MAGNETIC TAPE DATA HANDLING IN A MINI-COMPUTER BASED GAMMA-RAY SPECTROSCOPY SYSTEM

by

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Date

PREFACE

Much of the first gamma-ray spectroscopy work was performed with simple single channel analyzers and low resolution detectors. The small amounts of data collected were easily handled with simple mechanical equipment and the numerical analysis of the data was performed by hand. In the mid 1950's, simple pulse height analyzers were developed which could collect data in many energy ranges simultaneously. The speed of the analog-to-digital converters and the capacity of electronic memories limited the amount of data which could be collected. Mechanical printers and manual calculations were still practical.

Large scale integration and the development of high speed pulse processing electronics has made it possible to design pulse height analyzers capable of sorting thousands of counts per second into thousands of energy channels. High resolution detectors have added to the complexity of the data collected. Clearly, hardcopy output equipment is inadequate to handle the large amounts of data generated in a typical research project. Also, more sophisticated numerical analysis methods are needed to take full advantage of the large amounts of data which can now be collected. A mini-computer operating system can provide the extra computing power necessary for most applications, but it is sometimes necessary to use large computers in gamma-ray spectroscopy problems where many elements are present and doublet and triplet peaks exist.

A modern 4096-channel pulse height analyzer may collect over one hundred thousand bits of data in a single spectrum. It is desirable to save all data collected during the course of an investigation as well as transfer it to larger computers for analysis. The standard paper tape punch supplied with Teletype equipment is capable of output at the rate of ten characters per second. It takes over an hour to punch an entire spectrum with such equipment. The volume of paper tape generated may be very cumbersome.

Magnetic tape provides a means of storing and transferring the large amounts of data collected during the course of an investigation. The same spectrum which takes more than an hour to output onto paper tape may be stored on magnetic tape in less than five seconds. The amount of magnetic tape used is so small that over one thousand spectra may be stored on a single 2400-foot reel. Magnetic tape also allows complex, user-interactive functions to be included in the minicomputer operating system.

The purpose of this project was to develop the software necessary to store and manipulate data on magnetic tape in the most efficient and versatile manner possible.

I wish to acknowledge the many helpful suggestions provided by Dr. George W. Nelson and the technical support offered by Mr. Thomas A. Caffarella.

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ABSTRACT

Software was developed to interface a standard minicomputer controlled pulse height analyzer to a seven track magnetic tape drive. Algorithms were devised to maximize efficiency and versatility, yet maintain an easy to use instruction set which anticipates many user errors and provides diagnostics for service personnel. Complex functions such as background stripping and spectrum comparing were written to allow user interaction and manipulation of spectra without destroying the original data. All programs were written in a modular form to facilitate future software development.

CHAPTER 1

INTRODUCTION

The development of high speed microelectronics and mass memories has led to the construction of very sophisticated pulse height analyzers for gamma-ray spectroscopy. These analyzers are capable of collecting pulse height data in thousands of channels simultaneously. Obviously, this development has led to ever-increasing difficulty in handling and analyzing the large amounts of data collected. Fortunately, the same electronics which have made modern pulse height analyzers possible have also made possible the construction of mini-computers with the control and computing capability necessary to service these devices.

There are many pulse height analyzer - mini-computer systems available on the market today. The one in use at The University of Arizona is the Northern 636 - Nova 1200 combination. The ideas and algorithms developed for this particular system are directly applicable to most other systems available.

Basic Nova - Northern Operating System

The basic pulse height analyzer for gamma-ray spectroscopy includes a detector, instrumentation amplifier, analog-to-digital converter, and input-output devices.

Many types of detectors may be used for gamma-ray spectroscopy. Solid-state Ge-Li detectors are used for high energy resolution and NaI detectors are used for low level counting. The instrumentation amplifier and analog-to-digital converter employ the same high degree of electronic sophistication as the analyzer. Input-output is accomplished through a standard model 33 Teletype. The slow speed of operation of such a device limits the overall efficiency of the system which is otherwise made up of state-of-the-art devices. All user interaction with the system as well as all data output is channeled through the Teletype. A block diagram of the data and control logic flow in such a system is shown in Fig. 1.

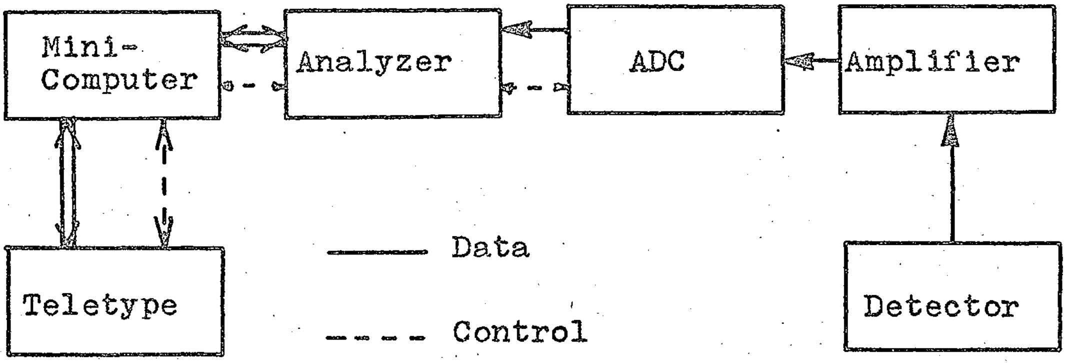


Fig. 1. Data Flow in the Nova - Northern System.

Computer Controlled Functions

Certain analyzer functions and operating modes may be controlled by the mini-computer by either software action or direct user interaction via the Teletype. These include selection of the Pulse Height Analysis (PHA) or Multi-Channel Scale (MCS) modes and memory addition or subtraction modes. Counting sequences may be initiated or terminated and a number of display modes selected by the operator or the mini-computer. The mini-computer may place the pulse height analyzer memory in the external mode for direct access to data. With the standard Nova - Northern operating system, these functions must be directly initiated by the user.

