taken with the same calibration in effect, this program need only be run once, since after this run the correct data for all of the spectra will be on the scratch tape.

When this program finishes executing, system control is automatically passed to the Directory program to await the next user program selection.

Program Descriptions: "Peak Search" Program

The peak search program resides in file 4 on the Program Tape. This is the largest and most complex program of the system. The function of this program is to allow the user to locate peaks

in a sampling spectrum. Once the peaks are located, subsequent programs calculate the peak energies and perform a qualitative analysis of the spectrum if the user requests.

The program provides three methods of peak location. We will discuss each of these methods in turn.

The first method available is referred to as the AUTO or automatic peak search. When this method is used, a sample spectrum is scanned for changes in the content of adjacent channels. A shifting register of five adjacent channel contents is maintained by the program. A peak is located when the content of the middle channel (defined as P3) of the register is greater than the sum of the average register content (H) and its standard deviation (approximately by $H^{1/2}$) multiplied by a user-supplied factor (M9):

$$\text{Peak criterion:} \quad P3 > H + M9 * H^{1/2}$$

in which

$$H = (1/5)\ [\Sigma\ (\text{register channel contents})]$$

If a peak is indicated, the five-channel register is scanned to ensure that the middle channel is the channel of maximum content in the register. If it is, a peak is confirmed; it is not, this indicates that a peak has not been found. In either event, the register is then shifted one channel and the search continues.

The peak search algorithm used is very simple, but it is capable of delivering excellent results. The success of the automatic

peak search lies in the proper selection of the "sensitivity" factor by the user. A value of 3 will usually provide satisfactory results, and the program recommends to the user a value between 2.8 and 3.2. In cases of low-level, poor-statistics spectra, a lower value can be selected, hence making the search more sensitive; in the case of spectra with strong, well-defined peaks, a higher value may be selected for a less sensitive search. The higher the value of this parameter, the few spurious peaks that will be detected; also, however, the possibility of a valid peak going unrecognized is increased. Likewise, a low value for this parameter will almost ensure the detection of all true peaks, but at the cost of having more spurious peaks indicated.

Since there is the possibility of error in the automatic peak search, the user must be able to determine the "goodness" of the peak search results. For this purpose, the high-resolution graphics capability of the 4051 is indispensible. The gamma spectrum being analyzed is first plotted on the 4051 display. As the peak search progresses, peaks are labeled as the program "finds" them. At the conclusion of the search, the user can inspect the results and determine if the results meet his requirements. If not, he can rerun the search, either automatically with a different value for the sensitivity parameter, or with one of the alternate available methods. He also will be provided with a hardcopy of this plot; this gives him an indication of the trivial or spurious peaks

located, and he can use this information when interpreting the results of later program runs.

The automatic peak search routine has both its advantages and its disadvantages. One of the advantages is the fact that when it does indicate a peak, the channel of maximum content is recorded accurately (this is indicated by our tests of the programs; see the Results Chapter). The major disadvantage is that this routine takes the longest of all routines available to execute; in fact, in a "worst case" situation (i.e., a complex 4096 channel spectra), it will take longer to execute than any other program in this package. This slowness can be attributed to the design of the program, which was constrained by the lack of available memory, and to the relatively slow operating speed of the computer's central processing unit. A minimum of three passes must be made through the spectral data when this routine is used; the first to determine a data maximum for scaling of the plot; the second to actually plot the data, and the third to perform the peak search. In the worst case, the routine can take in excess of twenty minutes to execute. Fortunately, since the process is automatic, the user need not be present while the search is being performed.

The second peak search method is referred to as the MANUAL peak search. When using this option, the user rather than the computer is responsible for locating peaks in a spectrum. The use of this routine offers several advantages. First, this routine executes considerably faster than does the automatic routine. It also allows

the user to visually locate the peaks, a process considerably more accurate and reliable than the automatic peak search algorithm used.

The powerful graphics capability of the 4051 is again invaluable to the operation of this routine. As in the automatic peak search, the spectrum is scanned twice to yield a scaled plot of the spectrum on the display screen. At this point, the user is supplied with a cursor in the form of a blinking arrow which may be moved to any position on the screen by the use of pre-defined user-definable keys. The user positions the arrow so that it is pointing at the maximum of a peak, then presses another user-definable key to enter the peak. The program then labels the peak indicated by the user with a reference number. The user continues this process until all desired peaks are entered. Besides saving time, the use of this routine virtually assures the user of the results he requires.

As with any computer routine, however, the manual peak search has its drawbacks. The most serious is as follows. In order to allow positioning of the arrow cursor on the display screen, the screen is discretized into a fine grid. In most cases, the adjacent points on this grid are so close togehter that very little apparent cursor movement is discernable by the user as he moves from one point to another. In order to enter a peak accurately, the user must position the tip of the arrow as close to the peak maximum as possible. Consider the following situation: The horizontal (channel) axis is broken into an array of 1000 equally spaced points, and the cursor can be positioned at any one of these values. Note that if a 4096

channel spectra is plotted on the screen, moving the cursor just one unit corresponds to a move of 4+ channels; in other words, if the user positions the cursor even one unit off the peak maximum, he is in effect missing the peak by more than four channels. When dealing with high-resolution Ge(Li) spectra, an error of this magnitude must be considered serious. Ways to minimize the magnitude of this error had to be devised in order to have the manual peak search function usefully.

An option was designed to allow the user to "peaksearch" not only an entire spectrum, but also one or more parts of a spectrum in succession. For example, the user may select to search channels 500-1500 of a spectrum only, or maybe channels 500-800, followed by channels 900-2000, followed by channels 3100-3500, and so on. The use of this option (called region-of-interest search by the program) offers the user several advantages, and may be used in conjunction with the automatic as well as the manual peak search.

Use of the region-of-interest (ROI) search option is the key to obtaining good results from the manual peak search. When the manual peak search option is selected, the program issues warnings to the user of the possible errors encountered when using the routine. The program then recommends that the user select the ROI search option and break the spectra into components containing no more than 1000 channels. The program will then plot each selected spectrum region on the display screen in turn. Note that in the case of 1000 channels on the screen, however, the movement of the cursor of one

grid unit, or 1/1000 of the plotted range, corresponds to a move of only one channel. In addition, the user is able to see more change in the position of the cursor as it is moved only one unit in the horizontal direction. The user is able to point more accurately at the peak maximum, and if he positions the cursor one unit off, he is missing the peak by only one channel. This magnitude of error is one that the system can handle fairly easily.

When the manual peak search is concluded, that is, after all selected regions have been plotted and searched, control is transferred to a limited peak correction routine. The program scans a seven channel region of the spectrum centered on the peak channel entered by the user. If the content of any channel in this region exceeds that of the user-entered channel, the channel of maximum content replaces the user-entered channel. In this way, for the case of 1000 channel ROI searches, the user could miss the peak by 3 channels and still obtain the correct results. Accuracy can be improved even more by using a smaller region of the spectra for the search. Tests of the program have indicated, however, that excellent, reproducible results can be obtained using the procedure outlined above.

Before we leave our discussion of the manual peak search option, let us mention one other important fact that must be borne in mind when using this option. Peaks should always be entered from low to high energy; i.e., from left to right. Subsequent programs in the series must have peak arrays arranged in ascending order to function properly. Failure to process the peaks in this order can

lead to unpredictable results. Also note that no more than 50 peaks may be entered per program run.

Although the manual peak search option offers significant advantages over the automatic search, it can still require more time to execute than the user would like to spend. For this reason, a streamlined method for entering peaks was included in the program.

This third option is not actually a peak search at all. The user locates spectrum peaks on the display of the MCA, recording peak channels and the counts in these channels using the alpha-numeric display capability of the ORTEC MCA. The program will then follow him to enter these peak channels and counts as he is prompted. After the peaks are so entered, the program treats them just as it would peaks specified by either of the two other options available, thus making them available to the other programs in the system.

This routine, called a Keyboard Entry peak search, takes at most a few minutes to run, and the accuracy depends only on the user's ability to properly record data from the MCA display. Though it is the simplest method for entering peaks, it is believed that it will be the method which is used the most, because of its simplicity, its accuracy, and its short execution time. Note that no plotted output is provided by this routine, and that, as before, peaks must be entered from low to high energy, the number of peaks entered not to exceed 50. Also note that to use this option, the spectrum for which information is entered must still have been transferred to a file on the Spectrum Data tape. This is required so that in the

event of any program failure, the gamma spectral data must remain available in some form, and a hand analysis can be performed if necessary.

When the peak search program has finished execution, the next program in the series is automatically called; that program uses the results of the completed peak search as well as the calibration data resulting from the most recent run of the calibration routine to calculate the energies of the peaks entered and to print out the results of the peak search for the user.

Program Descriptions: "List Results of Peak Search" Program

This program is stored in file 5 of the Program Tape. Its function is to convert the peak channels resulting from the most recent run of the peak search program into peak energies using the calibration information entered during the most recent run of the calibration routine. It also provides the user with an output list of the results, indexing peaks by the label reference number assigned to them in the peak search routine. The list includes peak channels, counts, and energies in KeV, as well as descriptive information on the spectrum searched and the calibration used. The program also creates a file on the Scratch Data Files tape containing the information needed by the Isotope Identification program.

This program is called automatically at the termination of the Peak Search program; it may also be called automatically from the directory if so desired, provided that the peak search and

calibration data stored on the scratch tape is the correct data to be processed by this program. When the program finishes executing, it automatically returns to the directory.

Program Descriptions: "Isotope Library" Program

The isotope library is stored in file 6 of the Program Tape. This library is not a functioning program in itself; it is a set of BASIC data statements containing information on nuclides of interest. The data statements are in a format which allows them to be appended to the Isotope Identification program during the execution of that program.

The library was constructed on the basis of the information contained in the "Gamma Spectra and Nuclide Identification Catalog"[6] compiled by Geoffery Gleason of Oak Ridge Associated Universities. The data reflects a partial listing of isotopes and the gamma rays associated with them that are seen relatively often in the course of gamma spectral measurements. The isotopes included in the catalog were selected on the basis of:

1. importance in Neutron Activation Analysis,
2. commercial availability,
3. use as standards,
4. use in medical applications, and
5. naturally occurring nuclides.

All gamma energies are expressed in KeV. The gamma rays associated with the included nuclides may be only partially listed as the catalog contains only the most prominent gamma rays for each.

Each nuclide in the library has associated with it a "key" gamma, that gamma being the one selected as being most characteristic of the nuclide by the authors of the catalog. Also included in the catalog and the program library are: 1) absolute gamma intensities (expressed in percent), 2) parent or daughter isotopes along with their associated "key" gammas, if any, and 3) nuclide half-lives.

Information is available in the catalog for 170 nuclides; the isotope library currently contains information on 168 of these nuclides. The two remaining nuclides were omitted on the basis of the unlikelihood of their presence in samples normally encountered at the Nuclear Science Center. Nuclides may be added to or removed from the library as needed. All information available from the catalog for each nuclide included was made a part of the isotope library for completeness. The absolute gamma intensities are never used during the course of any program, but they were included so that they would be available in the future if a program were ever written to require their use.

Data is arranged in the library in order of decreasing energy of the "key" gammas. This order is necessary due to the structure of the Isotope Identification program.

The library was constructed with future modification or expansion in mind. While it is believed that this library is currently a good general use library, it may not contain the data on a nuclide of interest to a user; likewise, it may contain more data than a user who would like to restrict possible results would like. Detailed instructions on the procedure to modify the library are

included in an appendix to this report. It is stressed that modifications should only be attempted by a user familiar with the operation of the 4051 computer.

A list of the isotopes currently included in this library is also included in an appendix.

Program Descriptions: "Isotope Identification" Program

This program resides in file 7 of the Program Tape. The program is called from the directory and uses the results of the List Peak Search Results program to perform a qualitative analysis on the sample being processed.

The only input this program requires from the user is that he input an "acceptance range" for nuclide identification. The function of this parameter is as follows.

Two sets of data are at the heart of this program. These sets are the peak energies resulting from a run of the List Peak Search Results program and the "key" gamma energies included in the isotope library. The function of the program is to compare the peak and library energies. Theoretically, when a peak energy equals a library energy, this indicates that the nuclide emitting the library energy is likely a contributor to the spectrum being analyzed. In reality, library and measured peak energies rarely, if ever, are exactly equal. The difference can be attributed to several causes, including the characteristics of the gamma detection equipment in use, the "goodness" of the channel-energy calibration, and possible errors in the cataloged gamma energies. For these

reasons, a measured peak energy is compared to a range of values, centered on the library energy being used in the comparison. When the user enters an "acceptance range", he sets the width of this comparison interval, and hence controls the sensitivity of the routine. This can best be illustrated with an example.

Assume the program is currently searching for a "match" for a measured peak energy of 2000 KeV, and that the user has entered an acceptance range of 1 KeV. Assume that the first library energy encountered is 2002 KeV. In this case, the range of values that the peak energy must fall in for an energy "match" to occur is 2002-1 to 2002 + 1; i.e., 2001 to 2003 KeV. Since the measured gamma energy does not fail in this range, a match does not occur and the program continues to scan the library for other possible matches. Assume the next library energy encountered is 1999.5 KeV. The acceptance range in this case is 1998.5 to 2000.5 KeV. Since the measured gamma energy falls within this range, an energy match occurs and the nuclide associated with the library energy is tagged as a possible contributor to the spectrum.

The program scans the isotope library one time, from high to low energy. The reason for this order is that high energy gamma rays are more unique to a given nuclide, and an energy match in this range indicates the presence of the nuclide in question with greater reliability than a low-energy match. This is also the reason that it is important for energies to be entered during the Peak Search program from low to high energies. The program processes the resulting array

of measured peak energies in reverse order. An out-of-place energy can cause some energies to be bypassed with no valid comparisons occurring.

If an energy match occurs, the program then compares the measured peak energies with any additional gammas (i.e., other than the "key" gamma) which are associated with the "matched" nuclide in the library. If additional gamma energy matches are found in this step, the gamma energies being processed are tagged as "confirmation" gammas; i.e., gamma energies present in the spectrum that support the tentative nuclide identification based on the original energy match. If a parent or daughter product is associated with the nuclide in the library, the program then scans the measured gamma energies for the key gamma associated with this product. If an energy match occurs, the program tags the product nuclide and associated gamma as additional confirmation of the original energy match.

Note that the measured gamma energy array is scanned for every library energy processed. For this reason, a single energy match does not preclude the possibility that more than one nuclide could be contributing to a peak, nor are problems caused when two measured gamma energies are very close together. The library scan continues until the end of the library is reached.

The output produced by the program includes an identification of the spectrum being processed, tentative nuclide assignments (including library key gamma, measured gamma, nuclide symbol, and nuclide half-life), associated confirmation gammas, if any, and

parent or daughter product gamma matches (including parent or daughter label, nuclide symbol, associated library gamma energy, and measured gamma energy), if any.

Very good results have been obtained with this program as illustrated in the Results Chapter, Still, the results must be inspected and interpreted by the user to yield the most accurate information. Because of the nature of the data and the architecture of the program, it is possible to have incorrect nuclide assignments made, or to have a contributing nuclide remain unidentified. There are several causes for these inaccuracies, among them the fact that library energies may be inaccurate, the calibration may be poor, or two nuclides emit gammas of almost equal energies. The width of the acceptance range heavily influences the quality of the results. A wide range increases the possibility of incorrect nuclide assignments; a narrow range increases the probability of a true contributing nuclide being discarded. An acceptance value in the range of 1.0 to 1.5 usually yields very good results. Still, the above inaccuracies considered, the program allows the user to perform a reasonably accurate, reliable analysis. The use of confirmation gammas and parent/daughter identifications, as well as the inclusion of the nuclide half-lives on the output from the program, allow the somewhat experienced user to quickly spot those tentative nuclide assignments most likely to be correct, as well as those likely to be incorrect. In addition, by the use of the list of peak energies provided at the end of the peak search, the user can quickly determine

if a major peak in the spectrum was bypassed by the program for any reason, and can attempt to account for its exclusion.

The program takes only a few minutes to run. In the event the user is unsatisfied with the results of a given run, he can rerun the program using a new acceptance value with little loss of time.

Program Descriptions: "Quantitative Analysis 1: Select ROIs" Program

This program is stored in file 8 of the Program Tape. It is the first of two programs that together allow the user to perform a qualitative analysis on a set of selected sample spectra. This program is called from the directory and is independent of the results of any previous program run. The program is designed to be the 'setup' program for the next program in the series. It is written to function in a highly interactive mode with the user, using both alphanumeric and graphical input techniques.

In the course of the program run, the user is required to enter the following information:

1. number of samples to be analyzed
2. file number of the standard sample spectrum
3. file numbers of the unknown samples
4. number of peaks to be used in the analysis
5. for each peak: a) peak channel in standard spectrum
   b) isotope corresponding to peak
   c) isotope half-life in seconds

d) element corresponding to measured isotope

e) amount of this element in the standard

f) units corresponding to this amount

Note that up to 10 samples may be processed per program run, and up to 10 peaks may be processed in each sample, thus allowing the user to analyze for up to 10 elements per sample per run. Also note that all spectra to be analyzed, including the standard, must be stored on a single Spectrum Data Tape.

After the requested information has been entered, the program locates the file containing the standard spectrum. The standard is used to select peak regions-of-interest, or ROI's; i.e., those channels in the region of a peak that will be used to calculate peak areas or integrals. Note that the ROI's entered for the standard spectrum will be used in the subsequent analysis of all spectra.

The ROIs are set by the user in the following way: the program uses the values of the peak channels entered by the user, each in turn. Taking a peak channel, the program reads from the standard spectrum file 41 data values, consisting of the contents of the peak channel and the contents of twenty channels to either side of this peak. These data are then scaled and plotted on the computer display screen. At this point, the user is given control of a movable narrow cursor, similar to that described in the Peak Search program description. The user moves the cursor via user-definable keys. He

first points the cursor at the channel he wishes to begin his ROI, the points at the channel to end the ROI, entering each channel via another user-definable-key. The program will print for the user messages indicating the peak currently being processed, the peak channel, and the beginning and ending ROI channels. Note that the peak channel is only printed after the program has scanned a 7 channel region of the spectrum centered on the user-entered peak channel in order to ensure that the user entered the correct peak channel.

The process outlined above is repeated until all peaks requested by the user have been processed. When finished, pertinent data is written to a file on the Scratch Data Tape to be recalled for use by the next program, which is called automatically by this program when finished execution.

Several aspects of the operation of this program should be mentioned. First, as stated before, all spectra to be included in an anlysis must reside on a single data tape; in addition, all spectra to be analyzed must be the same length. Of course, it is also necessary that all spectra be acquired using the same MCA calibration.

Because of the structure of the program, ROIs may not be processed for the following cases:

if the peak channel is < 21 or > 1003 for 1024 channel spectra

if the peak channel is < 21 or > 2027 for 2048 channel spectra

if the peak channel is < 21 or > 4075 for 4096 channel spectra

This constraint is expected to cause no problems to the user since a quantitative analysis would rarely, if ever, be based on data acquired at these spectrum extremes.

When the user enters the peak channels to be processed by the program, he must enter these channels in ascending order. All isotope half-lives must be entered in seconds. The program allows the user to have access to the computer for use as a "super calculator" prior to the entry of these half-lives.

Sample spectra need not have been accumulated for the same count time, nor do the samples have to be decayed for a fixed length of time; the program automatically corrects for these differences by processing the data in a counts/unit time format. It is necessary that all samples be subjected to the same irradiation conditions prior to counting.

The program provides detailed instructions to the user through out the run, including definitions of all user-definable-keys to be used, valid ranges for regions-of-interest, etc. Upon termination, this program automatically calls the next program in the series to complete the quantitative analysis.

Program Descriptions: "Quantitative Analysis Module 2" Program

This program resides in file 9 of the Program Tape. The function of this program is to perform the computations required for a quantitative analysis using the results of the first program in the quantitative analysis series. This program is executed automatically upon completion of the previous program.

No user input to this program is required.

The program functions in the following way: Using the ROI parameters entered by the user in the previous program, the program finds the files containing spectra requested for analysis. From each of these spectrum files it recalls the data in the requested regions-of-interest. These data, are then used to perform the calculations, described in the following paragraphs.

Gross integrals for each ROI are computed by summing the contents of the channels included in the ROI. A background integral is computed for each ROI by averaging the contents of the first and last channels of the ROI and multiplying the result by the number of channels in the ROI. Net integrals are then calculated as the difference between the gross and background integrals. The resulting net integral arrays are converted from net counts to net counts per second by dividing the net count integrals by the spectrum count time. This normalizes the data, compensating for differences in spectrum acquisition times. The resulting net integral arrays are then corrected for decay using the equation

$$A = A_o e^{-\lambda t}$$

in which

$A_o$ = computed net counts/second of the undecay-corrected sample

$\lambda$ = isotope decay constant, computed using the relation $\lambda = \ln(2)/T$ and based on the half-life (T) of the isotope corresponding to the peak being processed.

t = sample decay time measured from the end of the irradiation to the beginning of counting. This decay time is entered when the spectrum is dumped from the MCA.

When all spectral ROI data has been processed as described above, the unknown sample net integrals are ratioed with the net integrals for the standard sample. The resulting ratios are then multiplied by the associated amounts of the element-of-interest in the standard to yield the final results for each sample. A report is then printed for the user that includes the following information:

For the standard -

- sample label
- spectrum length
- count time
- decay time
- user initials, date and time of spectrum acquisition

For each peak -

- element-of-interest corresponding to the peak
- amount of the element computed to be in the sample
- isotope the measurement was based on

This same information is output for each unknown sample, and continues until each requested sample has been processed.

Note that if a decay time of 0 seconds is entered for a sample at the time of transfer from the MCA, no decay correction is performed.

This should only be the case where the sample decay time is small compared to the half-lives of the isotopes used in the analysis, or when decay times are unknown but assumed to be constant. Also note that if a resulting net integral is negative, the integral is reassigned a value of 0, since a negative integral has no real meaning.

Excellent results have been obtained with this program as shown in the Results Chapter. It is noted that the program may be used for purposes other than the standard qualitative analysis; applications include cross-calibration of gamma reference sources and the determination of peak half-lives using successive counts of a sample.

Program Descriptions: "List Contents of Data Tape" Program

This program is stored in file 10 of the Program Tape and is currently the last program currently available in this package. The program was provided as a convenience to the user.

The program is called from the directory. The user need only follow the instructions provided by the program to obtain a list of the contents of a specific data tape. The following information is printed out for each file on the data tape:

file number

stored spectrum length

stored spectrum label

user transferring spectrum data to the tape from the MCA

time and date of data transfer to tape

sample decay time in seconds

The listing will continue until the last file on the tape has been processed. If the tape is full, a message to that effect is printed for the user.

Note that if a file labeled "NEW" (meaning empty) is in any position other than the last file on the tape, this program will not execute correctly. This situation should not, however, occur during normal operation of these programs.

# CHAPTER 4

# RESULTS

This chapter contains examples of the results obtained using the programs described in this report. As stated previously, the results obtained have generally been very good; it is believed that these programs will satify the current requirements of the users at the Nuclear Science Center.

## Calibration Routine

To illustrate the results obtained from this program, the following was done:

1. The calibration program was run using calibration data acquired on two standard gamma-ray sources, $^{60}Co$ and $^{137}Cs$.
2. The peak search program was run for several spectra acquired for known gamma-emitting isotopes.
3. The known peak energies of the gamma-emitting isotopes analyzed in step 2 were compared to the energies calculated by the program on the basis of the data entered to the calibration program.

These results are listed in Tables 4-1 and 4-2.