On-Line Analysis Capability

The Nova mini-computer is capable of performing a certain amount of mathematical reduction of the data collected by the pulse height analyzer. Software has been implemented to calculate the areas, widths, and energies of peaks in spectra. The system may be calibrated by typing in channel numbers and associated energies. Peaks to be analyzed are identified (intensified) by the user prior to initiating the analysis programs.

Special background stripping, curve fitting, and analysis of multiple peaks is not possible with the programs stored in the mini-computer. It is possible to punch the spectrum on paper tape using the Teletype, but this is very time consuming.

Typical Research

Research performed with the pulse height analyzer may be divided into two broad categories; single isotope tracer analysis and multiple isotope unknown analysis. The first category includes experiments with single tracer elements, such as dysprosium, which are introduced into the system under investigation. The amount of the isotope present is determined by the area under specific peaks. Under these controlled conditions, interfering isotopes may be eliminated and data collected only in the energy range of interest. This reduces the amount and complexity of data to be analyzed and standard Teletype hardcopy output may be sufficient. It may be, however, desirable to keep a record of the entire spectrum for later review.

The second type of experiments commonly performed involve the analysis of complex unknown samples with many isotopes present. There is a great possibility of interference between peaks. In many cases, hundreds of individual peaks may be present. Clearly, the analysis of such spectra is out of the scopy of the mini-computer implemented programs. The analysis must be performed on large computers using sophisticated programs. It is very desirable to save the entire spectrum for later review if necessary. Paper tape is vastly inadaquate for this task.

Shortcomings of the Nova-Northern System

As indicated earlier, there are many limitations in the mini-computer/pulse height analyzer system. The limited computing capability makes it necessary to transfer the spectra to a larger machine. Input-output through the Teletype is very slow and the paper tapes generated require a large volume for storage. The user must be present to remove the spectra from the analyzer. Experiments involving the irradiation and counting of short half-life isotopes are needlessly slowed down by the time required to analyze and dump out the data after a count. Not only is the analyzer time poorly used, but the reactor time is also used inefficiently. What is needed is a fast, high density, portable mass memory system. Magnetic tape provides such a memory.

CHAPTER 2

MAGNETIC TAPE OPERATING SYSTEM

Magnetic tape drives may be added to almost any mini-computer system. Complex hardware and software support must also be added, however. The hardware connection between the mini-computer and the magnetic tape drive is accomplished through a device called a formatter or controller. This electronic device communicates data as well as the control pulses required by the magnetic tape drive. A complex set of programs is required to prepare the data for storage and operate the tape drive. The date and control logic flow in this expanded system is shown in Fig. 2.

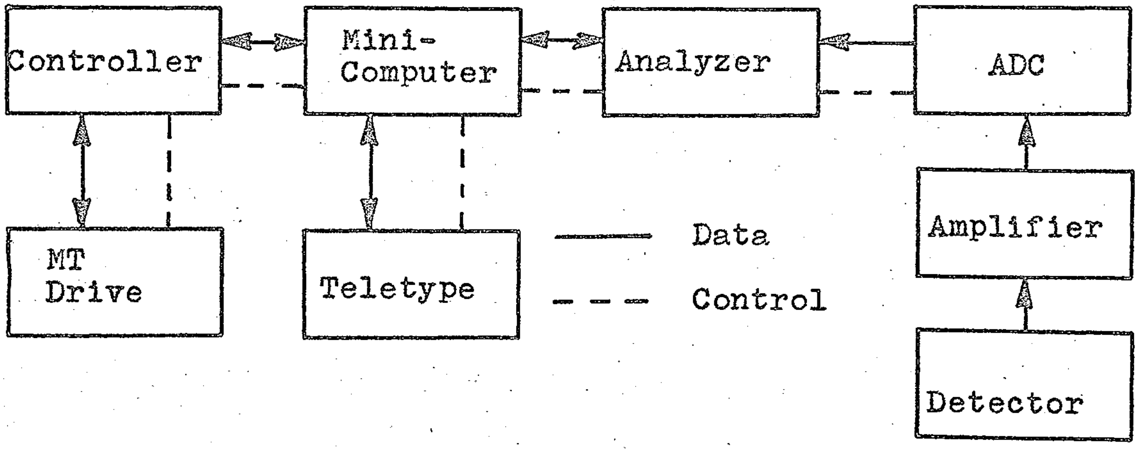


Fig. 2. Data flow in the Nova - Northern - Wang System

Software

Programs must be written to communicate instructions to the tape drive as well as data. The status of the tape system must be determined before and after data transfer. Descriptions of the control and status programs follow. The data handling programs will be discussed in the next chapter.

Control Programs

Paper tape readers and punches are largely mechanical, so they perform few additional functions and require little electronic hardware to operate. Software requirements of these and other hardcopy devices are minimal. Magnetic tape equipment not only reads and writes data, but also performs file search, rewind, parity check, and read-after-write operations. This requires a high degree of electronic technology and extensive software support.

Fortunately, the software required to control the tape motion functions and the transfer of data is usually supplied by the manufacturer of the controller. This software is tailored to the particular tape drive and minicomputer being used. All the user has to do is call certain subroutines and supply the requested information. A detailed knowledge of the operation of these programs is not necessary, however, it is important to fully understand all the details of their use. The magnetic tape handling routines supplied with the system are listed in Table 1.

TABLE 1

MAGNETIC TAPE HANDLING ROUTINES

1.	UNIT	Places the addressed tape drive on-line and sets the parity and data density.
2.	REWIND	Rewinds the selected tape to BOT.
3.	READ	Reads a record.
4.	WRITE	Writes a record.
5.	WEOF	Writes an end-of-file mark.
6.	SPACE	Spaces forward or backward a specified number of records or files.
7.	CMPLTE	Completes the previous command.