## Peak Search

To illustrate the results obtained from the Peak Search program the following was done:

TABLE 4-1

DATA ENTERED TO CALIBRATION PROGRAM

| Standard Isotope | Gamma Energy (KeV) | Peak Channel (MCA) |
|---|---|---|
| $^{137}Cs$ | 662 | 662 |
| $^{60}Co$ | 1173 | 1173 |
| $^{60}Co$ | 1332 | 1131 |

* Calibration equation returned by program:

Energy (KeV) = 1.001 * channel - 0.856

TABLE 4-2

COMPARISON OF KNOWN GAMMA ENERGIES
TO THOSE CALCULATED BY PROGRAM

| Known Isotope | Gamma Energies (known) | Gamma Energies (calculated) | ΔE |
|---|---|---|---|
| $^{22}Na$ | 511 KeV | 510.7 KeV | 0.3 KeV |
| | 1274.5 KeV | 1274.6 KeV | 0.1 KeV |
| $^{54}Mn$ | 834.8 KeV | 835.1 KeV | 0.3 KeV |
| $^{133}Ba$ | 81 KeV | 80.2 KeV | 0.8 KeV |
| | 223.2 KeV | 223.4 KeV | 0.2 KeV |
| | 276.4 KeV | 276.5 KeV | 0.1 KeV |
| | 302.9 KeV | 303.5 KeV | 0.6 KeV |
| | 356 KeV | 356.5 KeV | 0.5 KeV |
| | 383.9 KeV | 384.6 KeV | 0.7 KeV |

1) Compared peak channels taken for several spectra from the MCA screen to the peak channels returned by the program. This was done for each of the three peak search modes available (Automatic, Manual, and Keyboard Entry) to illustrate that when properly used, the peak search routines will return accurate peak channels. These results are given in Table 4-3.

2) Compared the peak channels and counts returned by the Automatic peak search to peak channels can counts taken from the MCA screen for the same sample. These data, shown in Table 4-4, illustrates the typical quality of the results obtained using this peak search option with a search sensitivity factor in the recommended range of 2.8 to 3.2; the factor used in this case was 3.0. Note that some minor peaks were missed, while other spurious peaks were detected; this is expected when using this routine.

Isotope Identification

To illustrate the results obtained with the isotope identification program, spectra from samples of known composition were analyzed. The isotopes identified by the program were compared to those known to be present. Tables 4-5, 4-6, and 4-7 include these results, as well as data and comments pertinent to the interpretation of the results.

TABLE 4-3

EXAMPLE OF PEAK CHANNELS
RETURNED BY PEAK SEARCH PROGRAM

| Sample | Peak Channel From MCA | Peak Channel From Program | Type of Peak Search |
|---|---|---|---|
| $^{22}Na$ | 511 | 511 | Manual |
| | 1274 | 1274 | |
| | 1783 | 1783 | |
| $^{133}Ba$ | 81 | 81 | Automatic |
| | 277 | 277 | |
| | 304 | 304 | |
| | 357 | 357 | |
| | 385 | 385 | |
| $^{54}Mn$ | 835 | 835 | Keyboard Entry |

TABLE 4-4

EXAMPLE RESULTS OF AUTOMATIC PEAK SEARCH

Sample: J. H. #1
Peak search mode: Automatic
Automatic peak search sensitivity factor: 3.0

| From MCA | | From Program | |
|---|---|---|---|
| Peak Channel | Peak Counts | Peak Channel | Peak Counts |
| 59 | 630 | 59 | 630 |
| -- | -- | 67 | 320 |
| 134 | 231 | 134 | 231 |
| -- | -- | 173 | 149 |
| 239 | 219 | 239 | 219 |
| 480 | 268 | 480 | 268 |
| 552 | 101 | — | -- |
| 583 | 114 | -- | -- |
| 619 | 134 | 619 | 134 |
| 686 | 205 | 686 | 205 |
| 847 | 2620 | 847 | 2620 |
| 911 | 31 | -- | -- |
| -- | -- | 1514 | 19 |
| 1807 | 281 | 1807 | 281 |
| -- | -- | 2072 | 8 |
| 2109 | 131 | 2109 | 131 |
| -- | -- | 2351 | 6 |

TABLE 4-5

EXAMPLE RESULTS OF ISOTOPE IDENTIFICATION PROGRAM

Sample: UNK #1
Count time: 78 seconds
Isotopes known to be present: $^{60}Co$, $^{22}Na$, and $^{65}Zn$
Acceptance value for isotope identification: (±) 1 KeV

| Isotopes Identified by Program | Key gamma, KeV | | | Confirmation gammas, KeV | | | Isotope Half-life |
|---|---|---|---|---|---|---|---|
| | Measured | Expected | Δ KeV | Measured | Expected | Δ KeV | |
| $^{60}Co$ | 1332.752 | 1332.500 | 0.252 | 1173.676 | 1173.200 | 0.476 | 5.27 yr |
| $^{22}Na$ | 1274.764 | 1274.500 | 0.264 | 510.731 | 511.000 | 0.269 | 2.6 yr |
| $^{65}Zn$ | 1115.688 | 1115.500 | 0.188 | -------none detected------- | | | 244 days |

Comments: Sample UNK #1 was known to contain isotopes that had been decaying for more than 1 year. Had the sample composition been unknown, this fact could be used to qualify the results on the basis of identified isotope half-lives.

TABLE 4-6

EXAMPLE RESULTS OF ISOTOPE IDENTIFICATION PROGRAM

Sample: 3 UNK
Count time: 451 seconds; Decay time: 60 seconds
Elements known to be present in sample: V, Au, and Mn
Acceptance value for isotope identification: (±) 1 KeV

| Isotopes Identified by Program | Key gamma, KeV | | | Confirmation gammas, KeV | | | Isotope Half-life |
|---|---|---|---|---|---|---|---|
| | Measured | Expected | Δ KeV | Measured | Expected | Δ KeV | |
| $^{52}V$ | 1433.916 | 1434.000 | 0.084 | -------none detected------- | | | 3.73 min |
| $^{56}Mn$ | 846.848 | 846.800 | 0.048 | 1810.422 | 1810.700 | 0.322 | 2.58 hr |
| $^{198}Au$ | 411.635 | 411.800 | 0.165 | -------none detected------- | | | 2.69 day |

Comments: The sample 3 UNK was activated for 80 minutes with thermal neutrons from a 1.8 mg Cf-252 source. The analysis was performed by students in the NS-7662 laboratory course; the students had no prior knowledge of the sample composition.

The results of the analysis shown above were accepted as true indications of V, Au, and Mn in the sample since 1) all isotopes identified can be produced by thermal neutron reactions; 2) the indicated constituent elements have large thermal neutron activation cross sections; 3) the differences in the measured and expected gamma energies forming the basis of the analysis are small; and 4) the isotope half-lives are consistant with those expected based on the sample irradiation and decay times.

TABLE 4-7

EXAMPLE RESULTS OF ISOTOPE IDENTIFICATION PROGRAM

Sample: J. H. #1
Count time: 1618 seconds; Decay time: 50 seconds
Elements known to be present in sample: W. Mn
Acceptance value for isotope identification: (±) 1.2 KeV

| Isotopes Identified by Program | Key gamma, KeV | | | Confirmation gammas, KeV | | | Isotope Half-life |
|---|---|---|---|---|---|---|---|
| | Measured | Expected | Δ KeV | Measured | Expected | Δ KeV | |
| $^{56}Mn$ | 847.880 | 846.800 | 1.080 | 2113.012 | 2113.100 | 0.088 | 2.58 hr |
| | | | | 1810.262 | 1810.700 | 0.438 | |
| $^{187}W$ | 686.480 | 685.700 | 0.780 | 619.314 | 618.200 | 1.114 | 24 hr |
| | | | | 552.148 | 551.500 | 0.648 | |
| | | | | 479.969 | 479.500 | 0.469 | |
| | | | | 133.111 | 134.200 | 1.089 | |
| $^{77}As$ | 238.371 | 239.000 | 0.629 | -------none detected------- | | | 38.8 hr |
| $^{197m}Hg$ | 133.111 | 134.000 | 0.889 | -------none detected------- | | | 24 hr |
| $^{144}Ce$ | 133.111 | 133.500 | 0.389 | -------none detected------- | | | 284 day |
| $^{60m}Co$ | 57.925 | 58.500 | 0.575 | -------none detected------- | | | 10 min |

TABLE 4-7 (Continued)

Comments: This sample was irradiated with thermal neutrons from a 3 μg $^{252}Cf$ source for 15 minutes prior to counting. No knowledge of the sample composition was available until after the sample was analyzed and the results interpreted. After interpretation it was decided that the sample contained W and Mn; this analysis proved correct when it was verified by a person aware of the sample composition.

It was decided that Mn and W were present based on 1) the small differences in the measured and expected gamma energies forming the basis of the analysis; 2) the number of confirmation gammas detected for the W and Mn isotopes; 3) the fact that the identified isotopes will be produced by thermal neutron bombardment; and 4) the isotope half-lives are reasonable for the irradiation and decay times used.

The remaining isotopes identified by the program were rejected for various reasons. As-77 cannot be produced by a thermal neutron bombardment of a stable sample; $^{144}Ce$ cannot be produced by thermal neutron bombardment, and the key gamma indicating its presence shows as a confirmation gamma for $^{187}W$; $^{60m}Co$ has a very low yield for irradiation with thermal neutrons; the formation of the isotope $^{197m}Hg$ is unlikely and the key gamma indicating its presence also shows as a confirmation gamma for $^{187}W$. In addition, none of the rejected isotopes had any associated confirmation gammas.

Quantitative Analysis

Table 4-8 contains the results obtained from the quantitative analysis programs for a set of samples of known composition. The samples consisted of a mixture of sand and a standard solution of manganese; each sample contained 6-8 ml of sand and various amounts of the manganese solution as shown in the following table.

| Sample Number | ml Mn Solution | Mn Relative Quantity |
|---|---|---|
| 1 | 0 | 0 units |
| 2 | 0.25 | 25 units |
| 3 | 0.50 | 50 units |
| 4 | 0.75 | 75 units |
| 5 | 1.00 | 100 units |
| 6 | 1.25 | 125 units |
| 7 | 1.50 | 150 units |

The samples were exposed to the same thermal neutron flux from a 1.8 mg $^{252}Cf$ source for a fixed time; this resulted in the production of $^{56}Mn$, the isotope on which the analysis was based. The samples were decayed and counted for various times, then analyzed using sample number 4, the 75 unit solution, as the standard.

Manganese-56 emits three strong gamma rays of energies 846, 1810, and 2113 KeV. An analysis based on each of these peaks was performed for each sample as an automatic cross-check on the results.

TABLE 4-8

EXAMPLE RESULTS OF QUANTITATIVE ANALYSIS PROGRAM

| Sample | Decay Time (seconds) | Count Time (seconds) | Known Mn Relative Quantity | Mn Relative Quantity Returned by Program |
|---|---|---|---|---|
| 4 (standard) | 50 | 400 | 75 unit solution | Peak 1: 75 units<br>2: 75 units<br>3: 75 units |
| 2 | 35 | 400 | 25 unit solution | Peak 1: 28 units<br>2: 27 units<br>3: 23 units |
| 3 | 80 | 272 | 50 unit solution | Peak 1: 50 units<br>2: 51 units<br>3: 48 units |
| 6 | 85 | 179 | 125 unit solution | Peak 1: 129 units<br>2: 128 units<br>3: 131 units |
| 7 | 60 | 400 | 150 unit solution | Peak 1: 153 units<br>2: 154 units<br>3: 139 units |
| 1 | 40 | 400 | 0 unit solution | Peak 1: 0 units<br>2: 1 unit<br>3: 0 units |
| 5 | (Sample 5 was not included in the analysis) | | | |

The 846, 1810, and 2113 KeV gammas are designated as gammas 1, 2, and 3, respectively, in Table 4-8.

Table 4-9 is a summary of the results obtained from the quantitative analysis program using standard gamma-ray sources as samples. A National Bureau of Standards $^{60}Co$ source was used as the standard and a New England Nuclear (NEN) standard $^{60}Co$ source was treated as the unknown. Again, since $^{60}Co$ produces two strong gamma peaks at 1.17 and 1.33 MeV, both peaks formed the basis of an analysis, thus providing an automatic cross-check of the results. These results illustrate the usefulness of this program to cross-calibrate gamma sources.

TABLE 4-9

EXAMPLE RESULTS OF QUANTITATIVE ANALYSIS PROGRAM

| Sample | Peak Used | Known dps | dps From Program | % Error |
|---|---|---|---|---|
| NBS std.* (standard) | 1.17 MeV | 118300 | 118300 | -- |
| | 1.33 MeV | 118300 | 118300 | -- |
| NEN std.** | 1.17 MeV | 22400 | 21980 | 1.9% |
| | 1.33 MeV | 22400 | 21690 | 2.0% |

* National Bureau of Standards

** New England Nuclear

# CHAPTER 5

## CONCLUSIONS AND RECOMMENDATIONS

It is believed that the system of programs described in this report fulfill the current needs of the users at the Nuclear Science Center. These requirements were listed in Chapter 2. During tests of the computer system, users with no computer programming skills, little background in gamma spectroscopy, and only a brief introduction to the programs, had no trouble running the programs. All of the programs in the package have been thoroughly tested and are believed to be free of errors. Results obtained from the programs have been accurate, reproducible, and satisfactory in most cases.

A number of recommendations concerning the future use and development of these programs can be made. The nuclide library used by the isotope identification program currently contains information on 168 isotopes. That data on isotopes of little or no interest to users at the Nuclear Science Center should be removed from the library; likewise, data on isotopes of interest not in the library should be added.

Two other specific recommendations can be made. The first is that some method be devised to allow a more rapid transfer of data from the MCA to the computer; the second that steps be taken to incorporate computer control of the MCA into the system. To

carry out these recommendations, it will be necessary to design additional hardware for the computer/MCA system.

Although other recommendations could be made, the general nature of these recommendations can be stated as follows: A computer program or system of programs is never really finished; something can always be done to make them more efficient, accurate, or better suited to the needs of the user. A system should continue to grow, both in hardware and software, as the needs and skills of the users grow. It is therefore recommended that the system be modified as necessary. This will require that the users make themselves familiar with the BASIC programming language and the operation of all equipment used with the system. This will result in an increasingly powerful and useful research tool for use at the Nuclear Science Center.

## REFERENCES


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2. Wilson, W. E. 1978. "Gamma-Ray Spectrum Processing with a Microprocessor System", Transactions of the American Nuclear Society, Volume 28, Supplement 1. p. 51

3. Phillips, G. W. 1978. "Automatic Computer Analysis of Gamma-Ray Spectra", Transactions of the American Nuclear Society, Volume 28, Supplement 1. p. 16

4. Visvanathan, A. and E. F. Zganjar. 1978. "SPKSAM - A Collection of SPEAKEASY Linkules for TSO Graphics Analysis of Nuclear Spectroscopic Data", Louisiana State University, Department of Physics and Astronomy, Report ORO-4935-25.

5. Cleveland, W. E. and E. F. Zganjar. 1978. "A Modified Version of SAMPO for TSO Graphics Analysis of Nuclear Spectroscopic Data", Louisiana State University, Department of Physics and Astronomy, Report ORO-4935-26.

6. Gleason, G, and H. R. Reed. 1977. Gamma Spectra and Nuclide Identification Catalog, Oak Ridge Associated Universities, Report ORAU-132.

## APPENDIX A

## CURRENT ENTRIES IN ISOTOPE LIBRARY

Ag-108
Ag-108m
Ag-110m
Ag-111
Al-26
Al-28
Am-241
Ar-41
As-74
As-76
As-77
Au-195
Au-198
Au-199
Ba-131
Ba-133
Ba-137m
Ba-139
Ba-140
Be-7
Bi-207
Br-80
Br-80m
Br-92
Ca-47
Ca-49
Cd-109
Cd-111m
Cd-115
Ce-139
Ce-141
Ce-143
Ce-144
Cl-38
Co-57
Co-58
Co-60
Co-60m
Cr-51
Cs-134
Cs-134m
Cs-137
Cu-64
Cu-66
Cu-67
Dy-165
Dy-165m
Er-171
Eu-152
Eu-152m
Eu-154
Eu-155
F-20
Fe-52
Fe-59
Ga-66
Ga-67
Ga-72
Gd-153
Gd-159
Ge-75
Ge-77
Hf-175
Hf-180m
Hf-181
Hg-203
Hg-197
Hg-197m
Ho-166
I-125
I-128
I-129
I-130
I-131
I-132
In-111
In-113m
In-114m
In-116m
Ir-192
Ir-194
K-40
K-42
K-43
La-140
Lu-176m
Lu-177
Mg-27
Mg-28
Mn-54
Mn-56
Mo-101
Mo-99
Na-22
Na-24
Nb-94
Nb-95
Nb-97
Nd-147
Nd-149
Nd-151
Ni-65
Np-239
Os-191
Pb-210
Pd-109
Pm-149
Pm-151
Pr-142
Pr-144
Pt-195m
Pt-199
Ra-226
Rb-86
Rb-88
Re-188
Rh-104m
Rh-105
Ru-103
Ru-105
Ru-97
S-37
Sb-122
Sb-122m
Sb-124
Sb-125
Sc-44
Sc-46
Sc-46m
Sc-47
Sc-48
Sc-49
Se-75
Sm-153
Sm-155
Sn-113
Sn-123m
Sn-125
Sn-125m
Sr-85
Sr-85m
Sr-87m
Ta-182
Tb-160
Tc-101
Tc-99m
Te-123m
Te-129
Te-131
Te-131m
Th-228
Ti-44
Ti-51
Tl-201
Tm-170
U-239
V-52
W-187
Xe-133
Y-48
Y-88
Y-90m
Yb-169
Yb-175
Zn-65
Zn-65m
Zr-95
Zr-97

## APPENDIX B

## HOW TO MODIFY THE NUCLIDE LIBRARY

The isotope library used by the isotope identification program was designed to allow for future modifications. Currently, the library consists of almost all nuclide information available in Gleason's catalog,[6] described in Chapter 3. The library contents can be optimized for the user's purposes by deletions of unwanted nuclei and/or additions of nuclei currently not included. For example, the library could be modified to include only those isotopes expected to be detected in environmental samples. Thus, when an environmental sample was analyzed, the chances of a spurious identification - the tentative identification of a nuclide that meets the requirements of an energy match, but whose presence is highly improbable - are greatly reduced. Likewise, only isotopes expected to result from thermal or fast neutron irradiation could be included. Also, if the user is interested in a single isotope, the information on only this isotope could be included.

In any event, when information is added to the library, it must be entered in the proper format to ensure correct execution of the isotope identification program. This format is described here and use of this description in conjunction with the library listing included in Appendix E, Program Listings, should allow the user to implement library modifications successfully. Note that these modifications should be attempted only by users who are familiar with the operation of the 4051 computer.

All information must be entered in the form of a BASIC language DATA statement. Information on a single nuclide can use as many successive DATA statements as necessary.

The first bit of information to be included in a DATA statement is a nuclide's "key" gamma, i.e., that gamma energy which when found to be present in a spectrum indicates the presence of the associated nuclide in the sample being analyzed. All library entries must be ordered by decreasing gamma energy, and all energies must be entered in KeV. Hence, there is only one correct position in the library for a new data entry based on its key gamma.

Following the numerical key gamma entry, the following information must be entered in the order shown:

A. isotope symbol (character string)

B. isotope half-life magnitude (numeric)

C. isotope half-life units (character string)

D. absolute intensity of key gamma (numeric)

Note that if the absolute intensity of the key gamma is unknown, any number greater than 100 but less than 99997 may be entered in its place without affecting the isotope identification program results.

At this point, one may enter data on any gammas other than the key gamma that are associated with the nuclide and that the user wishes to use for confirmation gammas (described in Chapter 3). As many of these gammas may be entered as the user desires, but none are required. If used, the gammas must be entered in the order:

E. gamma energy (numeric)

F. absolute intensity of the gamma (numeric)

Entries (E) and (F) may be repeated until all desired gammas have been entered. Note that the absolute gamma intensity may be treated in this case as described under item (D) if desired.

At this point, if no data on an associated parent of daughter isotope is to be entered, the user must enter the following in the given order:

G. 99999

H. 99999

I. 0

J. 0

If, however, information on a parent or daughter isotope is to be entered, the entries must be:

G. 99998

H. 99999

followed by:

I. "P" or "D" designating whether the (note !) library nuclide corresponding to the key gamma (initial entry) is a parent or daughter to the product (character string)

J. product isotope symbol (character string)

K. key gamma energy of the product (numeric)

Note that one of the above must be included in the DATA statement, regardless of whether or not any confirmation gammas are included.

All separate nuclide DATA statements must begin on a new line, i.e., a single data string can contain information on one nuclide only, except where a parent or daughter nuclide is included.

The following are examples included to aid the user.

Assume that we wish to add data on the nuclide "Dummy-1" to the existing library. Assume this isotope has a key gamma energy of 3000 KeV, a half-life of 23 days, an absolute key gamma abundance of 50%, no confirmation gammas and no parent or daughter nuclides of interest.

Referring to the listing of the isotope library, we find the proper location for this entry to be between lines 520 and 530, since lines 510-520 contain data on the isotope Ca-49 with a key gamma energy of 3084.2 KeV and line 530 contains data on the isotope Na-24 with a key gamma energy of 2754 KeV. We could enter our data in this way:

```
525 DATA 3000, "DUMMY-1",23,"D",50,99999,99999,0,0
```

Note that the number 525 refers to a BASIC line number.

Let us now assume that there are two gammas associated with the isotope "DUMMY-1" that we wish to use as confirmation gammas; assume that these gammas have energies of 4107.5 KeV and 300 KeV and absolute abundances of 2% and 43% respectively. Our entry in this case might look like this:

```
525 DATA 3000,"DUMMY-1",23,"D",50,4107.5,2,300,43
526 DATA 99999,99999,0,0
```

Finally, let us assume that the isotope "DUMMY-1" is the parent to the isotope "Babydummy-2", and that this daughter has a key gamma of 1700.6 KeV. To include this information we would make the entry as follows:

```
525 DATA 3000,"DUMMY-1",23,"D",50,4107.5,2,300,43
526 DATA 99998,99999,"P","Babydummy-2",1700.6
```

## APPENDIX C

## MAGNETIC TAPE HANDLING

There are two cases when a user will have to address a magnetic tape on a level below the program level. These two cases are:

1) when the user wishes to initialize a spectrum data tape;
2) when the scratch data tape must be reformatted (in the case of an error).

A data tape may be initialized by following this procedure:

1) write-enable the data tape
2) place the tape in the 4051 tape drive
3) enter the following commands: FIND 0
   MARK 3,1000
4) on the first run of the data transfer program using this tape, the user should choose to RECYCLE THE TAPE, and choose file number 2 as the first file to be deleted.
5) when the data transfer program has finished executing, the tape is completely initialized.

The Scratch Data Files tape may be reformatted by following the procedure shown on the following page.

1) write-enable the Scratch Data Files tape

2) insert this tape in the 4051 tape drive

3) enter the commands: FIND 0

MARK 17,10000

Note: Reformatting the tape destroys any data remaining on the tape!

## APPENDIX D

## OPERATING INSTRUCTIONS

This section has been included to provide the user an easy-to-reference section on operation of this system of programs. Annotated listings of actual program runs were selected as the best format for this section, providing the user with the most information at maximum clarity. This format has the following advantages for the user.

The user is able to see:

1. How to select all available program options, and the effect these selections have on program execution;
2. Exactly how information and user prompts will appear on the computer display screen;
3. Typical user responses to program prompts; and
4. The result of each response.

While this section will be most useful to the new user, all users should be thoroughly familiar with the information presented here in order to optimize the use of the programs and the user's time. It is stressed, however, that regardless of how familiar the user is with the programs, he should always take the time to read the instructions provided by the programs as they are executing, and be sure that he has correctly and completely carried out these instructions before continuing with program execution. It is further

recommended that the user make himself familiar with the operation of the Tektronix computer by referencing the available Tektronix-supplied literature.

Three magnetic tapes are required to run these programs. They are:

1. "Program" tape
2. "Scratch Data Files" tape
3. "Spectrum Data" tape

The tapes currently in use are well marked. Any tapes added to the system, such as additional spectrum data tapes, should also be so marked. Note that the Program tape should always be write-protected or "safed" during normal operation. This is accomplished by means of a rotating key located in the upper left of the tape cartridge. A tape is write-protected when the arrow on the key points to the word "safe". Otherwise it is write-enabled. The Scratch Data Files tape should always be write-enabled. Spectrum Data tapes should be write-protected except when running the data transfer program.

There are several things that need to be mentioned before we continue with the operating instructions.

If at any time a blinking "F" appears in the upper left corner of the computer display screen, this indicates that the display is full. This condition is cleared by pressing the "Home/Page" key located at the upper left of the keyboard.

If an error message appears at any time on the display, the user should obtain a copy of the display by pressing the "Make

Copy" button on the 4051, then consult with someone familiar with the operation of the computer to determine and correct the cause of the error. The user may also try to rerun the program in which the error occurred if a user error is suspected.

A program may be terminated at any time by pressing the 4051 "Break" key twice. Any program may be restarted by putting the Program tape in the 4051, pressing the "Auto Load" button, and entering the file number of the desired program to the directory program when prompted.

Figure D-1 is a drawing of the components of the computer system that the user needs to be familiar with. Important front panel controls of the ORTEC MCA currently in use with the system are shown in Figure D-2.

Operating Instructions

To get started:

1. Turn the 4051 computer on.
2. Turn the 4924 tape drive on.
3. Turn the 4631 hardcopy unit on.
4. Insert the Program Tape in the 4051.
5. Press the Auto Load button.

Following the directions given above causes the display on the following page to appear.

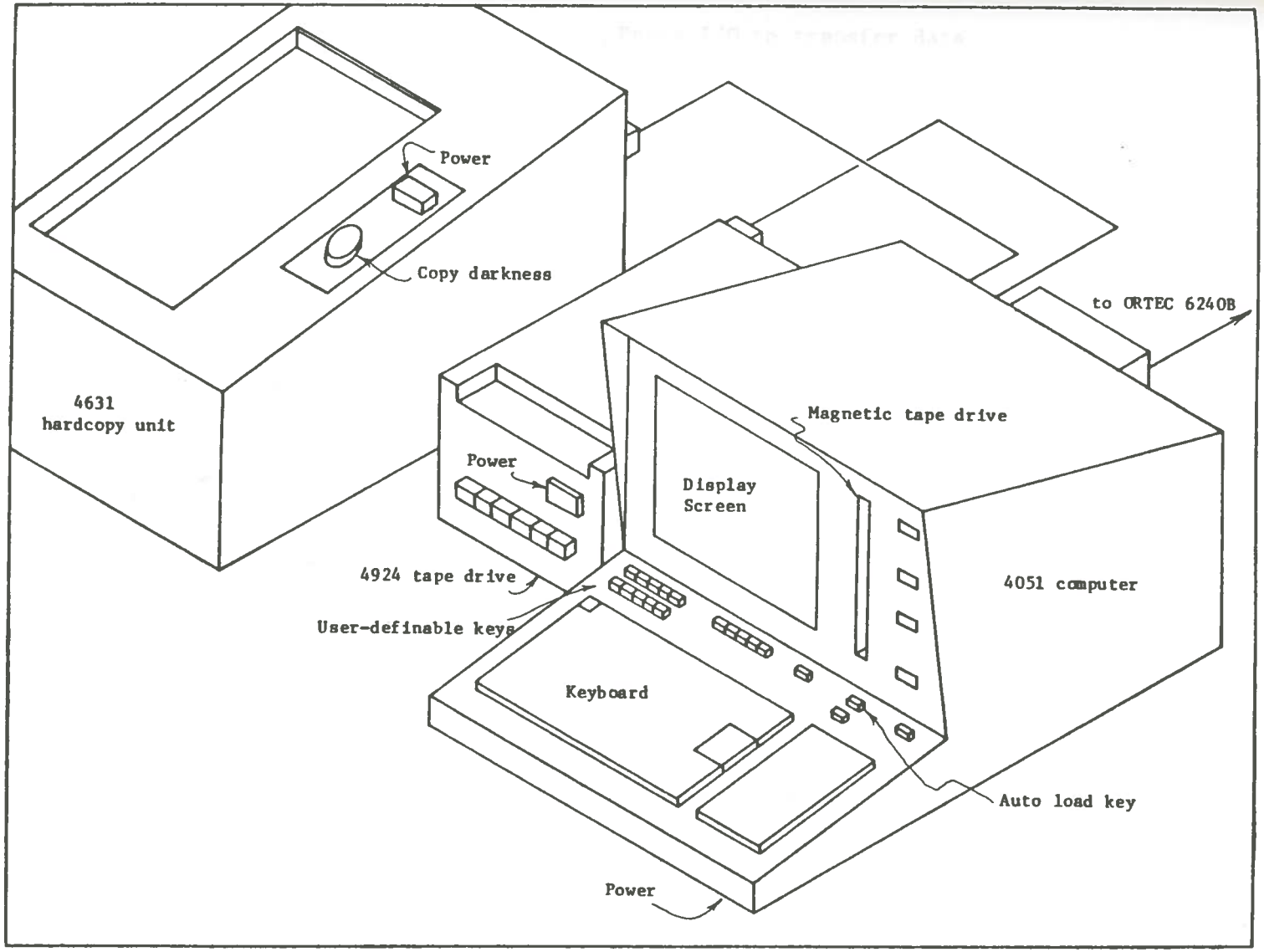



FIGURE D-1

IMPORTANT COMPUTER SYSTEM COMPONENTS

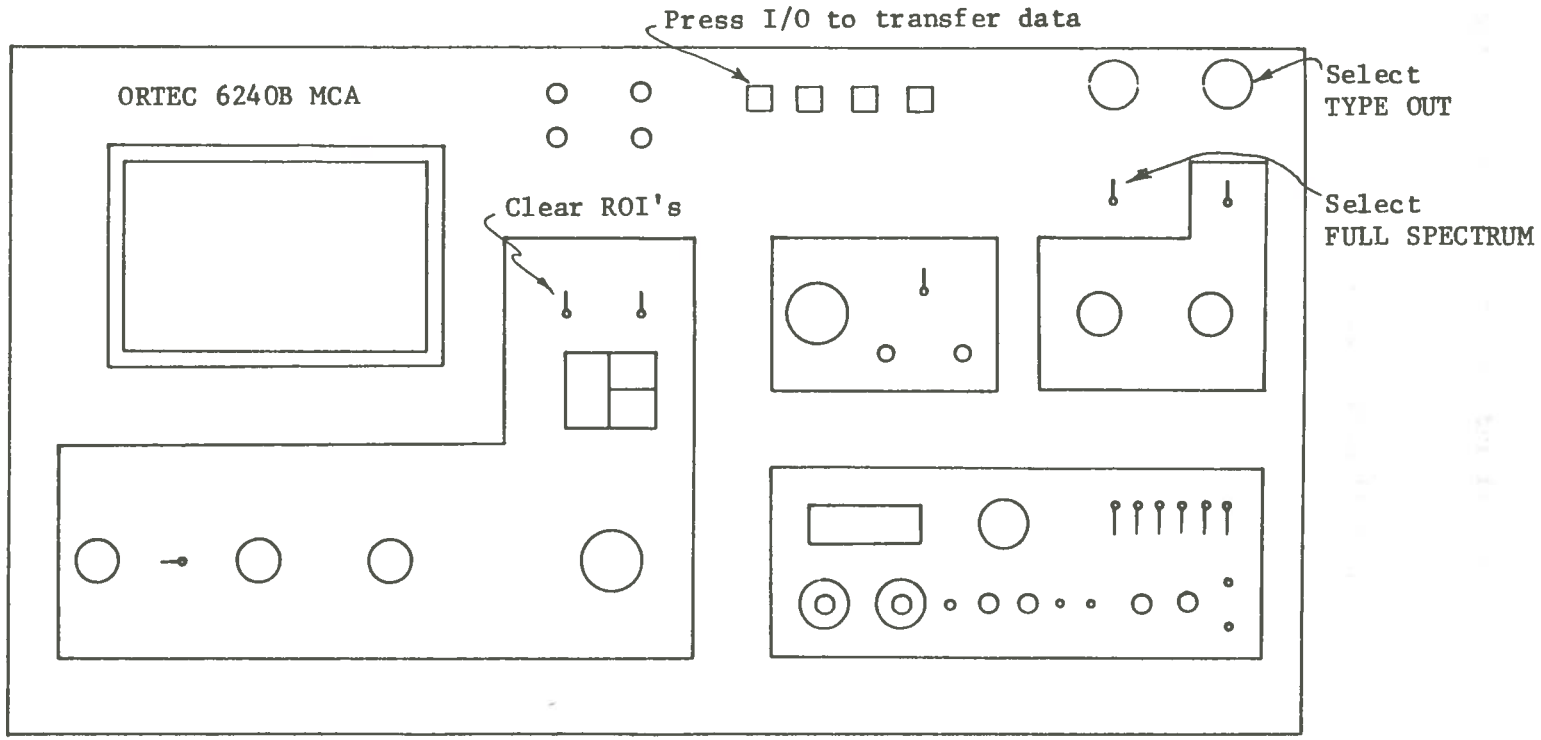



FIGURE D-2

IMPORTANT ORTEC MCA FRONT-PANEL CONTROLS

Note: When finished, do the following:

1. Press the Home/Page button three times.
2. Remove all tapes from the system.
3. Turn the 4051, the 4924, and the 4631 off.

```
***** MENU *****

 1.........Directory
 2.........Receive Spectrum from ORTEC
 3.........Calibration Routine
 4.........Peak Search
 5.........List Results of Peak Search
 6.........Isotope Library
 7.........Isotope Identification
 8.........Quantitative Analysis 1 : Select ROI's
 9.........Quantitative Analysis Module 2
 10........Display Data Tape Contents
 11........***** LAST *****
Would you like to run a program ? YES     Respond Yes or No
Enter file number : 2     Enter the number corresponding to the desired program.
                          Valid entries:  any number 1-10.
```

Here we have requested program #2, "Receive Spectrum from ORTEC", to be run. This program is automatically loaded and executed.

■■■ ~DATA DUMP~ ■■■

PUT THE SPECTRUM DATA TAPE IN THE 4051 INTERNAL TAPE DRIVE

Press RETURN to continue.

The programs will give instructions when a user action is necessary. Be sure to read all instructions and carry out these instructions completely before continuing with execution of the programs.

Do you want to recycle the tape ? NO Yes or No. A No response causes the following prompt.

Do you want to reuse an existing file ? NO Yes or No. A No response causes the program to locate the next file available for storage automatically.

```
Do you want to recycle the tape ? YES
```
A Yes response to this question causes the following prompt.

```
ARE YOU SURE ??? This will delete all or part
of the data now on the tape. YES
```
Yes or No. A Yes response causes the display on the next page. A No response causes the program to be restarted.

```
.......OK....but remember you said to !
```

```
Enter the number of the beginning file to be deleted.

This number must be an EVEN number. : 10
```
Enter an even number corresponding to the first file containing no longer needed data.

```
CHECK : Did you enter an EVEN number ?
You entered the number : 10  YES
```
Yes or No

```
Enter the number of channels in the first spectrum to
be dumped to this tape : 2048
```
Enter one of the following: 1024, 2048, 4096.

The user should be aware that all data currently on the Spectrum Data Tape in use from file number 10 on will be deleted!

```
Do you want to recycle the tape ? NO
Do you want to reuse an existing file ? YES
The file to be reused must be the proper size !

If you are not sure of the existing file sizes, press
the BREAK key to exit the program, then use the TLIST
statement to look at the file structure.

Proper file sizes are :

          8192 bytes for a 1024 channel spectrum
         16384 bytes for a 2048 channel spectrum
         32768 bytes for a 4096 channel spectrum

Press RETURN to continue.
```

Here we have a Yes response, causing the following instruction to be printed.

```
Enter the number of the spectrum data file to be reused.
This must be a EVEN number . Use file : 10
You said to reuse file 10
Is this correct ? YES
```

This may be any even number corresponding to any preexisting file of the proper size. The data in this file will be replaced with the new data transferred.

Yes or No

Regardless of the method selected by the user for the selection of the tape file to be used for storage (automatic, reuse, or recycle), execution continues with these messages.

```
THIS TAPE MUST BE WRITE ENABLED TO RECEIVE DATA !

NOTE :  All regions of interest MUST BE CLEARED on the ORTEC MCA
before data transfer. Failure to have all ROI cleared will
result in data being LOST DURING TRANSFER !. This data is
NOT recoverable. This is the responsibility of the USER.
If an incomplete transfer takes place, it WILL NOT be
detected by this computer ( I'm human, too ! ). So, do this
NOW, without fail ! Then press RETURN to continue.
```

Note that the user must press the RETURN key here.

```
Another note ! If a magnetic tape error 854 is received
at any time, it means that there is not room on the tape
to store another file of the size you specified. In that
case you may :

1. Use another data tape.
2. Recycle this tape.
3. Reuse an existing file OF THE PROPER SIZE !

Also note that an error of this type will terminate the
program. It can be restarted by typing RUN then pressing
the RETURN key.

Press RETURN to continue.
```

Enter the spectrum identification label : SOIL SAMPLE #1 The user may enter anything he likes here.

How many channels of data are in the spectrum ?
Valid entries are 1024, 2048, and 4096. Enter : 2048 Enter one of the valid entries.

Enter your initials : KVH

Enter today's date : 3/21/80 These three pieces of information may be entered in any format that the user desires.

Enter the time : 12:30 AM

You must now enter a decay time for the sample for later use in the quantitative analysis program. If you do not plan to perform a quantitative analysis, or if the decay time is unimportant ( as is the case with very long halflife isotopes ), you may enter a decay time of 0.

NOTE : This decay time must be entered in SECONDS. Note: Enter in SECONDS

If you need to make a calculation, do so now. When you are done, press USER DEFINABLE KEY #8 to resume the program.

```
56*24*3600
 4838400
12.5*3600
 45000
```

Here the program is exited to allow the user to use the 4051 as a "super calculator". All time values can be converted to seconds at this time. To resume program execution, the user presses user-definable-key number 8.

We have returned ! Did you record any calculations that made ? Press RETURN to continue.

This pause is included to remind the user to record the results of his calculations.

Enter the sample decay time in SECONDS : 45000

Here the computer is prepared to accept data from the MCA. The user should be sure that all instructions have been carried out.

```
We are ready to transfer data.

Set the ORTEC front panel controls to ** TYPE OUT **
and ** FULL SPECTRUM **

Remember : the data displayed on the ORTEC MCA screen while
in CRT mode is the data that will be dumped !

When the switches are set, press the ORTEC I/O button.

Numbers will flash on the screen while the transfer is in
progress. When they stop, press the brown BREAK key on the
4051, then the RETURN TO BASIC key (user-definale key #5 ).

Pressing the BREAK key generates an error message. Ignore
it.
```

```
COMM. INTERFACE ERROR
Comm. Aborted - error number  147
```

The BREAK key was pressed at the end of the data transfer. The error message at this point is expected and part of the normal operation of the program.

Pressing user-definable key number 5 causes the program to finish execution and produces the display shown on the following page.

```
Transfer complete.

Spectrum for sample SOIL SAMPLE #1 consists of 2048 channels
of infomation in tape file number 10.
```

The user should make a record of this file number for use in later programs.

```
If you wish to dump another spectrum, this program
can be rerun by typing RUN and pressing the RETURN key.

If you wish to run another program in the package, put
the PROGRAM TAPE in the 4051 and press AUTO LOAD.
```

The program has ended normally here. Follow the directions to perform additional program runs.

Here we are running the MCA calibration program. This program is selected from the directory by entering file number 3.

```
$$$ Energy calibration routine $$$

Put the SCRATCH DATA FILES tape in the 4924 tape drive.

Press RETURN to continue.


Note : This program package currently holds only one,
the most recent, calibration entered. This calibration is
used to process the results of a peak search program run,
so the results of an isotope identification program run
also depend on the calibration data currently in storage.

For this reason, the user is STRONGLY advised to retain
a copy of the calibration data entered, as well as a list
of the samples run under this calibration. This will
allow the user to reanalyze the samples at a later time,
merely by first running the calibration program and
entering the correct calibration information.

Press RETURN to continue.

Enter calibration reference label : CALIBRATION FOR SOIL #1

Enter calibration date : 3/21/80

Enter your initials : KUH

Enter calibration sources used, all on one line please.
COBALT-60, CESIUM-137
```

Take careful note of these instructions.

The user may enter anything he wishes here.

These two entries may be made in any format.

Any format can be used for these entries, as long as the entries fit on a single 72 character line.

```
Enter calibration data as prompted.

**********************************************************
*                                                        *
* Note : All energies in this program package must be    *
* entered in keV.Remember this when entering energies    *
* in this program and in other programs where a user     *
* supplied energy is requested !                         *
*                                                        *
**********************************************************
```

Note: Energies must be entered in KeV!

```
To terminate input, input a channel number 0.
Up to 20 calibration peaks may be entered.
At least 2 peaks MUST be entered !
```

To terminate input, the user must enter a CHANNEL NUMBER of 0.

```
Peak number 1: *Channel : 662
               *Energy  : 662

Peak number 2: *Channel : 1333
               *Energy  : 1332

Peak number 3: *Channel : 1171
               *Energy  : 1173

Peak number 4: *Channel : 2500
               *Energy  : 2502

Peak number 5: *Channel : 0
```

Note that decimal points need not be entered at any time if he wishes to enter a whole number.

Here we have terminated our calibration data input.

```
The calibration equation is :
Energy (keV) = 1.001 * channel + -0.627
```

The user might wish to make a record of this equation for future reference.

Here we are running the Peak Search program. This program is selected from the directory by entering file number 4.

```
*** Peak Search ***

Put the SPECTRUM DATA TAPE in the 4051 internal tape drive.

Put the SCRATCH DATA FILES tape in the 4924 tape drive.

Press RETURN to continue.

NOTE : Before this program is run, the calibration
program must be run, where the user (YOU) must enter the
proper calibration data for the sample to be analyzed. The
program need only be run once if all samples were taken
using the same calibration. Running the program before the
search assures having the proper data available to the
program. So, it is a VERY good idea for you to always make
a note of which set of calibration data goes with which
samples. If you need to do this, put the program tape in
the 4051 internal tape drive and press AUTO LOAD.

If this has been taken care of, press user-definable key #7
```

Note: The proper calibration data must have been entered to the computer by running the calibration routine in order to have the correct peak energies calculated by this program.

The user continues the program from this point by pressing user-definable key number 7. He may select a different program by following the directions given above.

I have a proposition for you. This program will give you the choice of an AUTOMATIC peak search (performed by yours truely), or a MANUAL peak search (performed by you and corrected by me, to the best of my ability). I would like to take this opportunity to offer yet a third alternative that I think might appeal to you.

If you like, you can enter from the keyboard the following information :

1. The number of peaks in your spectrum.
2. The channel of each peak.
3. The counts in this channel.

Note the information the user is required to enter to use this routine.

I believe that this could save you some time in certain cases. Your choice ! Note, however, that in any case, the spectrum MUST reside in a tape file, and that you must supply me with the number of this file.

Would you like to try this ? NO Yes or No. The results of a Yes response will be shown later.

This routine is usually the fastest 'peak search' to run.

```
.....forget I asked.............
Enter spectrum file number. This must be an EVEN number : 10
Select full spectrum (FULL) or ROI (ROI) search : ROI
                    *** ROI selected ***

NOTE *** VALID ROI RANGES ***

Valid ROI entries are : 1 through 1023 for a 1024 channel spectrum.
                        1 through 2047 for a 2048 channel spectrum.
                        1 through 4095 for a 4096 channel spectrum.

Any combination of channels is allowed, and ROI may overlap.
BE SURE,however,to observe the upper and lower limits listed
above. Failure to do so may result in an error !

Be sure to adhere to the constraints on ROI selection listed above!

ROI number 1
Begin with channel : 900
End with channel : 1200

Another ROI ? YES

ROI number 2
Begin with channel : 1200
End with channel : 2000

Another ROI ? NO
```

Enter the number of the tape file containing the spectrum to search.

Here the user selects to search all or part of the spectrum.
A search by parts has been selected here.

Yes or No.

Here the regions of the spectrum to be peak-searched are entered.

Do you want AUTO or MANUAL peak search ? AUTO  Enter AUTO or MANUAL

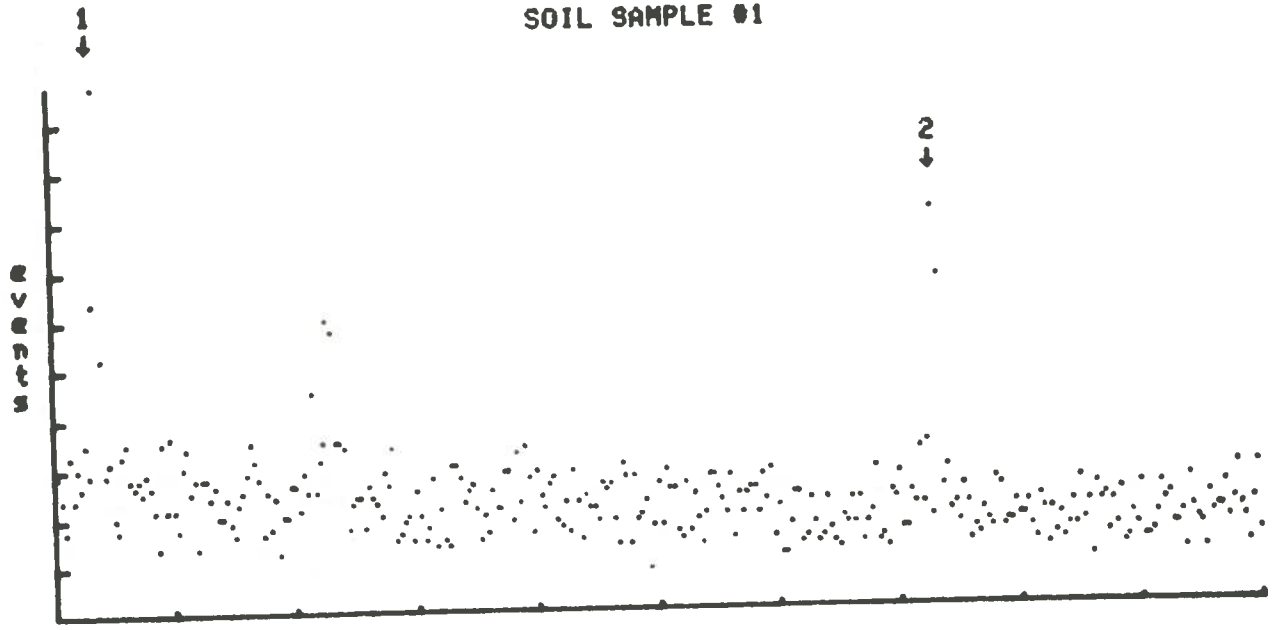
You must now enter an AUTO search sensitivity parameter.
We would recommend a value between 2.8 and 3.2  Enter : 3.0

The sensitivity parameter need only be entered if an automatic (AUTO) search is selected.

Here the computer has performed an automatic peak search on the first user-selected region.

Note that each peak found is labeled with a reference number.

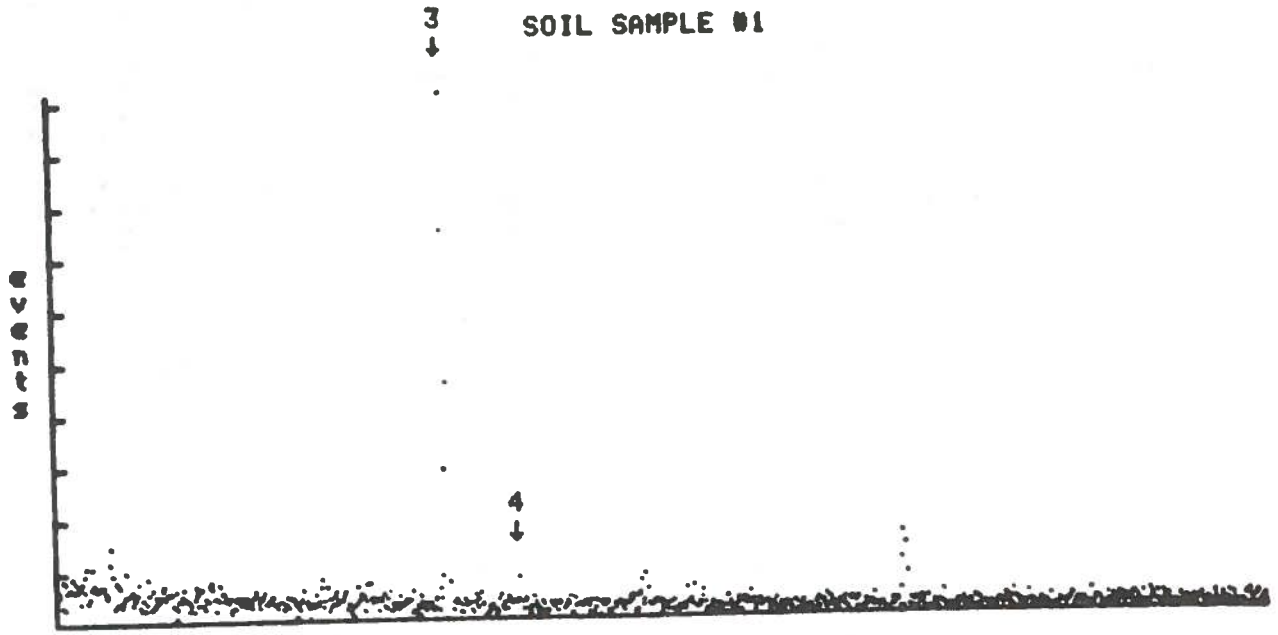
counted by : KVH
at : 12:30 AM
on : 3/21/80
count time : 20000 seconds
decay time : 45000 seconds
spectrum length : 2048 channels




Axis crossing : 900,0
X tic interval : 30
Y tic interval : 8

Results of AUTO search on second user-selected region.

counted by : KUH
at : 12:30 AM
on : 3/21/80
count time : 20000 seconds
decay time : 45000 seconds
spectrum length : 2048 channels




Axis crossing : 1200.0
X tic interval : 80
Y tic interval : 23

Enter the program tape in the 4051 internal tape drive.