Status Check

During the course of normal operation, two types of system malfunction are likely to occur. The first are classed as mechanical failures and include parity, bad tape, word count, and data late errors. The second type of malfunction is logical and stems from software which tries to perform certain functions which the magnetic tape transport is incapable of. These include such things as reading over end of file marks, spacing over beginning and end of tape marks, and giving a write command when the file protect mode is activated. It is of great importance to have a magnetic tape status check and error routine which is capable of checking the system during all operations involving the magnetic tape drive. This system should give detailed information about the location and nature of the malfunction and provide a means of recovery if possible.

Four routines have been included in the basic magnetic tape software package. The first one is called before any operations involving the magnetic tape are attempted and checks to see that the drive has been placed on-line. If the operator has neglected to press ON LINE after loading a new tape on the drive, a message to that effect will be typed out. The situation must be corrected before the program is allowed to continue. The system may recover from this error.

It is possible to protect tapes from accidential erasure by removing the write ring from the tape reel. If a routine is initiated which will attempt to write on the tape, a file protect check is made. If the write ring has been removed, a message will be typed out asking that it be replaced. The program will not continue until the situation has been rectified. Again, system recovery is possible.

Magnetic tapes come in a variety of lengths. It is therefore necessary to check for an End-of-tape flag after each write operation. If an End-of-tape is encountered during a write sequence, the file being written will be completed. No further write commands will be completed. The End-of-tape routine types a message when the end of tape is reached.

The final status routine is called if an error is detected by any of the other magnetic tape handling routines. These routines include those listed in Table 1. This routine interrogates the status buffer in the magnetic tape controller and determines whether the error is due to hardware or software problems. A message is typed out giving the type of error encountered as well as the address of the instruction which caused the error to occur. The contents of the status buffer are also printed out.

A careful review of the technical specifications for the equipment used, as well as the software operating system manuals, is required to insure that logical errors are not made. Flow charts for these routines are shown in Figs. 3, 4, 5, and 6.

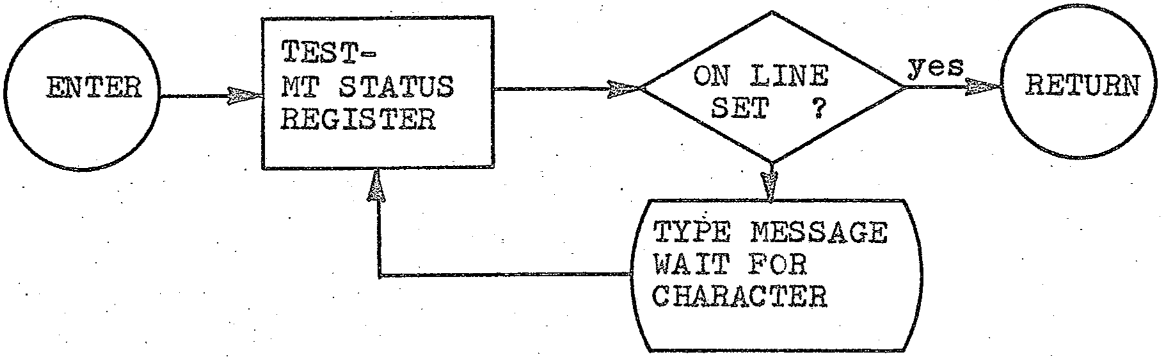


Fig. 3. Flow Chart of MT On-Line Check Subroutine

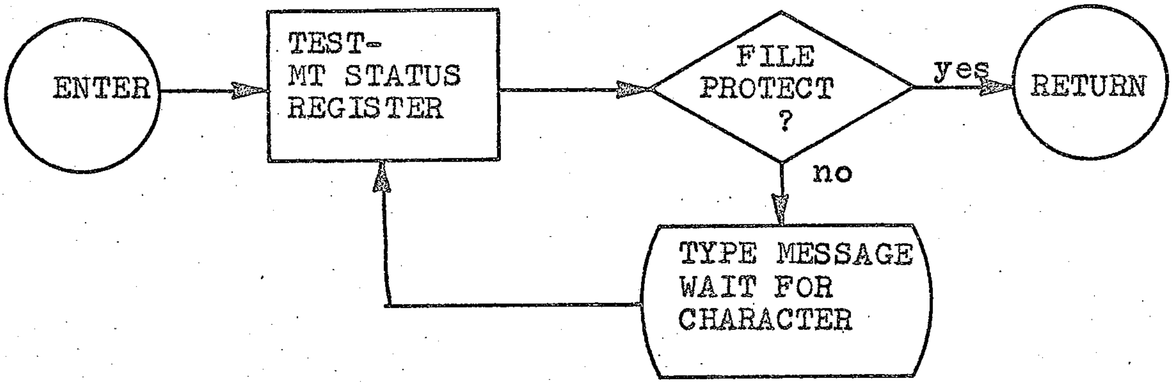


Fig. 4. Flow Chart of MT File Protect Check Subroutine

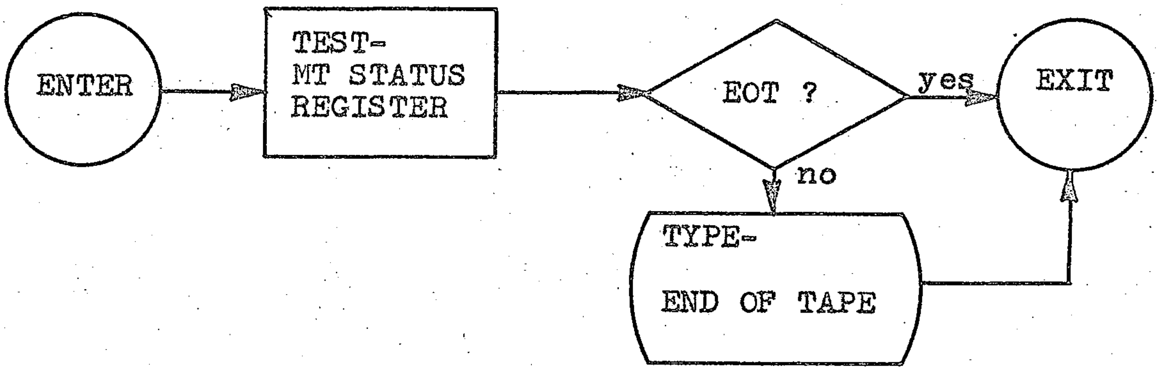


Fig. 5. Flow Chart of MT End-of-Tape Check Subroutine

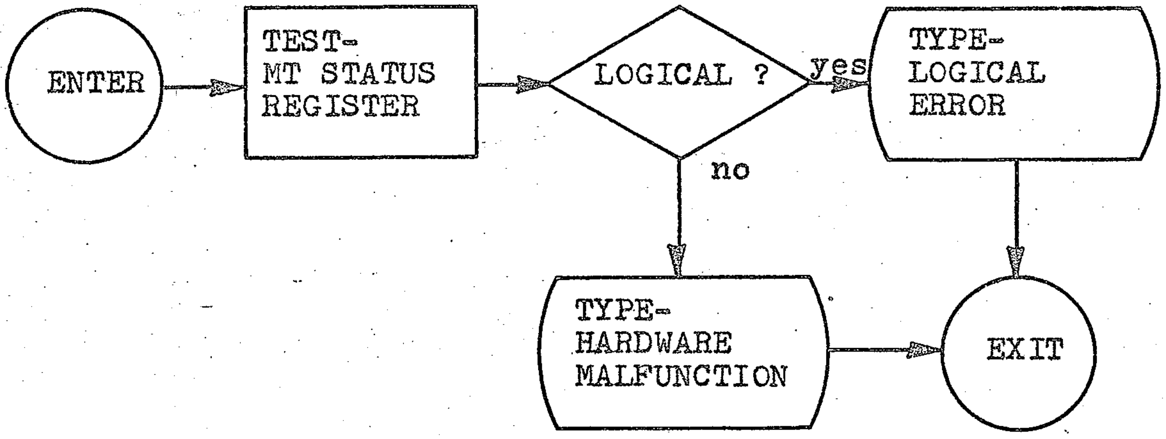


Fig. 6. Flow Chart of MT Error Check Subroutine

CHAPTER 3

DATA STORAGE ON MAGNETIC TAPE

Many types of mini-computers, formatters, and magnetic tape drives are available on the market today. Each has its own operating procedures and requirements. Special care must be taken to insure that data is handled properly and that no scrambling or loss occurs. This is only possible after a thorough review of all technical matter pertaining to the particular operating system in use.

Sixteen bit mini-computers are by far the most common machines on the market today, and when used with standard 9-track magnetic tape hardware, offer the simplest means of recording data on tape. The standard 16-bit computer word is broken into two 8-bit bytes by the formatter (which also supplies a parity bit) and is stored as two consecutive 9-bit frames on magnetic tape. No part of the word is lost, so no special manipulation is required. Likewise, some 16-bit mini-computers using 7-track magnetic tape drives write data in a 6-6-4 frame configuration with appropriate parity bits. Again, no data is lost.

Unconventional Hardware Systems

The Nova 1200 - Datum - Wang Mod 10 combination requires special consideration. When a 16-bit computer word is sent to the formatter, only 12 bits are actually stored on tape in two consecutive 7-bit frames. The formatter provides a parity bit for each frame. The opposite is true when a read sequence is initiated. Only 12 bits are recovered and assembled into the 16-bit computer word, the remaining bits being set to zero.

Data Packing

The bit configuration for the Datum - Wang system is shown in Fig. 7. The bits in the 0,1 and 8,9 positions must be shifted out of these positions and stored on tape in a later word. To achieve maximum data density on the magnetic tape, four bits are removed from three computer words and manipulated to form a fourth word which is then written on tape after the first three. When a magnetic tape read is performed, four words are read and reassembled into three complete 16-bit computer words. Careful bookkeeping is required to allow reassembly of the words in a read operation.

A convenient means of packing data utilizes the AND, SHIFT, and ADD functions of the mini-computer. The algorithm used to pack data for storage on magnetic tape is shown in Fig. 8. A mask word is used with the AND function to remove the bits which will not get stored on tape. These bits are then shifted and added together to form the fourth 12-bit word which is written after the first three. This process is continued until a complete record has been written.