Press RETURN to continue.

After the search is completed (regardless of whether it was AUTO, MANUAL, or a KEYBOARD ENTRY), the program tape must be entered at this point.

After the peak search has been completed, the program automatically calls the program in file number 5, which computes peak energies and produces the following listing.

* Peak Search Results *

These are the results of a AUTO peak search. The search
was for sample SOIL SAMPLE #1 acquired by KVH on 3/21/80 at 12:30 AM.
The spectra consists of 2047 channels.
Decay time was 45000 seconds. Count time was 20000 seconds.

The energies we calculated on the basis of the calibration
labeled : CALIBRATION FOR SOIL #1 which was performed by KVH
on 3/21/80 using the isotopes COBALT-60, CESIUM-137

| Peak Number | Channel | Energy (KeV) | Peak Counts |
|---|---|---|---|
| 1 | 911 | 911.259 | 86 |
| 2 | 1119 | 1119.461 | 65 |
| 3 | 1459 | 1459.791 | 234 |
| 4 | 1507 | 1507.838 | 19 |

Note that the program identifies the calibration in use. The user is advised to check this information to be sure that he had indeed entered the proper calibration.

If the calibration is incorrect, he may rerun the calibration program using the proper data, then rerun this program by selecting it from the directory (file #5).

Another listing will be produced showing the correct results.

```
.....forget I asked.............
Enter spectrum file number. This must be an EVEN number : 10
Select full spectrum (FULL) or ROI (ROI) search : FULL
```

Here we show what occurs when the user declines the KEYBOARD ENTRY peak search option, selects to search the full spectrum rather than parts of it, and on the next page, selects a MANUAL peak search.

```
Do you want AUTO or MANUAL peak search ? MANUAL
```

MANUAL peak search selected.

You have seleted a MANUAL peak search. There are some
things we need to discuss first.

First, remember this : YOU MAY ENTER NO MORE THAN 50 PEAKS.

Second , you will be using a pointer to specify peaks.
It is VERY important that you position the tip of the
pointer as close to the actual position of the peak point as
possible.If you don't understand what I mean, talk to
someone who has some experience running this program.

Next, it is much easier to accurately point to a peak if
the plotted field is smaller. In other words, the accuracy
of the pointer is better when you try to pick out a peak from
1000 plotted channels rather than 4095 plotted channels
(about 4095/1000 times better !). So, rather than
processing one large ROI, you might set
up 4 ROI's. For example ROI #1 from channel 1 to 1000,
ROI #2 from channel 1001 to 2000, ROI #3 from 2001 to 3000,
and ROI #4 from 3001 to 4095. Of course, ROI's need not
be distinct ! they can overlap. But it is best to do things
in a neat and orderly way. If you do overlap ROI's be sure
that the following constraint is applied !

********** ALWAYS (always!) enter peaks from left
to right (from lou energy to high energy). DO NOT skip
around ! One needs to be careful when using overlapping
ROI's.

Do you want to start over and do the search using ROI's ?
Enter NO if you have already seleted an ROI search. NO  Yes or No

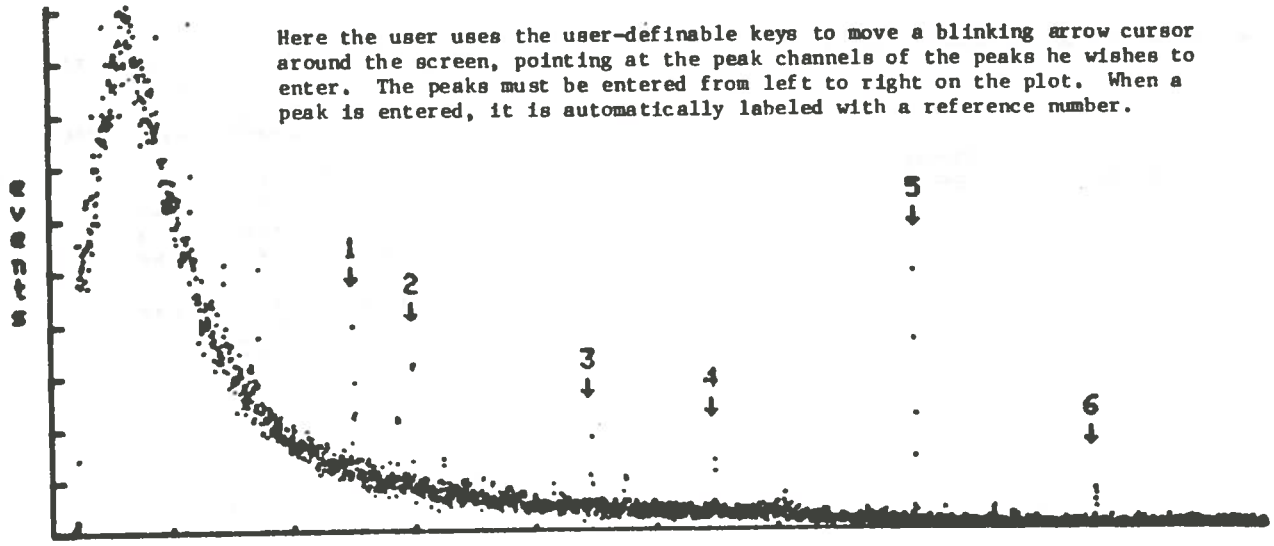
You have been informed !

The instructions given above are very important to the user. BE SURE they are understood before continuing.
Here we select to search the full 2048 channel spectrum anyway. If we instead chose to heed to warning provided, the program would start from the beginning.

```
Press UDK 10 to begin search.
Press UDK  5 to enter a peak.
Press UDK  9 to terminate search.
UDK :
1 moves cursor up ( #11:up*50 )
2            left ( #12:   *50 )
3           right ( #13:   *50 )
6            down ( #16:   *50 )
```

```
counted by : KUH
        at : 12:30 AM
        on : 3/21/80
count time : 20000 seconds
decay time : 45000 seconds
spectrum length : 2048 channels
```

SOIL SAMPLE #1




```
Axis crossing : 1,0
X tic interval : 204
Y tic interval : 47
```

The manual peak search is inherently inaccurate.
We will take this opportunity to correct it.

Hang on a minute.....

Here the program attempts to correct any errors in the MANUAL peak search. The program then calls program #5 from the program tape in the same way as the AUTO search routine.

Here are the results of the MANUAL peak search. Notice that the listing includes an indication of the type of search used.

* Peak Search Results *

These are the results of a MANUAL peak search. The search
was for sample SOIL SAMPLE #1 acquired by KUH on 3/21/80 at 12:30 AM.
The spectra consists of 2047 channels.
Decay time was 45000 seconds. Count time was 20000 seconds.

The energies we calculated on the basis of the calibration
labeled : CALIBRATION FOR SOIL #1 which was performed by KUH
on 3/21/80 using the isotopes COBALT-60, CESIUM-137

| Peak Number | Channel | Energy (KeV) | Peak Counts |
|---|---|---|---|
| 1 | 511 | 510.870 | 187 |
| 2 | 610 | 609.966 | 152 |
| 3 | 911 | 911.259 | 86 |
| 4 | 1119 | 1119.461 | 65 |
| 5 | 1459 | 1459.791 | 234 |
| 6 | 1760 | 1761.084 | 25 |

Here we show the use of the KEYBOARD ENTRY method of 'peaksearching'.

I have a proposition for you. This program will give you the choice of an AUTOMATIC peak search (performed by yours truely), or a MANUAL peak search (performed by you and corrected by me, to the best of my ability). I would like to take this opportunity to offer yet a third alternative that I think might appeal to you.

If you like, you can enter from the keyboard the following information :

1. The number of peaks in your spectrum.
2. The channel of each peak.
3. The counts in this channel.

I believe that this could save you some time in certain cases. Your choice ! Note, however, that in any case, the spectrum MUST reside in a tape file, and that you must supply me with the number of this file.

Would you like to try this ? YES

KEYBOARD ENTRY 'peaksearch' selected

```
OK !
What file is the spectrum in ? (Remember that the data
tape should now be in the 4051 internal tape drive).
Note that this must be an EVEN number !   File : 10

I read the following : We are entering peaks for the
sample SOIL SAMPLE #1 counted by KVH on 3/21/80 at 12:30 AM
The data consists of a 2048 channel spectrum.
Count time was 20000 seconds. Decay time was 45000 seconds

How many peaks do you want to enter ? 5   A number up to 50 may be entered.

Peak number 1

Peak channel : 511
Peak counts  : 187

Peak number 2

Peak channel : 610
Peak counts  : 152

Peak number 3

Peak channel : 911
Peak counts  : 86

Peak number 4

Peak channel : 1459
Peak counts  : 234

Peak number 5

Peak channel : 1760

Peak counts  : 25
Done.................
```

Note: Peak channel and peak counts must be entered!

Here we have entered all peaks we wished. Again, the program in file #5 of the program tape will be called automatically.

Note: As always, peaks must be entered from low to high energy. Reference numbers are assigned to the peaks in the order that they are entered.

Here are the results of the KEYBOARD ENTRY peak search.

*** Peak Search Results ***

These are the results of a Keyboard E peak search. The search
was for sample SOIL SAMPLE #1 acquired by KVH on 3/21/80 at 12:30 AM.
The spectra consists of 2048 channels.
Decay time was 45000 seconds. Count time was 20000 seconds.

The energies we calculated on the basis of the calibration
labeled : CALIBRATION FOR SOIL #1 which was performed by KVH
on 3/21/80 using the isotopes COBALT-60, CESIUM-137

| Peak Number | Channel | Energy (KeV) | Peak Counts |
|---|---|---|---|
| 1 | 511 | 510.870 | 187 |
| 2 | 610 | 609.966 | 152 |
| 3 | 911 | 911.259 | 86 |
| 4 | 1459 | 1459.791 | 234 |
| 5 | 1760 | 1761.084 | 25 |

Here is a run of the Isotope Identification program. It is called by entering file number 7 to the directory program.

```
<<<<< Isotope Identification >>>>>

The SCRATCH DATA FILES tape should be in the 4924 tape
drive, and the PROGRAM TAPE should be in the 4051.


You must now enter an 'acceptance' range in Kev
The number you enter is used in the following way.

Say you enter the number 1. This means that an energy
in the library that is within +- 1 KeV of an energy
output from the peak search program will satisfy the
requirement for an energy 'match', and therefore, the
assignment of the library gamma emitting isotope to the
peak in the spectrum being analyzed.

A value between 1 and 1.5 is recommended.

Enter the KeV range for isotope acceptance : 1.1
```

Any non-negative number is accepted. A number in the recommended range is advised.

This is the only user data input to this program.

Here are the results provided by this run of the Isotope Identification program.

```
Qualitative Analysis for sample SOIL SAMPLE #1

Spectrum acquired by KUH on 3/21/80 at 12:30 AM
Spectrum length : 2048 channels.
Sample count time : 20000 seconds. Decay time : 45000 seconds.

Tentative gamma assignment : Expected energy :  1460.700 KeV
                             Measured energy :  1459.791 KeV

                             Isotope  : K-40
                             Halflife : 1.3E+9 Y

Tentative gamma assignment : Expected energy :   609.300 KeV
                             Measured energy :   609.966 KeV

                             Isotope  : RA-226
                             Halflife : 1620 Y

End of library.....finished !
```

Run of the Quantitative Analysis 1: Select ROI's program. This program is called by entering the file number 8 to the directory program.

```
### Quantitative Analysis : Comparator method ###

Note * PROGRAM LIMITATIONS *

ROI's may not be processed in the following ranges :

Peak channels  <21 or >1003 in a 1024 channel spectrum
               <21 or >2027      2048
               <21 or >4075      4096
```

The user must adhere to the ROI constraints listed above!

```
How many samples do you want to analyze ? No more than
10 samples may be analyzed per program run. Include
the standard when entering this number : 4
```

Enter a number 2 through 10. Note that all samples must reside on a single Spectrum Data tape.

The standard counts as sample number 1.

```
Enter the number of the file containing the standard spectrum : 2
```

The number of the file containing the information on the standard must be entered here.

```
Enter:

Number of file for sample 2 : 10
Number of file for sample 3 : 8
Number of file for sample 4 : 12
```

Here enter the file numbers of the samples to be analyzed, in any order.

```
Put the SPECTRUM DATA TAPE in the 4051 internal tape
drive, and the SCRATCH DATA FILES tape in the 4924 tape
drive.

Press RETURN to continue.
```

I need some information now. How many peaks do you want to perform an analysis on ? A maximum of 10 peaks is allowed : 3

Enter the number of peaks to be used in the analysis program (maximum of 10).

I am next going to ask you to enter the following information FOR EACH PEAK.

* Peak channel
* ISOTOPE corresponding to this peak
* isotope halflife IN SECONDS
* ELEMENT corresponding to this isotope
* amount of this ELEMENT in the standard
* the UNITS of the above amount

It is best to have this information prepared before running the program.

NOTICE that all time values must be entered in SECONDS. We will now exit the program to give you a chance to make any calculations that may be necessary. To resume program execution, press USER DEFINABLE KEY ■ 8.

Half-life values must be entered in SECONDS.

2.58$3600
9288

Here the user may use the 4051 as a 'super calculator' to make any necessary calculations. To continue the program, press UDK #7.

We are back !!! Press RETURN to continue (be sure that you have recorded any numbers you may have calculated).

Notice that at this point, the user must press the RETURN key to continue.

Now you must enter the channels of the peaks. To avoid frustration, enter these numbers in ASCENDING ORDER !
Peak channel for peak number 1 : 848
Peak channel for peak number 2 : 1810
Peak channel for peak number 3 : 2111

Enter the peak channel for each peak to be used. Enter these values in ASCENDING ORDER!

Here the user must enter the required information for each peak as prompted. Note that the peak being processed is identified.

```
Enter the following information for the peaks
Peak number 1 in channel 848
1. ISOTOPE corresponding to peak : MANGANESE-56
2. The halflife of this isotope IN SECONDS : 9288
3. The ELEMENT in the standard corresponding to this isotope : MANGANESE
4. The AMOUNT of this element in the standard : 75
5. The UNITS corresponding to the above amount : % SOLUTION
```

Items 2 and 4 must be numerical entries. Items 1, 3 and 5 may be entered in any format the user wishes.

Three peaks were requested for processing in this program. In this case, all peaks belonged to the same isotope. This is not a requirement. Each peak may belong to a different isotope. The next two pages show the entries for the remaining two peaks.

```
Peak number 2 in channel 1818
ISOTOPE corresponding to peak : MANGANESE-56
The halflife of this isotope IN SECONDS : 9288
The ELEMENT in the standard corresponding to this isotope : MANGANESE
The AMOUNT of this element in the standard : 75
The UNITS corresponding to the above amount : % SOLUTION

Peak number 3 in channel 2111
ISOTOPE corresponding to peak : MANGANESE-56
The halflife of this isotope IN SECONDS : 9288
The ELEMENT in the standard corresponding to this isotope : MANGANESE
The AMOUNT of this element in the standard : 75
The UNITS corresponding to the above amount : % SOLUTION
```

Here the first and last channels to be used for a peak region-of-interest are entered for peak #1.

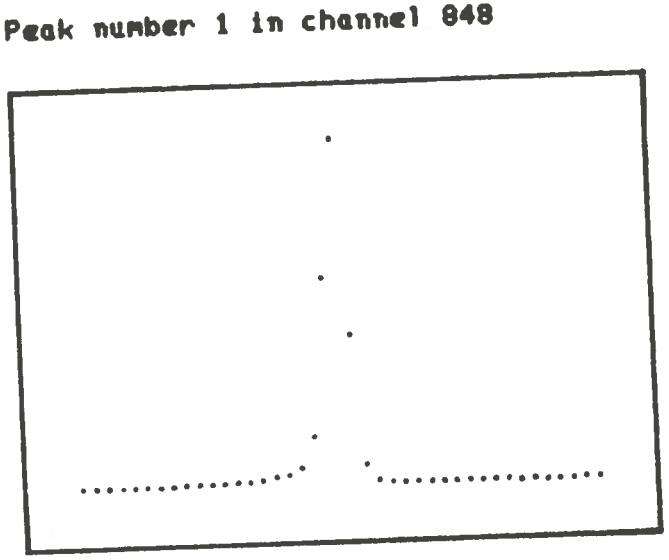
```
You requested a peak channel > 2027. This means that we
must have a 4096 channel spectra available in each sample
case, and that we will have to set our ROI in two passes.
Press UDK 10 to begin.
      UDK 5 to enter a point.
      UDK 9 when done.

UDK :
1 moves cursor up
2 moves cursor left
3 moves cursor right
4 moves cursor down.
```

The user uses the user-definable keys to move the arrow cursor around the plot. Point FIRST at the channel to begin the ROI, then at the channel to end it.

```
Peak channel  : 848

Begin channel : 841
End channel   : 854
```

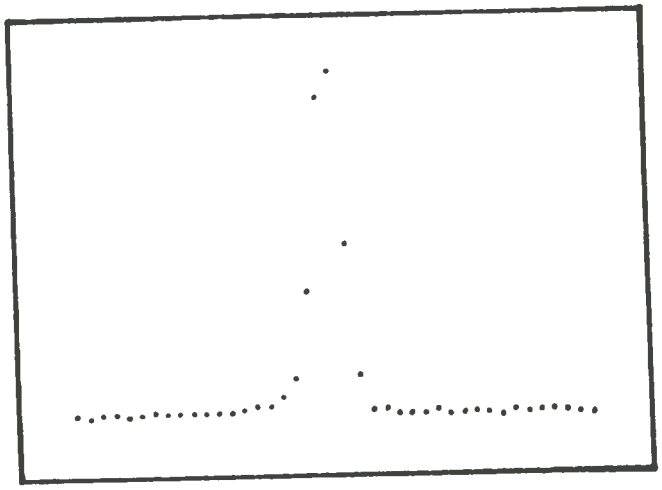



This process repeats until all requested peaks have been processed. The next two pages show the display during the selection of ROI's for the last two peaks requested.

```
Press UDK 10 to begin.
      UDK 5 to enter a point.
      UDK 9 when done.

UDK :
1 moves cursor up
2 moves cursor left
3 moves cursor right
4 moves cursor down.
```

Peak number 2 in channel 1810



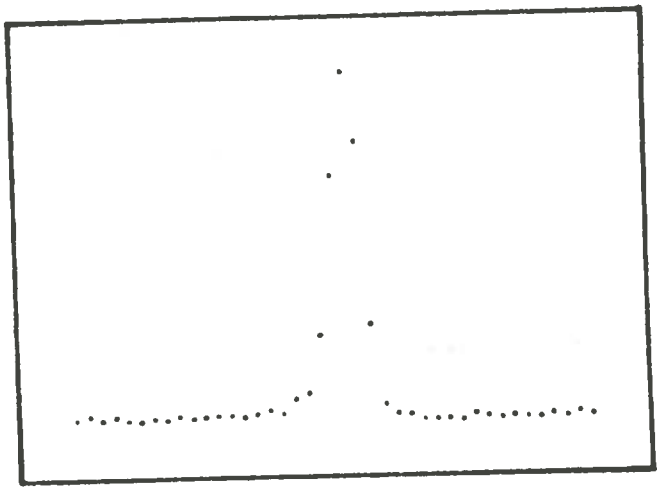
```
Peak channel  : 1810

Begin channel : 1803
End channel   : 1816
```

Press UDK 10 to begin.
      UDK 5 to enter a point.
      UDK 9 when done.

UDK :
1 moves cursor up
2 moves cursor left
3 moves cursor right
4 moves cursor down.

Peak number 3 in channel 2111



Peak channel  : 2111

Begin channel : 2103
End channel   : 2119

Put the PROGRAM TAPE in the 4051 internal tape drive.

Press RETURN to continue.

Run of program number 9. This program is called automatically, but may be called from the directory if desired.

```
Quantitative Analysis~~~Comparator Method

Put the SPECTRUM DATA TAPE in the 4051 internal tape drive.
Put the SCRATCH DATA FILES tape in the 4924 tape drive.

Press RETURN to continue.........
```

The ROI select program terminates by automatically calling the program in file number 9 of the program tape.

No user input data is required by this program.

These are the results produced by the quantitative analysis routines. Note that the first sample listed is the standard sample. This reflects the data entered by the user.

♦♦♦♦♦ Quantitative Analysis Results ♦♦♦♦♦

>>>Sample : Mn/Sand Sample 4 (Standard)

Spectrum length : 4096
Count time : 400 seconds
Decay time : 50 seconds
Acquired by KVH on 2/27/80 at 12:18 pm

| Element | Amount | Isotope Measured |
|---|---|---|
| MANGANESE | 75.00 % SOLUTION | MANGANESE-56 |
| MANGANESE | 75.00 % SOLN | MANGANESE-56 |
| MANGANESE | 75.00 % SOLUTION | MANGANESE-56 |

>>>Sample : Mn/Sand Sample 3

Spectrum length : 4096
Count time : 272 seconds
Decay time : 80 seconds
Acquired by KVH on 2/27/80 at 1:23 pm

| Element | Amount | Isotope Measured |
|---|---|---|
| MANGANESE | 50.01 % SOLUTION | MANGANESE-56 |
| MANGANESE | 51.29 % SOLN | MANGANESE-56 |
| MANGANESE | 48.41 % SOLUTION | MANGANESE-56 |

```
>>>Sample : Mn/Sand Sample 1

Spectrum length : 4096
Count time      : 400 seconds
Decay time      : 40 seconds
Acquired by KUH on 2/27/80 at 1:08 pm

     Element              Amount                    Isotope Measured

     MANGANESE            0.00 % SOLUTION           MANGANESE-56
     MANGANESE            1.07 % SOLN               MANGANESE-56
     MANGANESE            0.00 % SOLUTION           MANGANESE-56

>>>Sample : Mn/Sand Sample 6

Spectrum length : 4096
Count time      : 179 seconds
Decay time      : 85 seconds
Acquired by KUH on 2/27/80 at 1:37 pm

     Element              Amount                    Isotope Measured

     MANGANESE          128.70 % SOLUTION           MANGANESE-56
     MANGANESE          126.17 % SOLN               MANGANESE-56
     MANGANESE          140.26 % SOLUTION           MANGANESE-56

Put the PROGRAM TAPE in the 4051 internal tape drive.
```

Run of the List Data Tape Contents program. This program is called from the directory by entering the file number 10.

```
$$$$$ Data Tape Contents $$$$$

Put the SPECTRUM DATA TAPE in the 4051 internal tape drive.

Press RETURN to continue.

CCCCCCCCCC  File : 2  JJJJJJJJJJ

Contents : A 4096 channel spectra labeled Mn/Sand Sample 4
Spectrum acqusition time : 12:18 pm on 2/27/80
Acquired by : KVH       Decay time : 50 seconds.

CCCCCCCCCC  File : 4  JJJJJJJJJJ

Contents : A 4096 channel spectra labeled Mn/Sand Sample 2
Spectrum acqusition time : 12:33 PM on 2/27/80
Acquired by : KVH       Decay time : 35 seconds.

CCCCCCCCCC  File : 6  JJJJJJJJJJ

Contents : A 4096 channel spectra labeled Mn/Sand Sample 7
Spectrum acqusition time : 12:51 pm on 2/27/80
Acquired by : KVH       Decay time : 60 seconds.

CCCCCCCCCC  File : 8  JJJJJJJJJJ

Contents : A 4096 channel spectra labeled Mn/Sand Sample 1
Spectrum acqusition time : 1:08 pm on 2/27/80
Acquired by : KVH       Decay time : 40 seconds.

CCCCCCCCCC  File : 10  JJJJJJJJJJ

Contents : A 4096 channel spectra labeled Mn/Sand Sample 3
Spectrum acqusition time : 1:23 pm on 2/27/80
Acquired by : KVH       Decay time : 80 seconds.
```

CCCCCCCCCC File : 12 JJJJJJJJJJ

Contents : A 4096 channel spectra labeled Mn/Sand Sample 6
Spectrum acqusition time : 1:37 pm on 2/27/80
Acquired by : KVH Decay time : 85 seconds.

CCCCCCCCCC File : 14 JJJJJJJJJJ

Contents : A 2048 channel spectra labeled CO-60,CS-137 calibration
Spectrum acqusition time : 4:01 am on 3/14/80
Acquired by : KVH Decay time : 0 seconds.

CCCCCCCCCC File : 16 JJJJJJJJJJ

Contents : A 2048 channel spectra labeled Mn-54 test sample
Spectrum acqusition time : 4:05 am on 3/14/80
Acquired by : KVH Decay time : 0 seconds.

CCCCCCCCCC File : 18 JJJJJJJJJJ

Contents : A 2048 channel spectra labeled Ba-133 test sample
Spectrum acqusition time : 4:11 am on 3/14/80
Acquired by : KVH Decay time : 0 seconds.

CCCCCCCCCC File : 20 JJJJJJJJJJ

Contents : A 2048 channel spectra labeled Na-22 test sample
Spectrum acqusition time : 4:17 am on 3/14/80
Acquired by : KVH Decay time : 0 seconds.

CCCCCCCCCC File : 22 JJJJJJJJJJ

Contents : A 1024 channel spectra labeled TEST FILE CAPACITY
Spectrum acqusition time : 22222 on 22222

```
Acquired by : KVH       Decay time : 0 seconds.

CCCCCCCCCC  File : 24  JJJJJJJJJJ

Contents : A 1024 channel spectra labeled TEST FILE CAPACITY
Spectrum acqusition time : 22222 on 22222
Acquired by : KVH       Decay time : 0 seconds.

**** THIS TAPE IS FULL ****

End of files on this tape.
```

Note the message to the user indicating that the data tape scanned is full.

# APPENDIX E

## PROGRAM LISTINGS

```
100 REM.....menu program
110 PAGE
120 WINDOW 0,130,0,100
130 VIEWPORT 0,130,0,100
140 A$="***** MENU *****"
150 MOVE 65,95
160 FOR I=1 TO LEN(A$)/2
170 PRINT "H_";
180 NEXT I
190 PRINT A$
200 PRINT "J_G_G_G_"
210 PRINT 1;".........Directory"
215 PRINT
220 PRINT 2;".........Receive Spectrum from ORTEC"
225 PRINT
230 PRINT 3;".........Calibration Routine"
235 PRINT
240 PRINT 4;".........Peak Search"
245 PRINT
250 PRINT 5;".........List Results of Peak Search"
255 PRINT
260 PRINT 6;".........Isotope Library"
265 PRINT
270 PRINT 7;".........Isotope Identification"
275 PRINT
280 PRINT 8;".........Quantitative Analysis 1 : Select ROI's"
285 PRINT
290 PRINT 9;".........Quantitative Analysis Module 2"
305 PRINT
310 PRINT 10;".........Display Data Tape Contents"
311 PRINT
312 PRINT 11;".........***** LAST *****";
320 PRINT "G_G_G_G_G_G_G_G_"
330 PRINT "J_Would you like to run a program ? ";
340 INPUT A$
350 IF A$="y" OR A$="yes" THEN 370
360 END
370 PRINT "J_G_Enter file number : ";
380 INPUT F
390 FIND F
400 OLD
410 END
```

Note: In these listings, control characters that are normally represented by an underscored uppercase character are represented in these listings by an uppercase character followed by an underscore; for example "G" is represented by "G_".

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=NSHAG.THESIS.DATA                                (TWO     )

1 INIT
2 GO TO 100
32 REM.....here we are returning to the program after user calculations
33 GO TO 700
100 REM.....PROGRAM TO RECEIVE DATA FROM ORTEC
110 INIT
120 L$="no"
130 N$="no"
140 PRINT "L_    H_H_H_     ¬DATA DUMP¬     H_H_H_    G_G_G_G_G_J_J_"
150 PRINT "J_J_G_PUT THE SPECTRUM DATA TAPE IN THE 4051 INTERNAL";
160 PRINT " TAPE DRIVEG_G_G_"
170 PRINT "J_J_J_Press RETURN to continue. "
180 INPUT Z$
190 PAGE
200 PRINT "Do you want to recycle the tape ? ";
210 INPUT H$
220 IF H$="Y" OR H$="YES" THEN 1100
230 PRINT "J_Do you want to reuse an existing file ? ";
240 INPUT H$
250 IF H$="y" OR H$="yes" THEN 1530
260 PRINT "J_L_THIS TAPE MUST BE WRITE ENABLED TO RECEIVE DATA !G_G_G_"
270 PRINT "J_NOTE : G_G_G_G_G_";
280 PRINT " All regions of interest MUST BE CLEARED on the ORTEC MCA"
290 PRINT "before data transfer. Failure to have all ROI cleared will"
300 PRINT "result in data being LOST DURING TRANSFER !. This data is "
310 PRINT "NOT recoverable. This is the responsibility of the USER. "
320 PRINT "If an incomplete transfer takes place, it WILL NOT be "
330 PRINT "detected by this computer ( I'm human, too ! ). So, do this"
340 PRINT "NOW, without fail ! Then press RETURN to continue.G_G_G_G_J_";
350 INPUT Z$
360 PRINT "J_G_Another note ! If a magnetic tape error #54 is received"
370 PRINT "at any time, it means that there is not room on the tape"
380 PRINT "to store another file of the size you specified. In that"
390 PRINT "case you may :1. Use another data tape.2. Recycle this";
400 PRINT " tape.3. Reuse an existing file OF THE PROPER SIZE !"
410 PRINT "J_Also note that an error of this type will terminate the "
420 PRINT "program. It can be restarted by typing RUN then pressing"
430 PRINT "the RETURN key."
440 PRINT "J_Press RETURN to continue."
445 INPUT Z$
450 PRINT "J_Enter the spectrum identification label : ";
460 INPUT F$
470 IF L$="Y" OR L$="YES" THEN 520
480 PRINT "J_How many channels of data are in the spectrum ? "
490 PRINT "Valid entries are 1024, 2048, and 4096.  Enter : ";
500 INPUT A1
510 IF A1<>1024 AND A1<>2048 AND A1<>4096 THEN 480
520 PRINT "J_Enter your initials : ";
530 INPUT G$
540 PRINT "J_Enter today's date : ";
550 INPUT I$
560 PRINT "J_Enter the time : ";
570 INPUT K$
580 FOR K8=1 TO 100
590 NEXT K8
600 PAGE
610 PRINT "J_J_G_You must now enter a decay time for the sample for later"
```

```
620 PRINT "use in the quantitative analysis program. If you do not plan"
630 PRINT "to perform a quantitative analysis, or if the decay time is"
640 PRINT "unimportant ( as is the case with very long halflife ";
650 PRINT "isotopes ),you may enter a decay time of 0."
660 PRINT "J_NOTE * This decay time must be entered in SECONDS."
670 PRINT "J_If you need to make a calculation, do so now. When you are"
680 PRINT "done, press USER DEFINABLE KEY #8 to resume the program."
690 END
700 PRINT "J_G_We have returned ! Did you record any calculations that"
710 PRINT "made ? Press RETURN to continue."
720 INPUT Z$
730 PRINT "J_J_Enter the sample decay time in SECONDS : ";
740 INPUT Z1
750 CALL "cminit"
760 CALL "rate",2400,0,2
770 CALL "rstrin","","  ",""
780 IF L$="y" OR L$="yes" THEN 810
790 IF N$="y" OR N$="yes" THEN 810
800 GOSUB 1370
810 FIND F1-1
820 REM.....the following writes 1) the sample label, 2) the sampler's
830 REM.....initials, 3) date, 4) time, 5) # channels in spectrum
840 REM.....to the file preceeding the spectrum
850 PRINT @33:F$
860 PRINT @33:G$
870 PRINT @33:I$
880 PRINT @33:K$
890 PRINT @33:A1
900 REM.....also write the sample decay time to the file
910 PRINT @33:Z1
920 FIND F1
930 PAGE
940 PRINT "We are ready to transfer data."
950 PRINT "J_J_Set the ORTEC front panel controls to ** TYPE OUT ** "
960 PRINT "and ** FULL SPECTRUM **"
970 PRINT "J_Remember : the data displayed on the ORTEC MCA screen while"
980 PRINT "in CRT mode is the data that will be dumped !"
990 PRINT "J_When the switches are set, press the ORTEC I/O button."
1000 PRINT "J_Numbers will flash on the screen while the transfer is in "
1010 PRINT "progress. When they stop, press the brown BREAK key on the "
1020 PRINT "4051, then the RETURN TO BASIC key (user-definale key #5 )."
1030 PRINT "J_Pressing the BREAK key generates an error message. Ignore"
1040 PRINT "it."
1050 CALL "dtrecv"
1060 PRINT "L_J_J_G_G_Transfer complete."
1070 PRINT "J_J_Spectrum for sample ";F$;" consists of ";A1;" channels"
1080 PRINT "of infomation in tape file number ";F1;"."
1081 PRINT "J_J_If you wish to dump another spectrum, this program"
1082 PRINT "can be rerun by typing RUN and pressing the RETURN key."
1083 PRINT "J_If you wish to run another program in the package, put"
1084 PRINT "the PROGRAM TAPE in the 4051 and press AUTO LOAD."
1085 FIND 0
1090 END
1100 PRINT "J_J_G_G_ARE YOU SURE!_H_H_H_____ ??? This will delete all or part"
1110 PRINT "of the data now on the tape. ";
1120 INPUT L$
1130 IF L$="Y" OR L$="YES" THEN 1150
1140 GO TO 260
1150 PRINT "J_J_.....OK....but remember you said to !"
1160 PRINT "G_G_G_G_"
1170 PRINT "L_J_G_Enter the number of the beginning file to be deleted."
```

```
1180 PRINT "J_G_G_G_This number must be an EVEN number. : ";
1190 INPUT F2
1200 PRINT "J_G_CHECK : Did you enter an EVEN number ? "
1210 PRINT "You entered the number : ";F2;"  ";
1220 INPUT Q$
1230 IF Q$="n" OR Q$="no" THEN 1170
1240 PRINT "J_Enter the number of channels in the first spectrum to"
1250 PRINT "be dumped to this tape : ";
1260 INPUT A1
1270 FIND F2-1
1280 MARK 1,100
1290 FIND F2
1300 MARK 1,A1*8
1310 PRINT "G_G_G_Done !"
1320 FOR I=1 TO 300
1330 NEXT I
1340 F1=F2
1350 GO TO 260
1360 END
1370 REM.....
1380 F1=1
1390 PRINT @33,0:0,0,1
1400 FIND F1
1410 INPUT @33:A$
1420 B$=SEG(A$,9,1)
1430 IF B$="1" THEN 1460
1440 F1=F1+1
1450 GO TO 1400
1460 PRINT @33,0:0,0,0
1470 FIND F1
1480 MARK 1,100
1490 F1=F1+1
1500 FIND F1
1510 MARK 1,A1*8
1520 RETURN
1530 PRINT "J_The file to be reused must be the proper size !"
1540 PRINT "J_If you are not sure of the existing file sizes, press"
1550 PRINT "the BREAK key to exit the program, then use the TLIST"
1560 PRINT "statement to look at the file structure."
1570 PRINT "J_Proper file sizes are :"
1580 PRINT "J_            8192 bytes for a 1024 channel spectrum"
1590 PRINT "           16384 bytes for a 2048 channel spectrum"
1600 PRINT "           32768 bytes for a 4096 channel spectrum"
1610 PRINT "J_Press RETURN to continue."
1620 INPUT Z$
1630 PRINT "L_Enter the number of the spectrum data file to be reused."
1640 PRINT "J_This must be a EVEN number . Use file : ";
1650 INPUT F1
1660 PRINT "J_You said to reuse file ";F1
1670 PRINT "J_Is this correct ? ";
1680 INPUT M$
1690 IF M$="y" OR M$="yes" THEN 260
1700 GO TO 1630
1710 END
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=NSHAG.THESIS.DATA                                    (THREE   )

100 INIT
105 PRINT @32,26:3
110 PAGE
120 REM.....calibration routine
130 REM.....all input data is manual from the keyboard
140 REM.....an optional plot will be made available1 in the future
150 REM.....for now use 4924 as i/o device
160 DIM A$(72),B$(72),C$(72),D$(72)
170 REM.....x array for input channels; y array for energies
180 REM.....allow for 20 input peaks
190 DIM X(20),Y(20)
200 X=0
210 Y=0
220 REM.....initialize counter
230 N=0
240 PRINT "G_*** Energy calibration routine ***"
250 PRINT "J_G_Put the SCRATCH DATA FILES tape in the 4924 tape drive."
260 PRINT "J_Press RETURN to continue."
270 INPUT Z$
280 PRINT "J_G_G_Note : This program package currently holds only one,"
290 PRINT "the most recent, calibration entered. This calibration is"
300 PRINT "used to process the results of a peak search program run,"
310 PRINT "so the results of an isotope identification program run"
320 PRINT "also depend on the calibration data currently in storage."
330 PRINT "J_For this reason, the user is STRONGLY advised to retain"
340 PRINT "a copy of the calibration data entered, as well as a list"
350 PRINT "of the samples run under this calibration. This will "
360 PRINT "allow the user to reanalyze the samples at a later time,"
370 PRINT "merely by first running the calibration program and "
380 PRINT "entering the correct calibration information.J_"
390 PRINT "Press RETURN to continue.";
400 INPUT Z$
410 PRINT "J_Enter calibration reference label : ";
420 INPUT A$
430 PRINT "J_Enter calibration date : ";
440 INPUT B$
450 PRINT "J_Enter your initials : ";
460 INPUT C$
470 PRINT "J_Enter calibration sources used, all on one line please."
480 INPUT D$
490 REM.....now enter energy,channel information
510 PRINT "G_L_Enter calibration data as prompted."
520 PRINT
530 PRINT "*************************************************************"
                                                                      *"
540 PRINT "*
550 PRINT "* Note : All energies in this program package must be      *"
560 PRINT "* entered in keV.Remember this when entering energies     *"
570 PRINT "* in this program and in other programs where a user      *"
580 PRINT "* supplied energy is requested !                          *"
590 PRINT "*
600 PRINT "*************************************************************"
610 PRINT "J_To terminate input, input a channel number 0."
620 PRINT "Up to 20 calibration peaks may be entered."
630 PRINT "At least 2 peaks MUST be entered !"
635 FOR I=1 TO 20
640 PRINT "G_J_Peak number ";I;": *Channel : ";
650 INPUT X(I)
```

```
660 IF X(I)=0 THEN 710
670 PRINT "J_                    *Energy  : ";
680 INPUT Y(I)
685 PRINT "J_";
690 N=N+1
700 NEXT I
710 S=0
720 T=0
730 U=0
740 V=0
750 FOR I=1 TO N
760 U=X(I)^2+U
770 V=X(I)*Y(I)+V
780 S=X(I)+S
790 T=Y(I)+T
800 NEXT I
810 B=(T*U-S*V)/(N*U-S*S)
820 M=(N*V-S*T)/(N*U-S*S)
830 REM
840 PRINT "J_J_The calibration equation is : "
850 PRINT USING 9000:M,B
855 FOR X4=1 TO 1000
856 NEXT X4
860 COPY
870 PRINT @32,26:0
880 REM.....write data to tape
890 FIND @2:8
900 PRINT @2:A$
910 PRINT @2:B$
920 PRINT @2:C$
930 PRINT @2:D$
940 PRINT @2:N,M,B
950 PRINT "J_J_G_G_G_Done..........."
960 FIND 1
970 OLD
980 END
9000 IMAGE 1,"Energy (keV) = ",fd.3d," * channel + ",fd.3d
```

```
**** TSO FOREGROUND HARDCOPY ****                          (FOUR    )
DSNAME=NSHAG.THESIS.DATA

1 REM udk definitions
2 INIT
3 GO TO 100
4 REM - udk #1
5 RMOVE 0,A2
6 RETURN
8 REM - udk #2
9 RMOVE -A1,0
10 RETURN
12 REM - udk #3
13 RMOVE A1,0
14 RETURN
20 REM - udk #5
21 REM - process peak
22 GOSUB 4140
24 REM - udk#6
25 RMOVE 0,-A2
26 RETURN
28 REM.....calibration performed
29 GO TO 640
36 REM - exit search
37 REM - udk #9
38 GO TO 4340
39 REM - below is to begin manual search - udk #10
40 GOSUB 3970
41 PRINT @32,24:"|";
42 GO TO 41
44 REM - udk #11
45 RMOVE 0,50*A2
46 RETURN
48 REM - udk #12
49 RMOVE -50*A1,0
50 RETURN
52 REM - udk #13
53 RMOVE 50*A1,0
54 RETURN
64 REM - udk #16
65 RMOVE 0,-50*A2
66 RETURN
100 ON SRQ THEN 4600
110 REM initialize parameters
120 P$="noqrok"
130 REM
140 H=0
150 P1=0
160 P2=0
170 P3=0
180 P4=0
190 P5=0
200 REM.....if going to read/write char strings to tape,best to
210 REM.....dimension them first....may cause problems otherwise
220 REM c7 is peak counter
230 C7=1
240 REM R is ROI counter
250 R=1
260 REM define device addresses
270 REM for now use #2 for read/write....33 for program only
```

```
280 T1=33
290 T2=2
300 REM define viewport here....use 1/2 screen
310 DATA 0,130,0,80
320 READ V1,V2,V3,V4
330 V1=V1+3*1.79
340 V3=V3+5*2.82
350 V4=V4-3*2.82
360 VIEWPORT V1,V2,V3,V4
370 REM next few lines are temporary...define labels,title
380 E$="channel"
390 F$="events"
400 REM dimension variables to hold search results
410 DIM J1(50),J2(50)
420 J1=0
430 J2=0
440 REM....O.K...all is initialized
450 REM enter input data file number
460 PRINT "G_L_*** Peak Search ***"
470 PRINT "J_Put the SPECTRUM DATA TAPE in the 4051 internal tape drive."
480 PRINT "G_"
490 PRINT "J_Put the SCRATCH DATA FILES tape in the 4924 tape drive.G_"
500 PRINT "J_Press RETURN to continue."
510 INPUT Z$
520 PRINT "J_G_G_G_NOTE : Before this program is run, the calibration"
530 PRINT "program must be run, where the user (YOU) must enter the"
540 PRINT "proper calibration data for the sample to be analyzed. The"
550 PRINT "program need only be run once if all samples were taken"
560 PRINT "using the same calibration. Running the program before the"
570 PRINT "search assures having the proper data available to the"
580 PRINT "program. So, it is a VERY good idea for you to always make"
590 PRINT "a note of which set of calibration data goes with which "
600 PRINT "samples. If you need to do this, put the program tape in"
610 PRINT "the 4051 internal tape drive and press AUTO LOAD."
620 PRINT "J_If this has been taken care of, press user-definable key #7"
630 END
640 PRINT "L_G_G_G_I have a proposition for you. This program will give you"
650 PRINT "the choice of an AUTOMATIC peak search (performed by yours"
660 PRINT "truely), or a MANUAL peak search (performed by you and"
670 PRINT "corrected by me, to the best of my ability). I would like"
680 PRINT "to take this opportunity to offer yet a third alternative"
690 PRINT "that I think might appeal to you. "
700 PRINT "J_If you like, you can enter from the keyboard the following"
710 PRINT "information :"
720 PRINT "J_J_1. The number of peaks in your spectrum."
730 PRINT "2. The channel of each peak."
740 PRINT "3. The counts in this channel."
750 PRINT "J_I believe that this could save you some time in certain"
760 PRINT "cases. Your choice ! Note, however, that in any case, the"
770 PRINT "spectrum MUST resile in a tape file, and that you must "
780 PRINT "supply me with the number of this file."
790 PRINT "J_Would you like to try this ? ";
800 INPUT Z$
810 IF Z$="Y" OR Z$="YES" THEN 5380
820 PRINT "G_G_G_G_G_G_L_"
830 PRINT "......forget I asked..........."
840 PRINT "J_Enter spectrum file number. This must be an EVEN number : ";
850 INPUT F
860 REM select full or roi spec search
870 PRINT "J_Select full spectrum (FULL) or ROI (ROI) search : ";
880 INPUT A$
```

```
890 IF A$="roi" THEN 1000
900 REM.....here FULL selected...treat as one large roi
910 GOSUB 4610
920 REM set roi bounds
930 R1=1
940 R2=C8
950 REM write to roi select file
960 FIND @2:2
970 PRINT @2:R,R1,R2,999,0,0
980 CLOSE @T2:
990 GO TO 1380
1000 REM roi search selected
1010 PRINT "G_"
1020 FOR I=1 TO 10
1030 PRINT "                    *** ROI selected ***K_"
1040 NEXT I
1050 PRINT "J_"
1060 PRINT "J_NOTE *** VALID ROI RANGES ***"
1070 PRINT "J_Valid ROI entries are : 1 through 1023 for a 1024 channel";
1080 PRINT " spectrum."
1090 PRINT "                          1 through 2047 for a 2048 channel";
1100 PRINT " spectrum."
1110 PRINT "                          1 through 4095 for a 4096 channel";
1120 PRINT " spectrum."
1130 PRINT
1140 PRI "Any combination of channels is allowed, and ROI may overlap."
1150 PRI "BE SURE,however,to observe the upper and lower limits listed"
1160 PRINT "above. Failure to do so may result in an error !"
1170 FOR Y9=1 TO 4000
1180 NEXT Y9
1190 PRINT "G_G_G_"
1200 FIND @2:2
1210 PAGE
1220 PRINT "J_ROI number ";R
1230 PRINT "Begin with channel : ";
1240 INPUT R1
1250 PRINT "End with channel : ";
1260 INPUT R2
1270 REM write selection to tape
1280 PRINT @2:R,R1,R2
1290 PRINT "J_G_Another ROI ? ";
1300 INPUT B$
1310 IF B$="no" OR B$="n" THEN 1350
1320 REM increment ROI counter
1330 R=R+1
1340 GO TO 1220
1350 REM finished ROI input...write end numbers and close file
1360 PRINT @2:999,0,0
1370 CLOSE @2:
1380 REM.....choose AUTO or MANUAL peak search
1390 PRINT "G_G_L_Do you want AUTO or MANUAL peak search ? ";
1400 INPUT C$
1410 IF C$="auto" THEN 3270
1420 IF C$<>"manual" THEN 1390
1430 PRINT "L_G_G_G_G_You have seleted a MANUAL peak search. There are some"
1440 PRINT "things we need to discuss first."
1450 PRINT
1460 PRINT "First, remember this : YOU MAY ENTER NO MORE THAN 50 PEAKS."
1470 PRINT "J_Second , you will be using a pointer to specify peaks."
1480 PRINT "It is VERY important that you position the tip of the "
1490 PRI "pointer as close to the actual position of the peak point as"
```