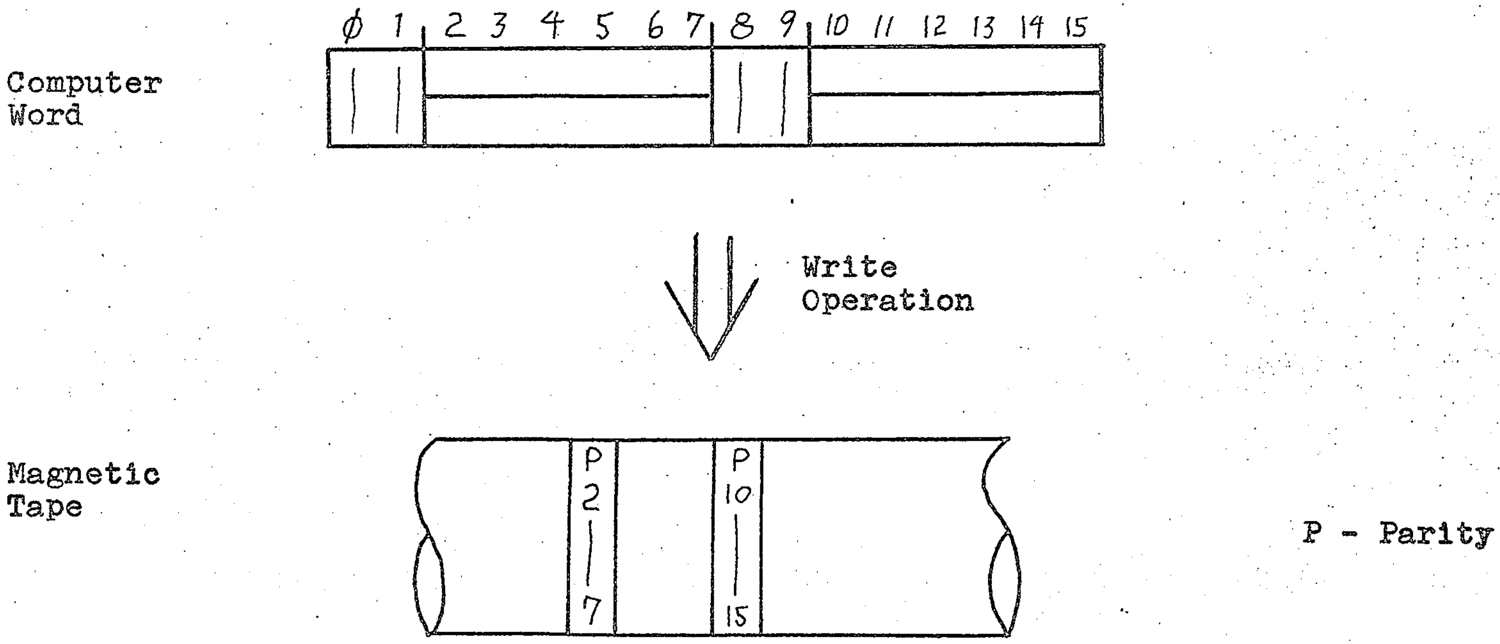


Fig. 7. Bit Configuration Before a Write Operation

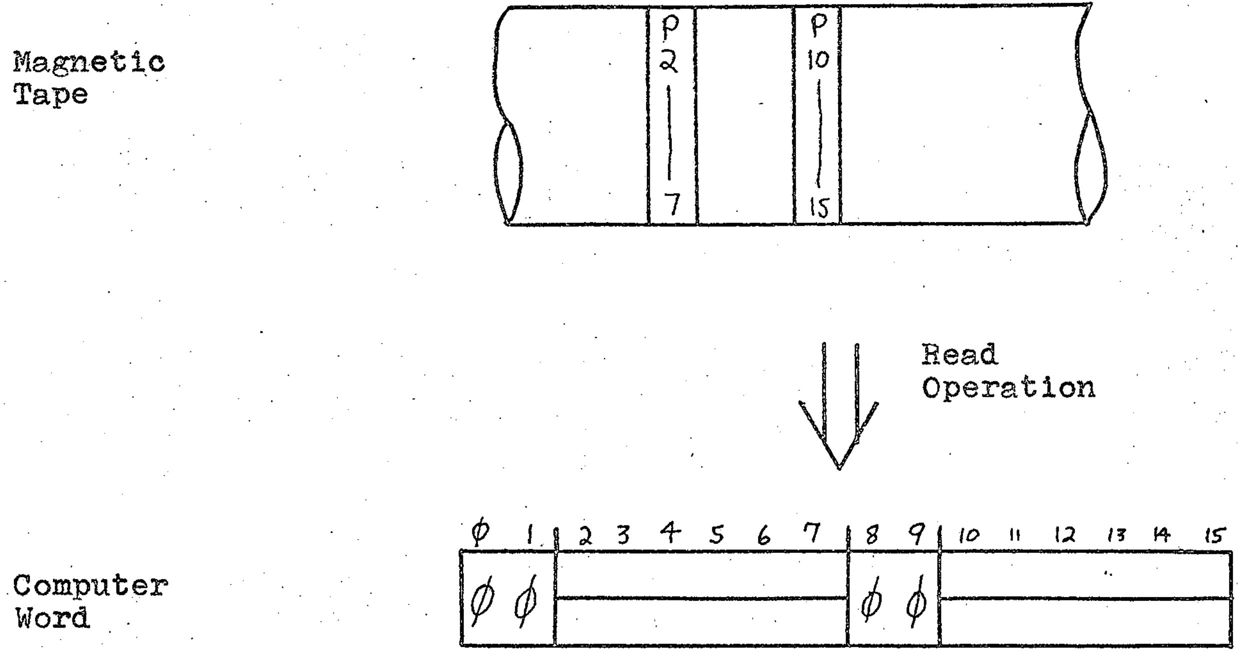


Fig. 8. Bit Configuration After a Read Operation

Data Unpacking

A reverse procedure of shifting, masking, and adding is used to reassemble the original three 16-bit computer words. As stated earlier, it is essential to keep track of where each bit is for each word, otherwise, bits from one word may be reassembled into another.

Record Length

The number of words which may be written in any one record (each word consisting of two frames) is determined by the particular hardware in use. Any number of words from 2 to 4096 may be written on tape in any single record with the Datum - Wang Mod 10 system. Each record is terminated with several special characters and a blank gap. If the number of words written in the records is small, much time and tape is wasted writing these characters and gaps. Long records, however, require large segments of computer memory for the packing and unpacking operations. There is a tradeoff between computer memory use and tape writing speed. For the Nova 1200 with an 8K memory, 300_8 computer words packed into 400_8 formatter words prove to be an efficient compromise. With this record length, it is possible to write a complete 4096 channel spectrum on tape in about five seconds, using less than three feet of magnetic tape.

File Structure

Once the most efficient way of storing individual records on magnetic tape has been determined, it is necessary to find an equally efficient way of organizing the spectra and associated data into files. Each file is made up of many data records and is separated from other files by special end-of-file marks. Most hardware systems have the capability of spacing forward or backward over any specified number of files regardless of the number of records in them. It would seem reasonable to organize the data into files such that each file contains all the information pertinent to a particular spectrum.

Record Configuration

Two systems were considered for storing the gamma-ray spectra and associated data on magnetic tape. Each system has its own attributes and shortcomings which must be taken into account and tailored to the specific demands of the system in use. The first method involves dividing the data into two groups, a spectrum block and a descriptive data block. The spectra are written in files starting with the second and the data blocks are written in consecutive records in the first file. Therefore, the first record in the first file contains the descriptive data for the first spectrum on tape. The second record in the first file contains the data for the second file on tape and so on.

When a new spectrum is written on tape, the following sequence of events takes place. First, the tape is rewound. The first blank record is then located and the data written there. The tape is then spaced to the corresponding file where the spectrum is written. Fig. 9 shows how the tape is organized in this situation.

This system is very efficient when it is necessary to examine the data contained in the descriptive block often. Little time is lost by spacing from file to file. This method is very cumbersome, however, when many spectra are written on the tape. It takes a longer time to write each successive spectrum. Problems also arise when this type of tape is read on another machine.

The second system is geared to fast writing of spectra on tape as well as rapid reading of data back into the analyzer. Examination of the descriptive data block is a little slower since the tape must be spaced a full file to get to the next descriptive data block. This type of file organization is shown in Fig. 10. This system allows examination of the descriptive data block of a previous spectrum without having to rewind the entire tape.

Number Representation

Many types of numbers are used to represent the various pieces of data collected. The type of number used to represent a particular parameter is determined by the use

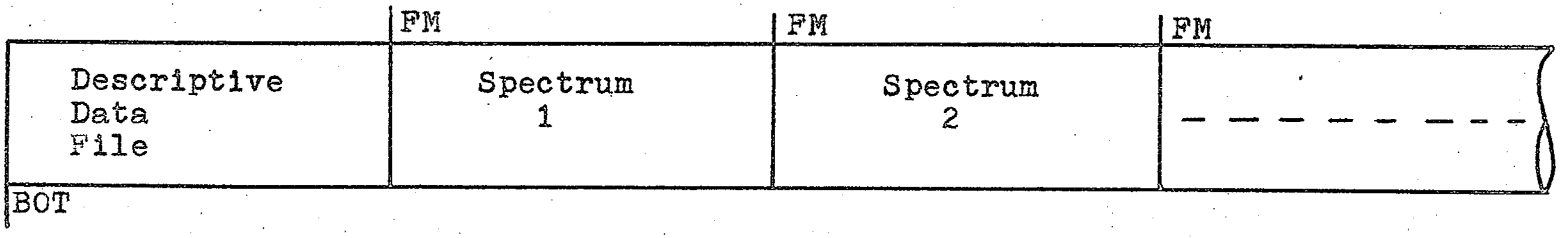
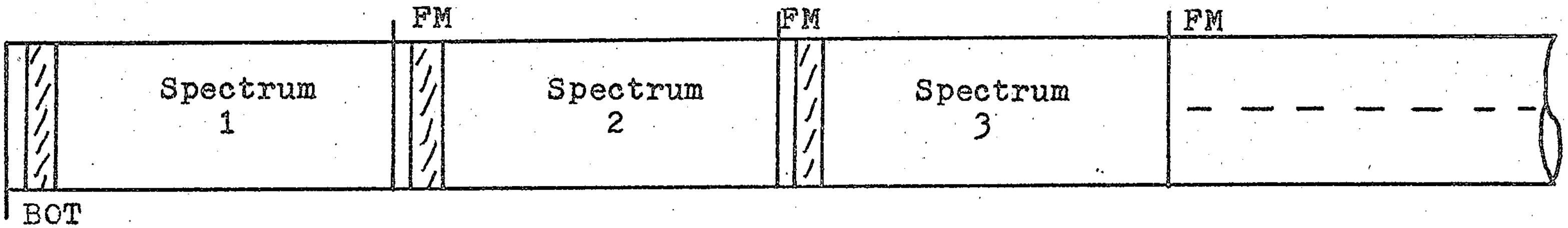


Fig. 9. First File Descriptive Data Structure



▨ - Descriptive Data Record

FM - End of File Mark

Fig. 10. Serial File Structure

to which the particular parameter will be put. Printed messages to the user, such as the sample name, are best represented in ASCII. Integer numbers, such as the file number and the raw spectrum data, are best left as pure binary numbers. Calibration numbers and various times are best represented in the floating point code employed by the particular computer in use. Details of the number types and their representation on magnetic tape will be discussed in a later section.

CHAPTER 4

MAGNETIC TAPE COMMANDS

Once the file structure and record length (as dictated by the particular hardware being used) have been determined, it is necessary to decide what operations using the magnetic tape are required. These operations may include reading in and listing the descriptive data about the spectra, reading and writing the spectra to and from the magnetic tape and analyzer, and performing certain manipulations on a particular spectrum of interest. Discussion of these three types of operations will follow.

Preliminaries

Before any programming begins, several things must be determined about the software operating system supplied by the analyzer manufacturer. A core map of the analyzer software should be made. This will allow the programmer to determine where he may store his additional software. Particular attention should be given to the page 0 locations used by the analyzer program. Page 0 locations are used for indirect addresses and are a convenient means of accessing often-used subroutines.

The utility routines used by the analyzer program should be identified. These routines typically include programs to input and output numbers and messages on the Teletype, convert numbers from one form to another, and output error conditions. These routines will be very useful in the development of new software and will reduce the amount of programming considerably.