```
1500 PRINT "possible.If you don't understand what I mean, talk to "
1510 PRINT "someone who has some experience running this program."
1520 PRINT "J_Next, it is much easier to accurately point to a peak if"
1530 PRINT "the plotted field is smaller. In other words, the accuracy"
1540 PRI "of the pointer is better when you try to pick out a peak from"
1550 PRINT "1000 plotted channels rather than 4095 plotted channels "
1560 PRINT "(about 4095/1000 times better !). So, rather than "
1570 PRINT "processing one large ROI, you might set"
1580 PRINT "up 4 ROI's. For example ROI #1 from channel 1 to 1000,"
1590 PRINT "ROI #2 from channel 1001 to 2000, ROI #3 from 2001 to 3000,"
1600 PRINT "and ROI #4 from 3001 to 4095. Of course, ROI's need not"
1610 PRINT "be distinct ; they can overlap. But it is best to do things"
1620 PRINT "in a neat and orderly way. If you do overlap ROI's be sure"
1630 PRINT "that the following constraint is applied !"
1640 FOR T9=1 TO 6000
1650 NEXT T9
1660 PRINT "J_G_G_G_ ********** ALWAYS (always!) enter peaks from left"
1670 PRINT "to right (from low energy to high energy). DO NOT skip"
1680 PRINT "around ! One needs to be careful when using overlapping"
1690 PRINT "ROI's."
1700 PRINT "J_Do you want to start over and do the search using ROI's ?"
1710 PRINT "Enter NO if you have already seleted an ROI search. ";
1720 INPUT Z$
1730 IF Z$="yes" OR Z$="y" THEN 1750
1740 GO TO 1830
1750 PRINT
1760 FOR W7=1 TO 25
1770 PRINT "A wise person sits before me."
1780 PRINT "K_";
1790 NEXT W7
1800 PRINT
1810 RUN
1820 END
1830 REM find ROI file
1840 PRINT
1850 FOR W7=1 TO 25
1860 PRINT "You have been informed !"
1870 PRINT "K_";
1880 NEXT W7
1890 PRINT
1900 FIND @2:2
1910 REM input region paramters
1920 INPUT @2:R,R1,R2
1930 REM find spectrum data file
1940 PAGE
1950 REM.....input spectrum info
1960 FIND F-1
1970 INPUT @33:D$
1980 REM.....d$=label,G$=initials,h$=date,j$=time of count,c8=channels
1990 INPUT @33:G$
2000 INPUT @33:H$
2010 INPUT @33:J$
2020 INPUT @33:C8
2030 REM.....we also want to input the decay time
2040 INPUT @33:D6
2050 C8=C8-1
2060 REM.....
2070 FIND F
2080 REM input spectrum information...now only time
2090 INPUT @33:T
2100 REM find roi max
```

```
2110 IF A$="full" THEN 2170
2120 IF R1=1 THEN 2170
2130 REM skip channels of no interest
2140 FOR I=1 TO R1-1
2150 INPUT @33:B
2160 NEXT I
2170 REM initialize max count flag
2180 M=0
2190 REM first pass through ROI for max
2200 FOR I=R1 TO R2
2210 INPUT @33:A
2220 IF A>M THEN 2240
2230 GO TO 2250
2240 GOSUB 3940
2250 NEXT I
2260 REM define window
2270 WINDOW R1,R2,0,M
2280 REM go to subroutine to add axes,tics,labels...
2290 GOSUB 3320
2300 REM now plot roi
2310 REM find spectrum data file
2320 FIND F
2330 REM - input spectrum descriptors
2340 INPUT @33:T
2350 REM skip no interest channels
2360 IF A$="full" OR R1=1 THEN 2400
2370 FOR I=1 TO R1-1
2380 INPUT @33:A
2390 NEXT I
2400 MOVE R1,0
2410 FOR I=R1 TO R2
2420 INPUT @33:A
2430 MOVE I,A
2440 DRAW I,A
2450 NEXT I
2460 REM branch to search here
2470 IF C$="auto" THEN 2500
2480 GO TO 4070
2490 REM
2500 REM....auto search here
2510 SET NOKEY
2520 HOME
2530 REM.....
2540 REM.....
2550 REM find ROI select file
2560 IF R>1 THEN 2610
2570 FIND @2:2
2580 REM input region parameters
2590 INPUT @2:R,R1,R2
2600 REM.....find spectrum data file
2610 FIND F
2620 REM.....input spectrum descriptors
2630 INPUT @33:T
2640 REM.....skip no interest channels
2650 IF A$="full" OR R1=1 THEN 2690
2660 FOR I=1 TO R1-1
2670 INPUT @33:A
2680 NEXT I
2690 REM input channels of interest and process
2700 FOR I=R1 TO R2
2710 INPUT @33:P1
```

```
2720 H=(P1+P2+P3+P4+P5)/5
2730 IF P3>M9*SQR(H)+H THEN 2750
2740 GO TO 2760
2750 IF P3=>P5 AND P3=>P4 AND P3=>P2 AND P3=>P1 THEN 3090
2760 P5=P4
2770 P4=P3
2780 P3=P2
2790 P2=P1
2800 IF C7=51 THEN 2830
2810 REM...above to avoid >50 peak failure.
2820 NEXT I
2830 REM .....go to exit routine
2840 GO TO 4340
2850 REM....here is end of all searches....write results to tape
2860 DELETE 1,2850
2870 C7=C7-1
2880 REM find peak search results file
2890 FIND @2:3
2900 IF C$="Manual" THEN 4710
2910 PRINT @2:C$
2920 PRINT @2:T,C7
2930 PRINT @2:J1
2940 PRINT @2:J2
2950 PRINT @2:D$
2960 PRINT @2:G$
2970 PRINT @2:H$
2980 PRINT @2:J$
2990 PRINT @2:C8,D6
3000 HOME
3010 PAGE
3020 PRINT "Enter the program tape in the 4051 internal tape drive."
3030 PRINT "J_J_Press RETURN to continue.G_G_G_G_G_";
3040 INPUT Z$
3050 PAGE
3060 FIND 5
3070 OLD
3080 END
3090 REM....the automatic search found a peak
3100 REM....ELIMINATE FALSE PEAK AT BEGINNING OF SEARCH REGION
3110 IF P4=0 AND P5=0 THEN 3260
3120 REM....peak channel = i-2
3130 R$=CHR(127)
3140 J1(C7)=I-2
3150 J2(C7)=P3
3160 REM.....label peak
3170 MOVE I-2,P3
3180 V5=(R2-R1+1)/(V2-V1)*1.55/2
3190 RMOVE -V5,V5
3200 PRINT "K_K_";C7;
3210 PRINT "H_J_";
3220 IF C7>9 THEN 4560
3230 PRINT R$;
3240 REM.....increment peak counter
3250 C7=C7+1
3260 GO TO 2760
3270 PRINT "J_You must now enter an AUTO search sensitivity parameter."
3280 PRINT "We would recommend a value between 2.8 and 3.2  Enter : ";
3290 INPUT M9
3300 PAGE
3310 GO TO 1890
3320 REM
```

```
3330 R3=R2-R1+1
3340 REM.....set tics
3350 R3=R3/10
3360 R3=INT(R3)
3370 REM.....r3=xtics,r4=ytics
3380 R4=INT(H/10)
3390 REM.....draw axes
3400 AXIS R3,R4,R1,0
3410 REM.....here we will write additional available data
3420 HOME                                              counted by : ";
3430 PRINT "
3440 PRINT G$                                                  at : ";
3450 PRINT "
3460 PRINT J$                                                  on : ";
3470 PRINT "
3480 PRINT H$                                          count time :";
3490 PRINT "
3500 PRINT T;" seconds"                                decay time :";
3510 PRINT "
3520 PRINT D6;" seconds"                             spectrum length :";
3530 PRINT "
3540 PRINT C8+1;" channels"
3550 REM.....add title
3560 HOME
3570 IF 1.79*LEN(D$)>V2-V1 THEN 3650
3580 R5=R2-R1+1
3590 MOVE R1+R5/2,H
3600 PRINT "K_";
3610 FOR I=1 TO LEN(D$)/2
3620 PRINT "H_";
3630 NEXT I
3640 PRINT D$
3650 REM.....add horizontal label
3660 MOVE R1+R5/2,0
3670 PRINT "J_J_";
3680 FOR I=1 TO LEN(E$)/2
3690 PRINT "H_";
3700 NEXT I
3710 PRINT E$
3720 REM.....add vertical axis label
3730 J=LEN(F$)/2
3740 MOVE R1,H/2
3750 FOR I=1 TO J
3760 PRINT "K_";
3770 NEXT I
3780 PRINT "H_H_";
3790 DIM S$(1)
3800 FOR I=1 TO LEN(F$)
3810 S$=SEG(F$,I,1)
3820 PRINT S$;
3830 PRINT "H_J_";
3840 NEXT I
3850 REM.....print axes data
3860 MOVE R1,0
3870 PRINT "J_J_Axis crossing : ";R1;",";0
3880 MOVE R1,0
3890 PRINT "J_J_J_X tic interval : ";R3
3900 MOVE R1,0
3910 PRINT "J_J_J_J_Y tic interval : ";R4
3920 PRINT "G_G_G_";
3930 RETURN
```

```
3940 REM.....subroutine to set max ROI count
3950 M=A
3960 RETURN
3970 REM.....UDK stmt 40 subroutine
3980 REM.....window height=m,width=r2-r1
3990 A1=(R2-R1)*1.0E-3
4000 A2=M*0.005
4010 REM.....initial pointer placement
4020 GIN G1,G2
4030 MOVE G1,G2
4040 REM.....change font
4050 PRINT @32,18:5
4060 RETURN
4070 REM.....manual peak search routine
4080 HOME
4090 PRINT "Press UDK 10 to begin search."
4100 PRINT "Press UDK  5 to enter a peak."
4105 PRINT "Press UDK  9 to terminate search."
4110 PRINT "UDK :"
4111 PRINT "1 moves cursor up ( #11:up*50 )"
4112 PRINT "2              left ( #12:  *50 )"
4113 PRINT "3             right ( #13:  *50 )"
4114 PRINT "6              down ( #16:  *50 )"
4120 SET KEY
4130 END
4140 REM.....manual peak search process
4150 REM.....pointer is positioned
4160 GIN G1,G2
4170 J1(C7)=INT(G1)
4180 J2(C7)=INT(G2)
4190 REM.....label peak
4200 PRINT @32,18:0
4210 MOVE G1,G2
4220 R$=CHR(127)
4230 REM.....calc 1/2 character width in UDU's
4240 V5=(R2-R1+1)/(V2-V1)*1.55/2
4250 RMOVE -V5,V5
4260 PRINT "K_K_";C7;
4270 PRINT "H_J_";
4280 IF C7>9 THEN 4580
4290 PRINT R$;
4300 PRINT @32,18:5
4310 REM.....increment peak counter
4320 C7=C7+1
4330 GO TO 41
4340 REM.....exit here from auto or manual roi peak search
4350 COPY
4360 IF A$="full" THEN 4510
4370 REM.....save current roi no. Input next in sequence from tape
4380 R9=R
4390 FIND @2:2
4400 INPUT @2:R,R1,R2
4410 IF R=999 THEN 4510
4420 IF R<=R9 THEN 4400
4430 REM.....if we get here we have another roi to process
4440 M=0
4450 P1=0
4460 P2=0
4470 P3=0
4480 P4=0
4490 P5=0
```

```
4500 GO TO 1930
4510 REM....end of ROI's to process
4520 REM.....reset font - disable UDK's
4530 PRINT @32,18:0
4540 SET NOKEY
4550 GO TO 2850
4560 PRINT "H_";
4570 GO TO 3230
4580 PRINT "H_";
4590 GO TO 4290
4600 INPUT @2:L
4610 REM.....input spectrum descriptors for AUTO search
4620 FIND F-1
4630 INPUT @33:D$
4640 INPUT @33:G$
4650 INPUT @33:H$
4660 INPUT @33:J$
4670 INPUT @33:C8
4680 C8=C8-1
4690 RETURN
4700 END
4710 REM.....here we correct results of Manual P.S.
4720 PRINT "L_The manual peak search is inherently inaccurate."
4730 PRINT "We will take this opportunity to correct it.J_J_J_J_J_"
4740 PRINT "Hang on a minute.........................."
4750 IF C8>1023 THEN 4850
4760 IF C8>2047 THEN 4920
4770 REM.....here we have 1024 channels
4780 DELETE A
4790 DIM A(1023)
4800 FIND F
4810 INPUT @33:B8
4820 INPUT @33:A
4830 GO TO 5090
4840 REM.....here we have 2048 channels
4850 DELETE A
4860 DIM A(2047)
4870 FIND F
4880 INPUT @33:B8
4890 INPUT @33:A
4900 GO TO 5090
4910 REM.....here we have 4096 channels
4920 DELETE A
4930 DIM A(2060)
4940 FIND F
4950 INPUT @33:B8
4960 INPUT @33:A
4970 GO TO 5090
4980 REM.....here for second pass
4990 DELETE A
5000 DIM A(2035)
5010 FIND F
5020 INPUT @33:B8
5030 INPUT @33:A
5040 DELETE A
5050 DIM A(2060)
5060 INPUT @33:A
5070 REM.....the above gives us channels 2036-4095
5080 GO TO 5240
5090 REM.....here we are ready to process for max
5100 REM.....here also our channel register is ok
```

```
5110 FOR I=1 TO C7
5120 K=J2(I)-J2(I)/2
5130 K1=J1(I)
5140 IF K1>2044 THEN 4980
5150 FOR J=K1-3 TO K1+3
5160 IF A(J)>K THEN 5200
5170 NEXT J
5180 NEXT I
5190 GO TO 2910
5200 J2(I)=A(J)
5210 K=J2(I)
5220 J1(I)=J
5230 GO TO 5170
5240 REM.....here 2nd part 4096#
5250 FOR I1=I TO C7
5260 K=J2(I1)-J2(I1)/2
5270 K1=J1(I1)
5280 FOR J=K1-3-2035 TO K1+3-2035
5290 IF A(J)>K THEN 5330
5300 NEXT J
5310 NEXT I1
5320 GO TO 2910
5330 J2(I1)=A(J)
5340 K=J2(I1)
5350 J1(I1)=J+2035
5360 GO TO 5300
5370 END
5380 REM.....here user will manually input channels,counts
5390 PRINT "L_OK !"
5400 PRINT "G_What file is the spectrum in ? (Remember that the data"
5410 PRINT "tape should now be in the 4051 internal tape drive)."
5420 PRINT "Note that this must be an EVEN number !   File : ";
5430 INPUT F
5440 FIND F-1
5450 INPUT @33:D$
5460 INPUT @33:G$
5470 INPUT @33:H$
5480 INPUT @33:J$
5490 INPUT @33:C8
5500 INPUT @33:D6
5510 FIND F
5520 INPUT @33:T
5530 CLOSE
5540 C$="Keyboard Entry"
5550 PRINT "J_G_I read the following : We are entering peaks for the "
5560 PRINT "sample ";D$;" counted by ";G$;" on ";H$;" at ";J$
5570 PRINT "The data consists of a ";C8;" channel spectrum."
5580 PRINT "Count time was ";T;" seconds. Decay time was ";D6;" seconds"
5590 PRINT "J_How many peaks do you want to enter ? ";
5600 INPUT C7
5610 FOR I=1 TO C7
5620 PRINT "J_Peak number ";I
5630 PRINT "J_Peak channel : ";
5640 INPUT J1(I)
5650 PRINT "Peak counts  : ";
5660 INPUT J2(I)
5670 NEXT I
5680 PRINT "G_G_G_Done..................."
5690 GO TO 2880
5700 END
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=NSHAG.THESIS.DATA                                    (FIVE     )

100 INIT
110 REM.....j3 will hold peak energies
120 DIM J3(50)
130 REM.....input results of peak search
140 DIM A$(10),J1(50),J2(50)
150 J1=0
160 J2=0
170 J3=0
180 FIND @2:3
190 INPUT @2:A$
200 INPUT @2:T,C7
210 INPUT @2:J1
220 INPUT @2:J2
230 INPUT @2:X$
240 INPUT @2:I$
250 INPUT @2:X$
260 INPUT @2:Y$
270 INPUT @2:M$
280 INPUT @2:O$
290 INPUT @2:V,W
300 REM.....input calibration results
310 FIND @2:8
320 DIM B$(72),C$(72),D$(72),E$(72)
330 INPUT @2:B$,C$,D$,E$,N,M,B
340 REM.....calculate peak energies
350 FOR I=1 TO C7
360 J3(I)=M*J1(I)+B
370 NEXT I
380 REM.....write all information to another file
390 REM.....a$=auto/manual;b$=calib label;c$=calib date;d$=initials
400 REM.....e$=calib iso list;t=count time;c7=# peaks found;j1=channels
410 REM.....j2=counts;n=# calib peaks;m=cal slope;b=cal intercept
420 FIND @2:9
430 PRINT @2:A$
440 PRINT @2:B$
450 PRINT @2:C$
460 PRINT @2:D$
470 PRINT @2:E$
480 PRINT @2:T,C7
490 PRINT @2:J1
500 PRINT @2:J2
510 PRINT @2:J3
520 PRINT @2:N,M,B
530 PRINT @2:X$
540 PRINT @2:Y$
550 PRINT @2:M$
560 PRINT @2:O$
570 PRINT @2:V,W
580 REM.....produce a printout of the results
590 PRINT @32,26:3
600 PRINT "L_G_* Peak Search Results *"
610 PRINT "J_These are the results of a ";A$;" peak search. The search"
620 PRINT "was for sample ";I$;" acquired by ";Y$;" on ";M$;" at ";O$;
630 PRINT "."
640 PRINT "The spectra consists of ";V;" channels. Decay time was";
650 PRINT W;" seconds.";
655 PRINT " Count time was ";T;" seconds."
```

```
660 PRINT "J_The energies we calculated on the basis of the calibration"
670 PRINT "labeled : ";B$;" which was performed by ";D$
680 PRINT "on ";C$;" using the isotopes ";E$
690 PRINT "J_J_J_"
700 PRINT USING 750:"Peak Number","Channel","Energy (KeV)","Peak Counts"
710 FOR I=1 TO C7
720 PRINT USING 760:I,J1(I),J3(I),J2(I)
730 NEXT I
740 GO TO 770
750 IMAGE 6x,11a,5x,7a,5x,12a,5x,11a
760 IMAGE11,11x,2d,10x,4d,8x,5d.3d,9x,c7d
770 PRINT @32,26:0
780 FIND 1
790 COPY
800 OLD
810 END
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=HSHAG.THESIS.DATA                                    (SIX      )

500 DATA 3103.8,"S-37",5.06,"H",100,99999,99999,0,0
510 DATA 3084.2,"CA-49",8.8,"H",91,4071,8,99998,99999,"P","SC-49"
520 DATA 1780
530 DATA 2754,"NA-24",15,"H",100,1368.6,100,99999,99999,0,0
540 DATA 2614.5,"TH-228",1.91,"Y",36,860.5,5,727.3,7,583.2,31,510.7
550 DATA 10,300.1,4,277.4,2,238.6,49,99999,99999,0,0
560 DATA 2167.5,"CL-38",37.3,"H",44,1642.7,33,99999,99999,0,0
570 DATA 1836,"RB-88",17.8,"H",22,2677.9,2,898,14,99999,99999,0,0
580 DATA 1836,"Y-88",107,"D",99,898,93,99999,99999,0,0
590 DATA 1808.7,"AL-26",740000,"Y",100,1129.6,3,511,163
595 DATA 99999,99999,0,0
600 DATA 1780,"SC-49",57.5,"H",0.03,99998,99999,"D","CA-49",3084.2
610 DATA 1779,"AL-28",2.24,"H",100,99998,99999,"D","MG-28",1342
620 DATA 1633.5,"F-20",11.6,"S",100,99999,99999,0,0
630 DATA 1596.6,"LA-140",40.2,"H",96,925.2,7,867.8,6,815.8,23
640 DATA 487,45,328.8,21,99998,99999,"D","BA-140",537.3
650 DATA 1575.8,"PR-142",19.1,"H",4,99999,99999,0,0
660 DATA 1524.7,"K-42",12.4,"H",18,312.7,0.4,99999,99999,0,0
670 DATA 1481.7,"NI-65",2.52,"H",25,1115.4,16,366.3,5,99999,99999,0,0
680 DATA 1460.7,"K-40",1.3E+9,"Y",11,99999,99999,0,0
710 DATA 1434,"V-52",3.73,"H",100,99999,99999,0,0
720 DATA 1408,"EU-152",13.5,"Y",21,1112.1,13,1085.8,11,964,15
730 DATA 778.9,13,344.3,27,244.7,7,121.8,28,99999,99999,0,0
740 DATA 1345.8,"CU-64",12.8,"H",0.5,511,36,99999,99999,0,0
750 DATA 1342,"MG-28",20.9,"H",53,941.5,38,399.8,37,30.6,66
760 DATA 99998,99999,"P","AL-28",1779
770 DATA 1332.5,"CO-60",5.27,"Y",100,1173.2,100,99999,99999,0,0
780 DATA 1311.9,"SC-48",1.83,"D",100,1037.5,100,983.4,100
790 DATA 175.4,6,99999,99999,0,0
800 DATA 1297.1,"CA-47",4.54,"D",75,807.9,7,489.2,7,99998,99999
810 DATA "P","SC-47",159.4
820 DATA 1293.5,"AR-41",1.83,"H",99,99999,99999,0,0
830 DATA 1274.5,"NA-22",2.6,"Y",100,511,181,99999,99999,0,0
840 DATA 1221.4,"TA-182",111,"D",29,1189.1,18,1121.3,37,222.1,8
850 DATA 100.1,15,67.8,44,99999,99999,0,0
860 DATA 1156.95,"SC-44",3.93,"H",100,1499.4,1,511,189,99998
870 DATA 99999,"D","TI-44",78.3
880 DATA 1122.6,"ND-151",12,"H",33,1180.9,10,423.5,6,255.7,13
890 DATA 138.9,7,116.8,45,99998,99999,"P","PM-151",339.9
900 DATA 1115.5,"ZN-65",244.1,"D",51,511,3,99999,99999,0,0
910 DATA 1099.2,"FE-59",44.6,"D",56,1291.6,44,192.3,3,99999,99999,0,0
920 DATA 1097.3,"IN-116M",54.2,"H",56,2112.1,16,1507.4,10,1293.5,84
930 DATA 818.7,12,416.9,29,99999,99999,0,0
940 DATA 1077.4,"GA-66",68,"H",3,511,179,99999,99999,0,0
950 DATA 1076.6,"RB-86",18.7,"D",9,99999,99999,0,0
960 DATA 1067.2,"SN-125",9.6,"D",4,2002.1,1088.9,4,915.7,1,822.6,2
970 DATA 469.9,0.4,99998,99999,"P","SB-125",427.9
980 DATA 1039.2,"CU-66",5.1,"H",9,99999,99999,0,0
990 DATA 983.5,"V-48",16,"D",100,1312,97,944.1,8,511,100
1000 DATA 99999,99999,0,0
1010 DATA 889.3,"SC-46",83.9,"D",100,1120.5,100,99999,99999,0,0
1020 DATA 879.3,"TB-160",72,"D",30,1271.9,8,1177.9,15,966.1,25
1030 DATA 962.1,10,298.6,27,197.5,86.8,14,99999,99999,0,0
1040 DATA 871.1,"NB-94",20000,"Y",100,702.6,100,99999,99999,0,0
1080 DATA 846.8,"MN-56",2.58,"H",99,2113.1,14,1810.7,27
1090 DATA 99999,99999,0,0
1100 DATA 843.8,"MG-27",9.5,"H",72,1014.2,28,99999,99999,0,0
```