Since the mini-computer performs some mathematical reduction of data, it will have a floating point interpreter software package as part of the general analyzer software. This set of routines is used to perform basic mathematical operations on floating point numbers. Input and output of floating point numbers is also possible. Particular attention should be given to this program as it will be used often in most of the additional software developed. The manuals supplied with the mini-computer software package should be studied and special needs of the floating point interpreter noted.

One final area which must be studied prior to any programming is the use of interupts by the main program. Interupts are used to allow the computer to continue operation while slower input-output devices are in operation. The interupt priorities must be established and the enable and disable interupt routines understood. Input-output on the magnetic tape is rapid enough so that, in most instances, interupts may be disabled during all magnetic tape operations.

Instruction Decode

Once the entire operating system has been studied and understood, programming may begin. The first routine to be written is an instruction decode program. This program is used to input an instruction sequence from the Teletype and convert it to the starting address of the software required. Instruction input should be limited to as few characters as necessary to decrease the probability of errors. For this thesis project, new routines were initiated by typing R@ (where @ represents a space character) followed by appropriate characters. Once R@ has been typed, the program waits for additional characters. The next character is typed in and then compared with a list of allowed operation codes. If the character matches a code, the program jumps to that routine, otherwise an error message is typed and the sequence may be retried. A flow chart of the R@ decode routine is shown in Fig. 11.

Descriptive Data Block

While it is of great interest to store spectra on magnetic tape, the spectrum itself is of little use. A number of other bits of information about the spectrum must be stored along with it on tape. For gamma-ray spectroscopy applied to neutron activation analysis, this information should include:

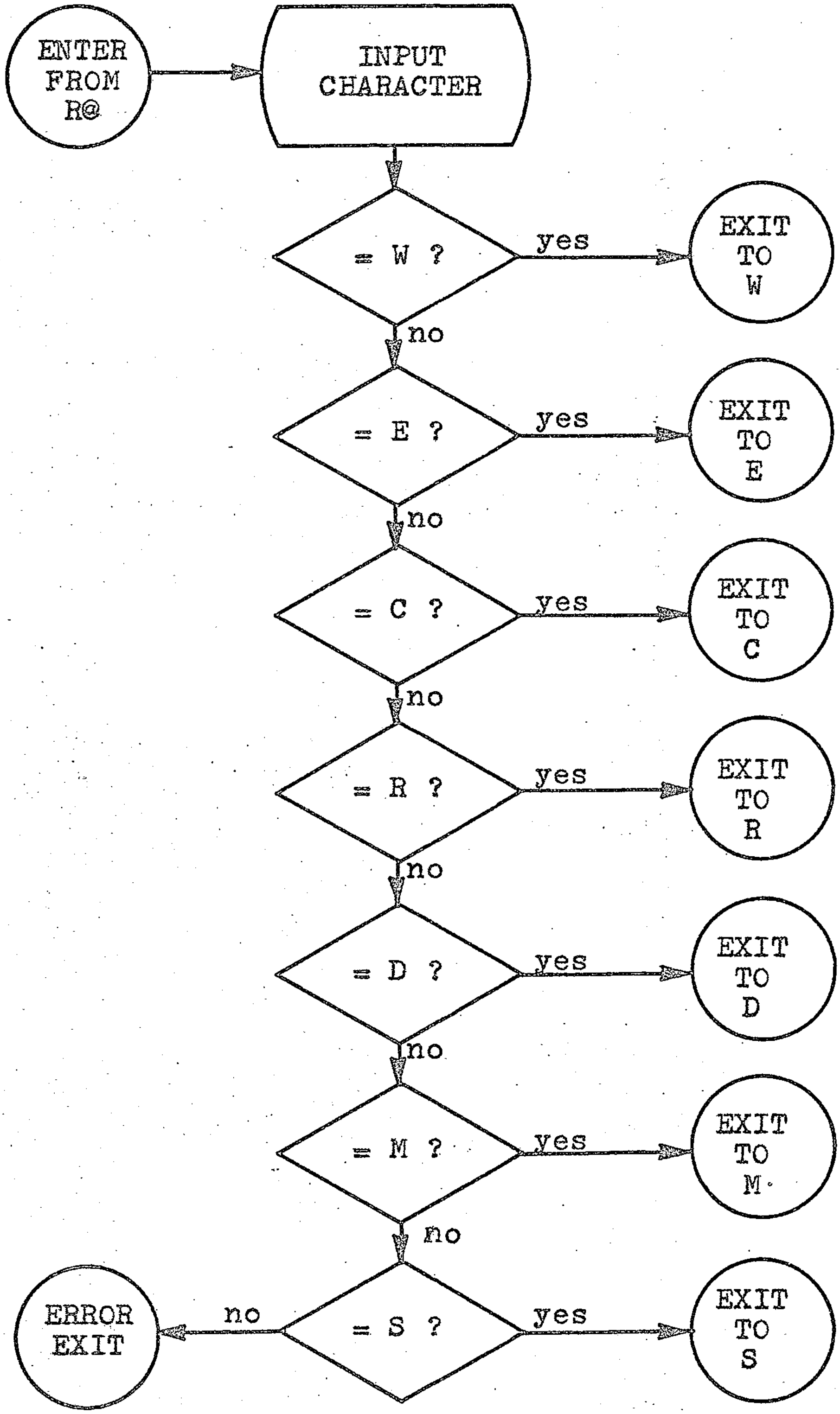


Fig. 11. Flow Chart of R@ Decode Routine

1. Sample name
2. Date and sample ID number
3. Time of day
4. Real and live count times
5. Delay time
6. Irradiation time and reactor power
7. Detector geometry factor

Provision should be made for additional entries. Also, it may be determined that some of the information is not required. It should be possible to terminate the data input after the basic information has been entered. This allows for faster processing of samples and data. Data input and output is handled by two subroutines called DATAI and DATAO. These routines may input or output long or short data tables and be used to list data from either the data buffer or the magnetic tape pack-unpack buffer. A detailed description of these routines as well as the number representation used and a map of the descriptive data buffer is given in Appendix A.