```
1110 DATA 841.6,"EU-152M",9.3,"H",13,1389,1,1314.7,1
1120 DATA 963.3,12,344.3,3,121.7,8,99999,99999,0,0
1130 DATA 834.8,"MN-54",312.5,"D",100,99999,99999,0,0
1140 DATA 834,"GA-72",14.1,"H",96,2507.6,13,2490.9,8,2201.7
1150 DATA 26,1861,5,1596.7,4,1464,4,1050.7,7,894.2,10
1160 DATA 629.9,25,600.9,5,99999,99999,0,0
1170 DATA 810.8,"CO-58",70.8,"D",99,511,30,99999,99999,0,0
1180 DATA 795.8,"CS-134",2.06,"Y",85,801.9,9,604.7,98
1190 DATA 569.4,8,99999,99999,0,0
1200 DATA 776.5,"BR-82",35.3,"H",83,1474.8,17,1317.5,27,1044,27
1210 DATA 827.8,24,698.3,28,619,43,554.3,71,99999,99999,0,0
1220 DATA 773.7,"TE-131M",1.2,"D",46,1125.5,15,1206.6,12,882.8,7
1230 DATA 852.3,26,793.8,16,782.5,8,665.1,5,452.4,7,334.3,11
1240 DATA 240.9,8,200.7,8,149.8,24,102.2,8,99998,99999
1250 DATA "P","I-131",364.5
1260 DATA 765.8,"NB-95",35.1,"D",100,99998,99999,"D","ZR-95",756.9
1270 DATA 756.9,"ZR-95",65,"D",55,724.2,44,99998,99999
1280 DATA "P","NB-95",765.8
1290 DATA 739.5,"MO-99",66.2,"H",13,777.9,5,366.4,1,181.7,7
1300 DATA 99998,99999,"P","TC-99M",140.5
1310 DATA 724.2,"RU-105",4.43,"H",45,676.3,15,469.4,18,316.5,10
1320 DATA 262.9,7,129.7,5,99998,99999,"P","RH-105",319.2
1330 DATA 722.9,"AG-108M",127,"Y",91,614.3,91,433.9,90,79.1,5
1340 DATA 99999,99999,0,0
1350 DATA 696.5,"PR-144",17.3,"H",1.5,2185.7,0.8,99998,99999
1360 DATA "D","CE-144",133.5
1370 DATA 685.7,"W-187",24,"H",32,772.8,5,618.2,7,551.5,6,479.5
1380 DATA 27,134.2,10,99999,99999,0,0
1390 DATA 667.7,"I-132",2.3,"H",99,954.6,18,812.3,6,772.6,76
1400 DATA 670,5,630.2,14,522.6,16,505.9,15,99999,99999,0,0
1410 DATA 661.6,"BA-137M",2.55,"H",90,99998,99999,"D","CS-137",661.6
1420 DATA 661.6,"CS-137",30,"Y",90,99998,99999,"P","BA-137M",661.6
1430 DATA 658.1,"NB-97",74,"H",98,99998,99999,"D","ZR-97",507.8
1440 DATA 657.7,"AG-110M",252.4,"D",95,1505,13,1384.3,25
1450 DATA 937.5,34,884.7,73,818,7,764,22,687,16,677.6,11
1460 DATA 99999,99999,0,0
1470 DATA 633,"AG-108",2.42,"H",2,618.9,0.3,433.9,0.5,99999
1480 DATA 99999,0,0
1490 DATA 616.9,"BR-80",17.6,"H",7,666.3,1,511,5,99999,99999,0,0
1500 DATA 609.3,"RA-226",1620,"Y",47,2204.1,5,1764.5,17
1510 DATA 1238.2,6,1120.4,16,768.4,5,352,39,295.2,20,241.9,7
1520 DATA 99999,99999,0,0
1530 DATA 602.7,"SB-124",60.2,"D",98,2091,6,1691,49
1540 DATA 1368.1,5,722.8,11,645.8,7,99999,99999,0,0
1550 DATA 595.9,"AS-74",17.8,"D",60,634.8,15,511,56,99999,99999,0,0
1560 DATA 590.9,"MO-101",14.6,"H",21,1012.5,16,505.9,11,191.9,18
1570 DATA 99998,99999,"P","TC-101",306.8
1580 DATA 569.7,"BI-207",38,"Y",98,1770.2,7,1063.6,74,99999
1590 DATA 99999,0,0
1600 DATA 564,"SB-122",2.7,"D",71,1256.9,1,1140.6,1,692.8,4
1610 DATA 99999,99999,0,0
1620 DATA 559.1,"AS-76",26.3,"H",43,1216.2,4,657,6,99999,99999,0,0
1630 DATA 542.9,"PT-199",30,"M",11,493.8,4,317,4,246.4,1,185.8
1640 DATA 2,99998,99999,"P","AU-199",158.4
1650 DATA 537.3,"BA-140",12.8,"D",24,304.8,5,162.9,6,30,14
1660 DATA 99998,99999,"P","LA-140",1596.6
1670 DATA 536,"I-130",12.4,"H",99,1157.4,11,739.5,82,668.5,96
1680 DATA 418,34,99999,99999,0,0
1690 DATA 527.9,"CD-115",2.21,"D",28,492.3,8,260.9,2,99999,99999,0,0
1700 DATA 514,"SR-85",64.9,"D",98,99999,99999,0,0
1710 DATA 507.8,"ZR-97",16.9,"H",5,1750.5,1,1362.7,1,1148.3
```

```
1720 DATA 355.6,2,99998,99999,"P","NB-97",658.1
1730 DATA 497.1,"RU-103",39.4,"D",86,610.3,5,99999,99999,0,0
1740 DATA 496.3,"BA-131",11.8,"D",44,373.3,13,216.1,20,123.8,29
1750 DATA 99999,99999,0,0
1760 DATA 482.2,"HF-181",42.4,"D",86,345.9,14,136.3,6,133,43
1770 DATA 99999,99999,0,0
1780 DATA 477.6,"BE-7",53.3,"D",10,99999,99999,0,0
1790 DATA 459.5,"TE-129",70,"H",7,1083.8,0.6,487.3,1.4,278.4,0.6
1800 DATA 250.6,0.4,99998,99999,"P","I-129",39.6
1810 DATA 442.9,"I-128",25.1,"H",12,526.6,1,99999,99999,0,0
1820 DATA 438.6,"ZN-65M",13.8,"H",95,99999,99999,0,0
1830 DATA 427.9,"SB-125",2.77,"Y",30,636,11,606.7,5,600.6,18
1840 DATA 463.4,10,176.3,6,35.6,6,99998,99999,"D","SN-125",1067.2
1850 DATA 411.8,"AU-198",2.69,"D",95,675.9,1,99999,99999,0,0
1860 DATA 396.3,"YB-175",4.2,"D",7,282.5,3,113.5,2,99999,99999,0,0
1870 DATA 391.7,"IN-113M",1.66,"H",65,99998,99999,"D","SN-113",255.1
1880 DATA 388.5,"SR-87M",2.81,"H",82,99999,99999,0,0
1890 DATA 372.8,"K-43",22.6,"H",87,617.5,81,593.4,11,396.9,11
1900 DATA 99999,99999,0,0
1910 DATA 364.5,"I-131",8.04,"D",81,722.9,2,637.7,284.3,6,99998
1920 DATA 99999,"D","TE-131M",773.7
1930 DATA 363.5,"GD-159",18.6,"H",11,348,0.2,99999,99999,0,0
1940 DATA 356,"BA-133",10.5,"Y",62,383.9,9,302.9,19,276.4,7
1950 DATA 81,33,99999,99999,0,0
1960 DATA 343.6,"HF-175",70,"D",85,89.6,3,99999,99999,0,0
1970 DATA 342.2,"AG-111",7.45,"D",6,245.4,1,99999,99999,0,0
1980 DATA 339.9,"PM-151",28,"H",24,717.9,4,275.1,7,177.1,5,167.8
1990 DATA 10,99998,99999,"D","NB-151",1122.6
2000 DATA 332.3,"HF-180M",5.5,"H",94,500.7,13,443.2,82,215.2,82
2010 DATA 93.3,17,57.4,48,99999,99999,0,0
2020 DATA 332,"SN-125M",9.55,"H",97,99999,99999,0,0
2030 DATA 328.5,"IR-194",19.38,"H",13,293.4,3,99999,99999,0,0
2040 DATA 320.1,"CR-51",27.7,"D",10,99999,99999,0,0
2050 DATA 320,"TI-51",5.79,"H",95,928.6,5,608.4,2,99999,99999,0,0
2060 DATA 319.2,"RH-105",1.47,"D",20,306.3,5,99998,99999
2070 DATA "D","RU-105",724.2
2080 DATA 316.5,"IR-192",74.2,"D",86,612.4,5,604.4,9,468.1,51
2090 DATA 416.4,7,374.4,8,308.4,31,296,29,99999,99999,0,0
2100 DATA 308.1,"ER-171",7.52,"H",63,295.8,28,124,9
2110 DATA 111.6,23,99999,99999,0,0
2120 DATA 306.8,"TC-101",14,"H",90,545.1,5,127.2,2,99998
2130 DATA 99999,"D","MO-101",590.9
2140 DATA 293.2,"CE-143",1.37,"D",47,722,6,664.6,6,57.4,13
2150 DATA 99999,99999,0,0
2160 DATA 285.9,"PM-149",2.21,"D",3,99998,99999,"D","ND-149",211.3
2170 DATA 279.2,"HG-203",47,"D",81,99999,99999,0,0
2180 DATA 264.7,"SE-75",120,"D",60,400.6,12,279.5,25,136,57
2190 DATA 121.1,17,99999,99999,0,0
2200 DATA 264.6,"GE-75",82.8,"H",11,198.6,1,99999,99999,0,0
2210 DATA 264.4,"GE-77",11.3,"H",54,1085.2,6,631.8,7,558,16
2220 DATA 416.3,22,367.4,14,215.5,29,211,31,99998,99999
2230 DATA "P","AS-77",239
2240 DATA 255.1,"SN-113",115.2,"D",2,99998,99999,"P","IN-113M"
2250 DATA 391.7
2260 DATA 245.4,"CD-111M",48.6,"H",94,150.8,30,99999,99999,0,0
2270 DATA 245.3,"IN-111",2.83,"D",94,171.2,91,99999,99999,0,0
2280 DATA 239,"AS-77",38.8,"H",1.6,520.7,0.6,99998,99999
2290 DATA "D","GE-77",264.4
2300 DATA 231.7,"SR-85M",68,"H",87,151.2,13,99999,99999,0,0
2310 DATA 215.7,"RU-97",2.9,"D",88,324.5,24,99999,99999,0,0
2320 DATA 211.3,"ND-149",1.73,"H",27,654.8,7,540.5,8,423.6,9
```

```
2330 DATA 270.2,11,267,6,155.9,6,114.3,19,99998,99999
2340 DATA "P","PM-149",285.9
2350 DATA 208.4,"LU-177",6.71,"D",11,113,6,99999,99999,0,0
2360 DATA 202.5,"Y-90M",3.14,"H",97,479.4,91,99999,99999,0,0
2370 DATA 198,"YB-169",31.8,"D",35,307.7,10,177.2,22
2380 DATA 130.5,11,109.8,18,63.5,45,99999,99999,0,0
2390 DATA 190,"IN-114M",50,"D",18,725.2,5,558.4,5
2400 DATA 99999,99999,0,0
2410 DATA 184.6,"CU-67",61.9,"H",48,300.2,0.8,93.3,17,91.3,8
2420 DATA 99999,99999,0,0
2430 DATA 168.8,"FE-52",8.28,"H",100,511,112,99998,99999
2440 DATA "P","MN-52",1434
2450 DATA 167.4,"TL-201",73.5,"H",12,135.3,4,99999,99999,0,0
2460 DATA 165.9,"BA-139",82.7,"M",22,1420.5,0.3,99999,99999,0,0
2470 DATA 165.8,"CE-139",140,"D",80,99999,99999,0,0
2480 DATA 160.2,"SN-123M",40.1,"H",84,99999,99999,0,0
2490 DATA 159.4,"SC-47",3.42,"D",68,99998,99999,"D","CA-47",1297.1
2500 DATA 159,"TE-123M",120,"D",84,99999,99999,0,0
2510 DATA 158.4,"AU-199",3.14,"D",37,208.2,8,99998,99999,"D","PT-199"
2520 DATA 542.9
2530 DATA 155,"RE-188",16.7,"H",15,633.2,99999,99999,0,0
2540 DATA 149.7,"TE-131",25,"H",68,1147.4,6,997.4,4,602.2
2550 DATA 4,492.8,5,452.4,16,99998,99999,"P","I-131",364.5
2560 DATA 145.4,"CE-141",32.5,"D",48,99999,99999,0,0
2570 DATA 142.5,"SC-46M",18.7,"S",57,99999,99999,0,0
2580 DATA 140.5,"TC-99M",6,"H",90,99998,99999,"D","MO-99",739.5
2590 DATA 134,"HG-197M",24,"H",42,279.2,7,99999,99999,0,0
2600 DATA 133.5,"CE-144",284,"D",11,696.5,2,80.1,2,99998,99999
2610 DATA "P","PR-144",696.5
2620 DATA 129.4,"OS-191",15.4,"D",35,99999,99999,0,0
2630 DATA 127.4,"CS-134M",2.9,"H",14,99999,99999,0,0
2640 DATA 123.1,"EU-154",8.6,"Y",40,1274.5,34,1004.8,18
2650 DATA 996.3,11,873.3,11,723.3,19,247.7,7,99999,99999,0,0
2660 DATA 122.1,"CO-57",270.9,"D",86,136.5,11,14.4,10
2670 DATA 99999,99999,0,0
2680 DATA 108.2,"DY-165M",1.26,"H",3,515.2,2,99999,99999,0,0
2690 DATA 106.1,"NP-239",2.4,"D",23,277.6,14,228.2,11
2700 DATA 209.8,3,99998,99999,"D","U-239",74.6
2710 DATA 104.3,"SM-155",22,"H",73,245.7,4,141.4,2,41.5,17
2720 DATA 99998,99999,"P","EU-155",86.5
2730 DATA 103.2,"SM-153",46.8,"H",28,97.5,1,69.7,4,99999,99999,0,0
2740 DATA 98.9,"AU-195",183,"D",11,129.8,1,99999,99999,0,0
2750 DATA 98.9,"PT-195M",4.1,"D",11,129.8,1,99999,99999,0,0
2760 DATA 97.5,"GD-153",242,"D",37,103.2,27,69.6,13
2770 DATA 99999,99999,0,0
2780 DATA 94.6,"DY-165",139,"M",4,545.7,2,361.7,1,99999,99999,0,0
2790 DATA 93.3,"GA-67",78,"H",38,393.5,4,300.2,16,184.6,24
2800 DATA 99999,99999,0,0
2810 DATA 91.1,"ND-147",11.1,"D",28,531,13,99999,99999,0,0
2820 DATA 91.1,"ND-147",11.1,"D",28,531,13,99999,99999,0,0
2830 DATA 88.3,"LU-176M",3.69,"H",10,99999,99999,0,0
2840 DATA 88,"CD-109",4.53,"D",4,99999,99999,0,0
2850 DATA 88,"PD-109",13.5,"H",4,99999,99999,0,0
2860 DATA 86.5,"EU-155",1.8,"Y",34,105.3,22,99998,99999
2870 DATA "D","SM-155",104.3
2880 DATA 84.4,"TM-170",129,"D",3,99999,99999,0,0
2890 DATA 81,"XE-133",5.3,"D",37,79.6,0.2,99999,99999,0,0
2900 DATA 80.6,"HO-166",27,"H",6,1581.9,0.2,1379.4,1
2910 DATA 99999,99999,0,0
2920 DATA 78.3,"TI-44",47.3,"Y",95,67.9,88,99998,99999
2930 DATA "P","SC-44",1156.95
```

```
2940 DATA 77.4,"HG-197",65,"H",20,191.5,0.6,99999,99999,0,0
2950 DATA 74.6,"U-239",23.5,"M",51,43.5,4,99998,99999
2960 DATA "P","NP-239",106.1
2970 DATA 61.6,"SB-122M",4.2,"M",50,76.3,17,99999,99999,0,0
2980 DATA 59.5,"AM-241",433,"Y",35,26.4,3,99999,99999,0,0
2990 DATA 58.5,"CO-60M",10.5,"M",2,99999,99999,0,0
3000 DATA 51,"RH-104M",4.41,"M",47,775,0.2,555.8,0.2
3010 DATA 99999,99999,0,0
3020 DATA 46.5,"PB-210",22,"Y",4,99999,99999,0,0
3030 DATA 39.6,"I-129",1.57E+7,"Y",8,99999,99999,0,0
3040 DATA 38.7,"BR-80M",4.42,"M",36,99999,99999,0,0
3050 DATA 35.5,"I-125",60.1,"D",7,99999,99999,0,0
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=WSHAG.THESIS.DATA                                    (SEVEN    )

1 PAGE
3 GO TO 100
4 INIT
5 PAGE
6 GO TO 300
100 REM.....program to test isotope id routine.....first draft
101 INIT
110 PAGE
130 PRINT "<<<<< Isotope Identification >>>>>"
131 PRINT "J_The SCRATCH DATA FILES tape should be in the 4924 tape"
132 PRINT "drive, and the PROGRAM TAPE should be in the 4051."
140 PRINT "J_J_You must now enter an 'acceptance' range in Kev"
150 PRINT "The number you enter is used in the following way. "
160 PRINT "J_Say you enter the number 1. This means that an energy"
170 PRINT "in the library that is within +- 1 KeV of an energy"
180 PRINT "output from the peak search program will satisfy the"
190 PRINT "requirement for an energy 'match', and therefore, the"
200 PRINT "assignment of the library gamma emitting isotope to the"
210 PRINT "peak in the spectrum being analyzed.J_"
215 PRINT "A value between 1 and 1.5 is recommended."
220 PRINT "J_Enter the KeV range for isotope acceptance : ";
230 INPUT Y7
250 PRINT @32,26:3
260 REM
270 FIND 6
280 APPEND 300
290 REM.........LIBRARY BEGINS HERE
300 DATA 3103.8,"S-37",5.06,"M",100,99999,99999,0,0
310 REM.....
320 REM.....
330 REM.....DO NOT DELETE THE BELOW !!!!!.....................
340 DATA 99997,"dummy",1,"d",100,99999,99999
350 REM.......o.k.....let us pull in some real data here.....
360 DIM J1(50),J2(50),J3(50)
370 DIM A$(10),B$(72),C$(72),D$(72),E$(72)
380 J1=0
390 J2=0
400 J3=0
410 FIND @2:9
420 INPUT @2:A$,B$,C$,D$,E$,T,C7,J1,J2,J3,N,M,B
421 INPUT @2:X$
422 INPUT @2:Y$
423 INPUT @2:R$
424 INPUT @2:O$
425 INPUT @2:V,W
430 REM.....................................................
440 REM.....................................................
450 REM.....................................................
459 PAGE
460 PRINT
461 PRINT "Qualitative Analysis for sample ";X$
462 PRINT "J_Spectrum acquired by ";Y$;" on ";R$;" at ";O$
463 PRINT "Spectrum length : ";V;" channels."
464 PRINT "Sample count time : ";T;" seconds. Decay time : ";W;
465 PRINT " seconds."
466 PRINT
467 PRINT
```

```
470 REM
480 RESTORE 300
490 REM
500 REM
510 REM
520 READ J4
530 IF J4=0 THEN 1320
540 READ I$,T5,T$,A9
550 IF J4=99997 THEN 1070
560 REM
570 REM
580 REM
590 L9=J4+Y7
600 L8=J4-Y7
610 REM
620 REM
630 FOR I=1 TO C7
640 IF J3(I)=>L8 AND J3(I)<=L9 THEN 850
650 NEXT I
660 READ Z
670 IF Z=99999 THEN 1280
680 IF Z=99998 THEN 1260
690 IF Z=99997 THEN 1090
700 IF Z=0 THEN 1340
710 GO TO 660
720 GO TO 520
730 READ Q$,V$,C3
740 L5=C3+Y7
750 L4=C3-Y7
760 FOR K=1 TO C7
770 IF J3(K)=>L4 AND J3(K)<=L5 THEN 1160
780 NEXT K
790 GO TO 520
800 REM.......confirm gamma found
810 REM..................do not delete this line.............
820 PRINT USING 1370:C1
830 PRINT USING 1380:J3(L)
840 GO TO 980
850 REM.................................peak found
860 REM.................................ie,key gamma match
870 PRINT USING 1390:
880 PRINT "K_";
890 PRINT USING 1400:
900 PRINT USING 1360:J4
910 PRINT USING 1410:J3(I)
920 PRINT "J_                                        Isotope  : ";I$
930 PRINT "                                        Halflife : ";T5;" ";T$;"J_"
940 REM
950 REM
960 REM
970 PRINT ""
980 READ C1,C2
990 IF C1=99999 THEN 650
1000 IF C1=99998 THEN 730
1010 L7=C1+Y7
1020 L6=C1-Y7
1030 FOR L=1 TO C7
1040 IF J3(L)<=L7 AND J3(L)=>L6 THEN 800
1050 NEXT L
1060 GO TO 980
1070 PRINT "End of library......finished !"
```

```
1080 PRINT @32,26:0
1100 REM....delete stmt below must be changed as library grows
1110 REM.....................................................
1120 DELETE 270,2640
1130 FIND 1
1135 COPY
1140 OLD
1150 END
1160 REM.............................do not delete these 3 rems
1170 REM.....................................................
1180 REM.....................................................
1190 IF Q$="d" THEN 1300
1200 M$="Daughter"
1210 REM....target string
1220 PRINT "J_*** ";M$;" isotope peak found: Isotope : ";V$
1230 PRINT "                              Energy expected : ";C3;" KeV"
1240 PRINT "                              Energy measured : ";J3(K);" Kev"
1250 GO TO 520
1260 READ Z,M$,N$,O
1270 GO TO 520
1280 READ Z
1290 GO TO 520
1300 M$="Parent"
1310 GO TO 1210
1320 READ B9
1330 GO TO 520
1340 READ Z
1350 GO TO 520
1360 IMAGE"Tentative gamma assignment : Expected energy : ",5d.3d," KeV"
1370 IMAGE"Confirmation peak found :    Expected energy : ",5d.3d," KeV"
1380 IMAGE29x,"Measured energy : ",5d.3d," Kev"
1390 IMAGE 72(" ")
1400 IMAGE 72(" ")
1410 IMAGE29x,"Measured energy : ",5d.3d," KeV"
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=NSHAG.THESIS.DATA                                    (EIGHT    )

1 INIT
3 GO TO 100
4 RMOVE 0,R6/50
5 RETURN
8 RMOVE -0.5,0
9 RETURN
12 RMOVE 0.5,0
13 RETURN
20 GOSUB 2420
24 RMOVE 0,-R6/50
25 RETURN
32 REM.....this is return to program after calculations
33 GO TO 1110
40 GOSUB 2340
41 PRINT @32,24:R$
42 GO TO 41
100 REM
110 Z9=0
120 P2=1
125 O4=0
130 REM.....quantitative analysis program
140 REM.....
150 REM.....this program will do the following
160 REM.....
170 REM.....use FULL spectra stored on tape
180 REM.....the user will be expected to supply appropriate file numbers
190 REM.....read ONE of these spectra into memory and process it
200 REM.....to allow the user to establish his ROI's.
210 REM.....the ROI's so established will be processed as a peak
220 REM.....channel +- entered values. These +- values will remain
230 REM.....constant throughout the analysis, but the peak may shift
240 REM.....within set bounds (probably +- 3 channels).
250 REM.....when a second spectra is processed, the spectra will be
260 REM.....read into memory, as well as the previously set peak channel
270 REM.....and associated information on the peak. The maximum count
280 REM.....in the range of OLD PEAK +-3 will be assigned as the peak
290 REM.....channel for this spectrum. The ROI will then be set
300 REM.....based on our input ROI +- bounds to give same total width.
310 REM.....
320 REM.....all spectra used in an analysis must be the same length
330 REM.....due to memory constraints, 4096 channel spectra must be
340 REM.....processed in two parts, the first handling all peaks
350 REM.....<=2047, the second, all peaks 2048 or greater.
360 REM.....
370 REM.....
380 REM.....
390 REM.....let us get started
400 REM.....
410 PRINT "G_G_G_L_### Quantitative Analysis : Comparator method ###"
420 PRINT "J_G_Note * PROGRAM LIMITATIONS *"
430 PRINT "J_ROI's may not be processed in the following ranges :"
440 PRINT "J_Peak channels  <21 or >1003 in a 1024 channel spectrum"
450 PRINT "                 <21 or >2027      2048"
460 PRINT "                 <21 or >4075      4096"
470 PRINT "G_J_"
480 PRINT
490 PRINT "J_J_How many samples do you want to analyze ? No more than "
```

```
500 PRINT "10 samples may be analyzed per program run. Include "
510 PRINT "the standard when entering this number : ";
520 INPUT N
530 PRINT "J_The standard counts as sample number 1.J_"
540 PRINT "J_J_Enter the number of the file containing the standard ";
550 PRINT "spectrum : ";
560 DIM F1(N)
570 INPUT F1(1)
580 PRINT "J_Enter:J_"
590 FOR I=2 TO N
600 PRINT "Number of file for sample ";I;" : ";
610 INPUT F1(I)
620 NEXT I
630 REM.....ok.....let us find the standard spectrum description file
640 PRINT "G_G_G_L_Put the SPECTRUM DATA TAPE in the 4051 internal tape "
650 PRINT "drive, and the SCRATCH DATA FILES tape in the 4924 tape "
660 PRINT "drive.J_J_"
670 PRINT "Press RETURN to continue."
680 INPUT Z$
690 REM.....ok...we have the data tape
700 FIND F1(1)-1
710 REM.....now input the spectrum descriptors
720 INPUT @33:V$
730 INPUT @33:W$
740 INPUT @33:X$
750 INPUT @33:Y$
760 INPUT @33:A1
770 REM.....v$:label;w$:initials;x$:date;y$:time;.....a1=#channels
780 REM.....now we are ready to process the spectra to set ROI'S
790 REM.....remember that the variable a1 will tell us if we
800 REM.....have to process the spectrum in two parts
810 REM.....we also have another test
820 REM.....if no peaks of interest greater than 2047 are entered
830 REM.....we can also do it in one step
840 REM.....now let's give the user some instructions and get the
850 REM.....peak channels
860 PRINT "G_L_I need some information now. How many peaks do you want"
870 PRINT "to perform an analysis on ? A maximum of 10 peaks is "
880 PRINT "allowed : ";
890 INPUT N1
900 DIM P(N1)
910 DIM Q(N1)
920 DIM T(N1)
930 DIM D(N1)
940 DIM C(N1)
950 REM....p=pk chan;q=quantity;t=halflife;d=decay;c=count
960 REM.....now give the user a chance to make some calculations
970 PRINT "J_J_I am next going to ask you to enter the following"
980 PRINT "information FOR EACH PEAK."
990 PRINT
1000 PRINT "           * Peak channel"
1010 PRINT "           * ISOTOPE corresponding to this peak"
1020 PRINT "           * isotope halflife IN SECONDS"
1030 PRINT "           * ELEMENT corresponding to this isotope"
1040 PRINT "           * amount of this ELEMENT in the standard"
1050 PRINT "           * the UNITS of the above amount"
1060 PRINT "J_NOTICE that all time values must be entered in SECONDS. We"
1070 PRINT "will now exit the program to give you a chance to make any"
1080 PRINT "calculations that may be necessary. To resume program "
1090 PRINT "execution, press USER DEFINABLE KEY # 8."
1100 END
```

```
1110 PRI "J_G_We are back !!! Press RETURN to continue (be sure that you"
1120 PRINT "have recorded any numbers you may have calculated)."
1130 INPUT Z$
1140 PRINT "G_L_"
1150 PRINT "Now you must enter the channels of the peaks. To avoid"
1160 PRINT "frustration, enter these numbers in ASCENDING ORDER !"
1170 FOR I=1 TO N1
1180 PRINT "Peak channel for peak number ";I;" : ";
1190 INPUT P(I)
1200 NEXT I
1210 REM.....we have to get those character string to be input
1220 REM.....out of the way....let us use scratch file #13
1230 FIND @2:13
1240 REM.....ok...let us get the info
1250 PAGE
1260 PRINT "G_Enter the following information for the peaks       "
1270 FOR I=1 TO N1
1280 PRINT "Peak number ";I;" in channel ";P(I)
1290 PRINT "J_ISOTOPE corresponding to peak : ";
1300 INPUT U$
1310 PRINT "J_The halflife of this isotope IN SECONDS : ";
1320 INPUT T(I)
1330 PRINT "J_The ELEMENT in the standard corresponding to this isotope";
1340 PRINT " : ";
1350 INPUT R$
1360 PRINT "J_The AMOUNT of this element in the standard : ";
1370 INPUT Q(I)
1380 PRINT "J_The UNITS corresponding to the above amount : ";
1390 INPUT S$
1400 REM.....write identifiers and character strings to file 13
1410 PRINT @2:I,P(I)
1420 PRINT @2:U$
1430 PRINT @2:R$
1440 PRINT @2:S$
1450 FOR K=1 TO 100
1460 NEXT K
1470 PRINT "G_L_"
1480 NEXT I
1490 REM.....remember....sometime we have to read in the decay
1500 REM.....times from the spectrum data tape...we can get the
1510 REM.....count times from the spectra
1520 REM.....
1530 REM.....now let's see if we have to make one or two passes
1540 M=0
1550 FOR I=1 TO N1
1560 M=P(I) MAX M
1570 NEXT I
1580 DELETE 100,1580
1590 IF M>2027 THEN 1940
1600 REM.....regardless, here we begin our first pass
1610 REM.....dimension our array to hold the data
1620 REM.....but delete it first, in case this is our second pass
1630 IF A1=2048 OR A1=4096 THEN 3320
1640 IF A1=1024 THEN 3350
1650 PRINT "L_G_G_G_%%%% FATAL ERROR %%%%% INVALID SPECTRUM LENGTH"
1660 END
1670 REM.....ok...check to see if it is first or second pass
1680 IF P2=2 THEN 3050
1690 REM.....here we are on our first pass
1700 FIND F1(1)
1710 INPUT @33:Z6
```

```
1720 INPUT @33:A
1730 REM.....we need to dimension our variables to hold
1740 REM.....our beginning (R1) and ending (R2) channels
1750 REM.....for each peak
1760 DIM R1(N1),R2(N1)
1770 R1=1.0E+10
1780 R2=0
1790 REM.....we will worry about computations later
1800 REM.....here we actually begin to set our ROI's
1810 REM.....for now, only GIN mode available
1820 GO TO 1990
1830 REM
1840 REM.....here n>2027 so we have to make two passes
1850 REM.....but, let us make as sure as possible that this is possible
1860 IF N>2047 AND A1<4096 THEN 1930
1870 REM.....the above is our # passes indicator
1880 PRINT "J_You requested a peak channel > 2027. This means that we"
1890 PRINT "must have a 4096 channel spectra available in each sample"
1900 PRINT "case, and that we will have to set our ROI in two passes."
1910 GO TO 1600
1920 END
1930 PRINT "G_L_Guess what ? You just tried to process a peak in channel"
1940 PRINT N;" while having only 2047 channels of data available !!!"
1950 PRINT "J_It was a good try,my friend, but it is also a";
1960 PRINT " %%%%% FATAL ERROR %%%%%"
1970 PRINT "and this program is hereby TERMINATED !G_"
1980 END
1990 I=0
2000 I=I+1
2010 REM.....HERE we must make a test to see if the data we are
2020 REM.....requesting is in memory....if it is not, then we have to
2030 REM.....read it in, i.e., begin our second pass
2040 REM.....we do this by checking our peak counter,p. If it (P(i))
2050 REM.....is > 2027, then we go to the second pass
2060 REM.....
2070 IF P(I)>2027 THEN 2720
2080 R$=CHR(127)
2090 VIEWPORT 60,125,15,65
2100 WINDOW 0,1,0,1
2110 MOVE 0,0
2120 DRAW 1,0
2130 DRAW 1,1
2140 DRAW 0,1
2150 DRAW 0,0
2155 MOVE 0,1
2156 PRINT "K_";
2157 PRINT "K_";
2158 PRINT "Peak number ";I;" in channel ";P(I)
2160 VIEWPORT 66,119,21,59
2170 M6=0
2180 IF P(I)>2027 THEN 2900
2190 FOR I9=P(I)-20 TO P(I)+20
2200 IF A(I9)>M6 THEN 2660
2210 NEXT I9
2220 WINDOW P(I)-20,P(I)+20,0,M6
2230 FOR I9=P(I)-20 TO P(I)+20
2240 MOVE I9,A(I9)
2250 DRAW I9,A(I9)
2260 NEXT I9
2270 HOME
2280 PRINT "J_J_J_J_J_Press UDK 10 to begin.      UDK 5 to enter a point."
```

```
2290 PRINT "       UDK 9 when done."
2300 PRINT "J_UDK :"
2310 PRINT "1 moves cursor up2 moves cursor left3 moves cursor right"
2320 PRINT "4 moves cursor down."
2330 END
2340 GIN G1,G2
2350 SET KEY
2360 IF P(I)>2027 THEN 2990
2370 IF Z9=66 THEN 2830
2380 MOVE P(I)-10,M6/2
2390 GIN G1,G2
2400 IF P(I)>2027 THEN 3010
2410 RETURN
2420 REM.....pointer is positioned
2430 GIN G1,G2
2440 IF P(I)>2027 THEN 3030
2450 G1=INT(G1)
2460 IF G1>R1(I) THEN 2510
2470 HOME
2480 PRINT "Begin channel : ";G1+1
2490 R1(I)=G1+1
2500 GO TO 41
2510 HOME
2520 PRINT "End channel   : ";G1+1
2530 REM.....here we want to be sure that we have input the peak
2540 REM.....channel. So, we will search a region of  input peak
2550 REM.....+-3 channel for the true maximum. This maximum will then
2560 REM.....replace the input peak.channel
2561 IF P(I)<=2027 THEN 2570
2562 GOSUB 7000
2563 GO TO 2580
2570 GOSUB 3210
2580 PRINT "K_K_K_K_Peak channel  : ";P(I)
2590 R2(I)=G1+1
2600 FOR K8=1 TO 600
2610 NEXT K8
2620 PAGE
2630 IF I<N1 THEN 2000
2640 GO TO 3060
2650 END
2660 REM.....set max count
2670 M6=A(I9)
2680 IF P(I)>2027 THEN 2920
2690 GO TO 2210
2700 END
2710 END
2720 REM.....her we are ready for our second pass
2725 IF O4=93.6 THEN 2890
2730 DELETE A
2740 REM.....the above deletes our data array for reuse
2750 REM.....redimension a
2760 DIM A(2027)
2765 O4=93.6
2770 FIND F1(1)
2780 INPUT @33:Z6
2790 INPUT @33:A
2800 DELETE A
2810 DIM A(2068)
2820 INPUT @33:A
2830 Z9=66
2840 REM.....ok...we now have channels 2028 thru 4095 in memory
```

```
2850 REM.....we have to be sure increment our channel counter right
2860 REM.....OK...what do we do now??? We know that we are running
2870 REM.....out of memory. We may have to delete part of the
2880 REM.....program!!!
2890 GO TO 2080
2900 FOR I9=P(I)-2028-20 TO P(I)-2028+20
2910 IF A(I9)>M6 THEN 2660
2920 NEXT I9
2930 WINDOW P(I)-2029-20,P(I)-2028+20,0,M6
2940 FOR I9=P(I)-2028-20 TO P(I)-2028+20
2950 MOVE I9,A(I9)
2960 DRAW I9,A(I9)
2970 NEXT I9
2980 GO TO 2270
2990 MOVE P(I)-2028-10,M6/2
3000 GO TO 2390
3010 G1=G1+2027
3020 GO TO 2410
3030 G1=G1+2027
3040 GO TO 2450
3050 END
3060 REM.....here all of our ROI should be set
3070 REM.....we will write all of the information we have
3080 REM.....gathered to tape file #14 on the scratch tape
3085 PRINT "G_G_G_G_J_Put the PROGRAM TAPE in the 4051 internal tape drive."
3086 PRINT "J_J_Press RETURN to continue.";
3087 INPUT Z$
3090 REM.....then we will go to another program to
3100 REM.....find all of the data files of the samples, pull the
3110 REM.....data in the roi's we requested, and do the calculations
3120 REM.....on it.
3130 REM
3140 REM
3150 REM
3160 REM
3170 FIND @2:14
3180 PRINT @2:N,N1,F1,P,B1,B2,Q,T
3190 FIND 9
3191 OLD
3200 END
3210 REM.....subroutine to test for true peak
3220 K7=A(P(I))
3230 FOR K4=P(I)-3 TO P(I)+3
3240 IF A(K4)>K7 THEN 3270
3250 NEXT K4
3260 RETURN
3270 P(I)=K4
3280 K7=A(K4)
3290 GO TO 3250
3300 END
3310 END
3320 DELETE A
3330 DIM A(2047)
3340 GO TO 1670
3350 DELETE A
3360 DIM A(1023)
3370 GO TO 1670
3380 END
6999 END
7000 REM.....SUBROUTINE TO TEST FOR MAX CHANNEL IN ROI
7010 REM.....ON SECOND PASS FOR 4096 CHANNEL SPECTRA
```

```
7020 K7=A(P(I)-2028)
7030 FOR K4=P(I)-2028-3 TO P(I)-2028+3
7040 IF A(K4)>K7 THEN 7070
7050 NEXT K4
7055 P(I)=P(I)-1
7060 RETURN
7070 P(I)=K4+2028
7080 K7=A(K4)
7090 GO TO 7050
7100 END
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=NSHAG.THESIS.DATA                                    (NINE    )

100 REM.....Actual, real live quantitative analysis program
110 REM.....we need to input some data from the scratch data files
120 REM.....data resides in files 13 and 14....we are only concerned
130 REM.....with the data in file 14 right now
140 PRINT "G_L_Quantitative Analysis---Comparator MethodJ_J_"
150 PRINT "Put the SPECTRUM DATA TAPE in the 4051 internal tape drive."
160 PRINT "J_Put the SCRATCH DATA FILES tape in the 4924 tape drive."
170 PRINT "J_J_G_Press RETURN to continue.........."
180 INPUT Z$
190 PAGE
200 REM.....find the file
210 FIND @2:14
220 REM.....input the number of samples, n, and the number of peaks, n1
230 INPUT @2:N,N1
240 REM.....now we can dimension our variables to hold the rest of
250 REM.....the data
260 REM.....f1=sample file numbers, c=sample count times(from spec data)
270 REM.....d=sample decay times (from spec data tape)
280 REM.....p=pepak channels, r1=begin channels, r2=end channels
290 REM.....q=element quantities, t=isotopep halflives
300 DIM F(N),C(N),D(N)
310 DIM P(N1),R1(N1),R2(N1),Q(N1),T(N1)
320 REM.....ok....now input the data in file 14
330 INPUT @2:F,P,R1,R2,Q,T
340 REM.....we will try to process our samples while in a FOR loop
350 REM.....but, since the standard is unique to the program, let
360 REM.....us process it separately
370 REM.....first let us input the spectrum descriptors
380 FIND @2:15
390 FOR I6=1 TO N
400 FIND F(I6)-1
410 INPUT @33:A$
420 INPUT @33:B$
430 INPUT @33:C$
440 INPUT @33:D$
450 INPUT @33:C8,D(I6)
460 REM.....ok.....we now have the necessary information
470 REM.....we now need to begin our calculations
480 REM.....probably would be fastest to have spectrum read into
490 REM.....an array a.
500 REM.....if we have a 4096 channel spectrum, we will go through
510 REM.....twice
520 REM.....here let us see what size spectra we are dealing with
530 C8=C8-1
540 IF C8=1023 THEN 2220
550 IF C8=2047 THEN 2320
560 IF C8=4095 THEN 2400
570 REM....we are here if c8 is invalid
580 PRINT "G_L_%%%%% FATAL ERROR %%%%% Invalid spectrum length"
590 END
600 REM.....here we return
610 REM.....we have all of the data in the 1024 and 2048 channel
620 REM.....spectrum cases. The first 2048 channel in the 4096 case
630 REM.....so, let us begin
640 DIM G(N1),B(N1),N3(N1)
650 REM.....g=gross integral array,b=bkg array, n3=net array
660 G=0
```

```
670 B=0
680 N3=0
690 FOR I=1 TO N1
700 REM.....here we need to test to see if we have to go load some
710 REM.....more data
720 IF P(I)>2048 THEN 2490
730 REM.....compute gross integral
740 FOR I1=R1(I) TO R2(I)
750 G(I)=G(I)+A(I1)
760 NEXT I1
770 REM.....let us compute the background
780 REM.....for now, we will use the first and last channels in the
790 REM.....ROI
800 B(I)=(A(R1(I))+A(R2(I)))/2*(R2(I)-R1(I)+1)
810 REM.....now compute net
820 N3(I)=G(I)-B(I)
830 REM.....now go for next peak
840 NEXT I
850 GO TO 1010
860 REM.....we come her to process the second half of a 4096 channel
870 REM.....spectrum
880 REM.....counter i is already correctly set
890 REM.....remember, we must properly handled offset channel numbers
900 REM.....begin another loop with a new counter
910 FOR I2=I TO N1
920 REM.....compute gross integral
930 FOR I3=R1(I2)-2027 TO R2(I2)-2027
940 G(I2)=G(I2)+A(I3)
950 NEXT I3
960 REM.....compute background
970 B(I2)=(A(R1(I)-2027)+A(R2(I)-2027))/2*(R2(I)-R1(I)+1)
980 REM.....compute net
990 N3(I2)=G(I2)-B(I2)
1000 NEXT I2
1010 REM.....here, in any case, we are finished with sample 1
1020 REM.....best to write data to SCRATCH FILES file 15, then
1030 REM.....go back for the next sample
1040 REM.let us try to make the machine think that it has terminated
1050 REM.....all FOR loops
1060 I=N1
1070 REM.....here we are ready to write the results for sample 1
1080 REM.....to tape
1090 REM.....we already have the tape positioned
1100 PRINT @2:N,N1,P(I6),P,R1,R2,Q,T,D(I6),C(I6),C8,G,B,N3
1110 PRINT @2:A$
1120 PRINT @2:B$
1130 PRINT @2:C$
1140 PRINT @2:D$
1150 REM.....we will do computations in next program
1160 REM.....for now, do next sample
1170 NEXT I6
1175 PAGE
1180 HOME
1181 PRINT "          {{{{{  Quantitative Analysis Results  }}}}}"
1182 PRINT "K_";
1183 PRINT "          }}}}}                                        {{{{{"
1190 REM.....quantiatative analysis module 3...final module
1200 INIT
1210 PRINT @32,26:3
1230 REM.....find data file from last step
1240 FIND @2:15
```

```
1250 REM.....input number of sample,number of peaks per sample
1260 INPUT @2:N,N1
1270 REM.....dimension variables to hold data
1280 DIM F(N),D(N),C(N)
1290 DIM P(N1),R1(N1),R2(N1),Q(N1),T(N1),G(N1),B(N1),N3(N1)
1300 REM dimension variables to hold results of calculations this step
1310 DIM S(N1),R(N1),A(N1),A1(N1),L9(N1),E1(N1)
1320 REM.....begin sample loop
1330 FOR I6=1 TO N
1340 F9=1
1350 REM.....input sample information
1360 FIND @2:15
1370 INPUT @2:N,N1,F(I6)
1380 INPUT @2:P,R1,R2,Q,T,D(I6),C(I6),C8,G,B,N3
1390 INPUT @2:A$
1400 INPUT @2:A$
1410 INPUT @2:A$
1420 INPUT @2:B$
1430 INPUT @2:C$
1440 INPUT @2:D$
1450 IF F9=I6 THEN 1480
1460 F9=F9+1
1470 GO TO 1370
1480 REM.....here we have the right information
1490 REM.....begin calculations
1500 REM.....convert net integrals to net counts/second
1510 N3=N3/C(I6)
1520 REM.....calculate decay constants
1530 L9=LOG(2)/T
1540 REM.....correct for decay
1550 L8=-1*D(I6)
1560 E1=L8*L9
1570 FOR I=1 TO N1
1580 N3(I)=N3(I)/EXP(E1(I))
1590 NEXT I
1600 REM.....first sample processed is our standard
1610 REM.all subsequent numbers must be compared to standard numbers
1620 REM.....so, let us store them in a separate array
1630 IF I6=1 THEN 2090
1640 REM.....calculate quantity ratio
1650 FOR I=1 TO N1
1660 IF S(I)<=0 THEN 2130
1670 R(I)=N3(I)/S(I)
1680 REM.....if we get a negative integral, make integral=0
1690 IF R(I)<0 THEN 2110
1700 NEXT I
1710 REM.the quantity of the element of interest is read in on every
1720 REM.....pass
1730 REM.....calculate amount of element of interest in sample
1740 FOR I=1 TO N1
1750 A(I)=R(I)*Q(I)
1760 NEXT I
1770 REM.....here we want to output the results of this sample
1780 PRINT "G_J_J_>>>Sample : ";A$;"J_"
1790 PRINT USING 2150:C8+1
1800 PRINT USING 2160:C(I6)
1810 PRINT USING 2170:D(I6)
1820 PRINT "Acquired by ";B$;" on ";C$;" at ";D$
1830 PRINT USING 2180:
1840 REM.....go to descriptor file
1850 FIND @2:13
```

```
1860 FOR I=1 TO N1
1870 INPUT @2:X7,X8
1880 INPUT @2:I$
1890 INPUT @2:E$
1900 INPUT @2:U$
1910 PRINT "      ";E$;"K_"
1930 PRINT "                                    ";U$;"K_"
1950 PRINT "                                                    ";I$;"K_"
1970 PRINT USING 2190:A(I)
1980 NEXT I
1990 REM.....go for next sample
2000 NEXT I6
2020 PRINT "J_J_G_Put the PROGRAM TAPE in the 4051 internal tape drive."
2030 PRINT "J_Press RETURN to continue."
2035 COPY
2036 PRINT @32,26:0
2040 INPUT Z$
2060 FIND 1
2070 OLD
2080 END
2090 S=N3
2091 A$=A$&" (Standard)"
2100 GO TO 1640
2110 R(I)=0
2120 GO TO 1700
2130 S(I)=1.0E-12
2140 GO TO 1670
2150 IMAGE "Spectrum length : ",4d
2160 IMAGE "Count time      : ",fd," seconds"
2170 IMAGE "Decay time      : ",fd," seconds"
2180 IMAGE 5x,21,"Element",12x,"Amount",16x,"Isotope Measured",21
2190 IMAGE 18x,7d.2d
2200 END
2210 END
2220 REM.....here we have a 1024 channel spectrum
2230 DELETE A
2240 DIM A(1023)
2250 FIND P(I6)
2260 REM.....input the count time
2270 INPUT @33:C(I6)
2280 REM.....input spectrum
2290 INPUT @33:A
2300 GO TO 600
2310 END
2320 REM.....here we have a 2048 channel spectrum
2330 FIND P(I6)
2340 DELETE A
2350 DIM A(2047)
2360 INPUT @33:C(I6)
2370 INPUT @33:A
2380 GO TO 600
2390 END
2400 REM.....here we have a 4096 channel spectrum
2410 REM.....we will have to perform 2 passes (probably)
2420 REM.....allow the first pass to handle peak channels up to 2048
2430 DELETE A
2440 DIM A(2068)
2450 FIND P(I6)
2460 INPUT @33:C(I6)
2470 INPUT @33:A
2480 GO TO 600
```

```
2490 REM.....here we are going to set up to read for our second
2500 REM.....pass. We already have our count time
2510 DELETE A
2520 DIM A(2028)
2530 REM.....the following should give us channels 0-2028
2540 FIND F(I6)
2550 INPUT @33:A
2560 DELETE A
2570 REM.....the following should give us channels 2028-4095
2580 DIM A(2068)
2590 INPUT @33:A
2600 PRINT "G_"
2610 GO TO 860
```

```
**** TSO FOREGROUND HARDCOPY ****
DSNAME=NSHAG.THESIS.DATA                                    (TEN      )

100 REM.....PROGRAM TO DISPLAY CONTENTS OF DATA TAPE
110 REM.....give user instructions
120 PRINT "L_G_                          $$$$$ Data Tape Contents $$$$$"
130 PRINT "Put the SPECTRUM DATA TAPE in the 4051 internal tape drive."
140 PRINT "Press RETURN to continue.";
150 INPUT Z$
160 REM.....remember that odd numbered files are descriptor files
170 REM.....even numbered files are files containing spectra
180 I=1
190 REM.....here begin our loop
199 REM.....first go into non-header format
200 PRINT @33,0:0,0,1
220 FIND I
230 REM.....input the header information
240 REM.....see if we have the LAST file
250 INPUT @33:T$
260 U$=SEG(T$,9,1)
270 IF U$="L" THEN 480
275 IF U$="E" THEN 1000
280 REM.....here we do not have the last file, so let's get the info
290 REM.....return to header mode
300 PRINT @33,0:0,0,0
310 FIND I
320 INPUT @33:A$
330 INPUT @33:B$
340 INPUT @33:C$
350 INPUT @33:D$
360 INPUT @33:E
370 INPUT @33:F
380 REM.....now print out the SPECTRUM file number and the info
390 PRINT "            File : ";I+1;"              "
400 PRINT "Contents : A ";E;" channel spectra labeled ";A$
410 PRINT "Spectrum acqusition time : ";D$;" on ";C$
420 PRINT "Acquired by : ";B$;"      Decay time : ";F;" seconds."
430 REM.....ok, we are ready for the next one....increment counter
440 I=I+2
450 PRINT @33,0:0,0,0
460 GO TO 200
470 END
480 REM.....here we have found the last file
490 PRINT @33,0:0,0,0
500 PRINT "G_G_G_G_G_End of files on this tape."
505 FIND 0
510 END
1000 PRINT "G_**** THIS TAPE IS FULL ****"
1010 GO TO 480
```

# VITA

Kendrick Vernon Hagius was born on August 7, 1955 in Magnolia, Arkansas. He attended Glen Oaks High School in Baton Rouge, Louisiana and graduated in May, 1973.

In August, 1973 he entered Louisiana State University and graduated in August, 1978 with a B. S. in Engineering Science. After graduation he entered graduate school in Nuclear Engineering at Louisiana State University.

He is currently a candidate for the degree of Master of Science in Nuclear Engineering. After graduation he will be employed with the Tennessee Valley Authority in Knoxville, Tennessee.