Data Commands

Data may be input to the computer while counting is taking place. Entry into these routines is initiated by typing R@D-. A description of the operation of the D@ and A@ routines is given in Table 2.

TABLE 2

DATA COMMANDS

R@D0@	Output full data block
R@D1@	Input short data block
R@D2@	Output full data block
A@D1@	Input short data block
A@D2@	Input full data block
A@P0@	No data output Do peak analysis
A@P1@	Output short data block Do peak analysis
A@P2@	Output full data block Do peak analysis

The data block used for magnetic tape read and write operations should be made common to any other data blocks used by other programs. Peak analysis routines are initiated by typing A@. Data is requested by A@D-@ and is stored in the same buffer as data entered after the R@D-@ command. Fig. 12 shows a flow chart of the modified A@ routines which now use the DATAI and DATAO subroutines. The routine for input of data is made very simple by use of the DATAI subroutine. A flow chart is shown in Fig. 13.

Contents List

It is often desirable to examine the descriptive data record which is stored on the magnetic tape as the first record in a spectrum file. A special contents list routine was written to allow this. Entry into this routine is made after the instruction R@C-@ is given. Subroutine DATAO is used to output the data in either a long or short format. After entry, the computer asks for a starting file number. This allows the user to examine the contents of a file which is located far from the beginning of the tape. After a spectrum is written on tape, the tape is held in that position. No rewind and space forward is required to locate the file. A subroutine called FFIL is used to locate the file. It checks to see that the tape is not blank and that the file number requested does exist on the tape. This subroutine is described in full in Appendix B.

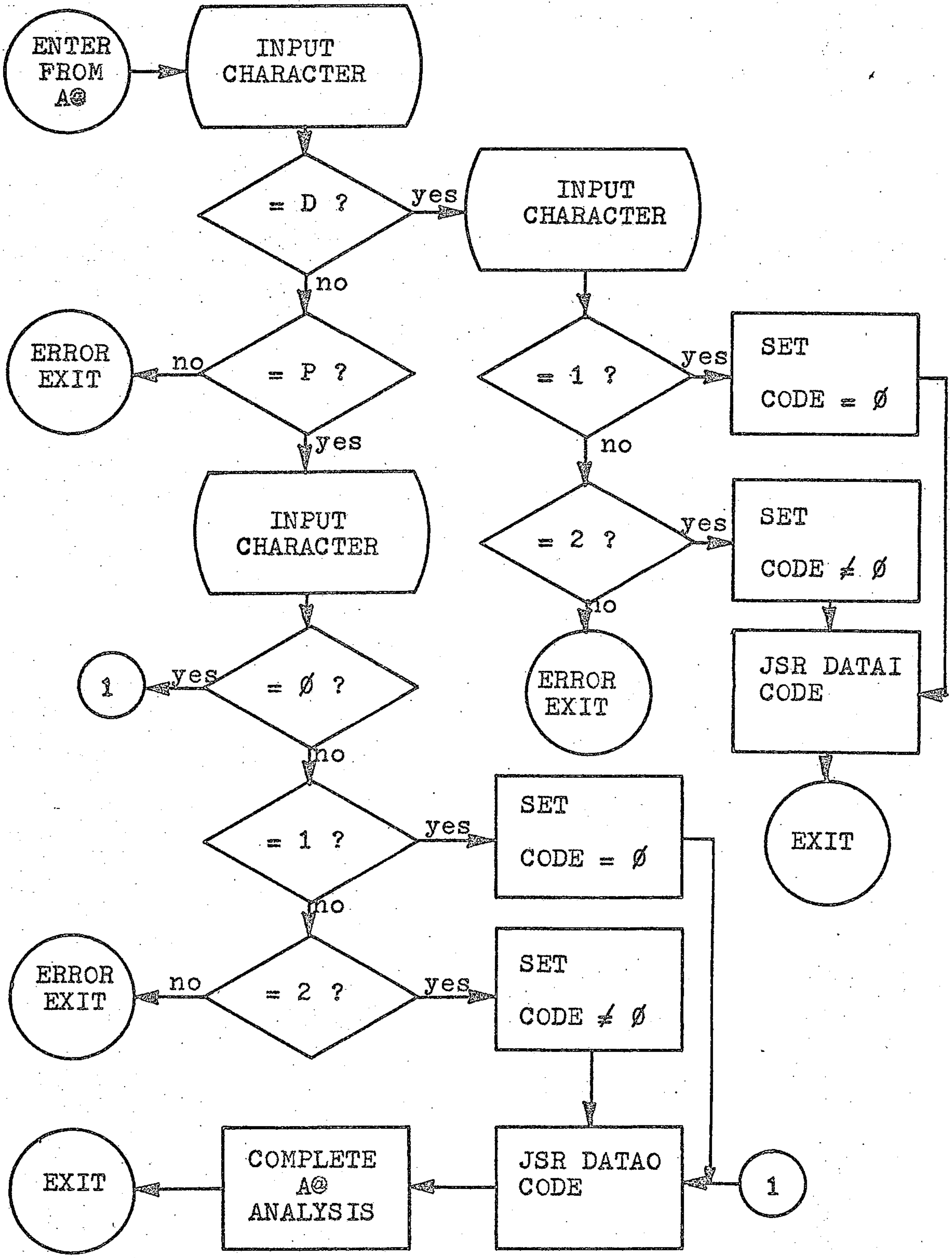


Fig. 12. Flow Chart of A@D@ and A@P@ Routines

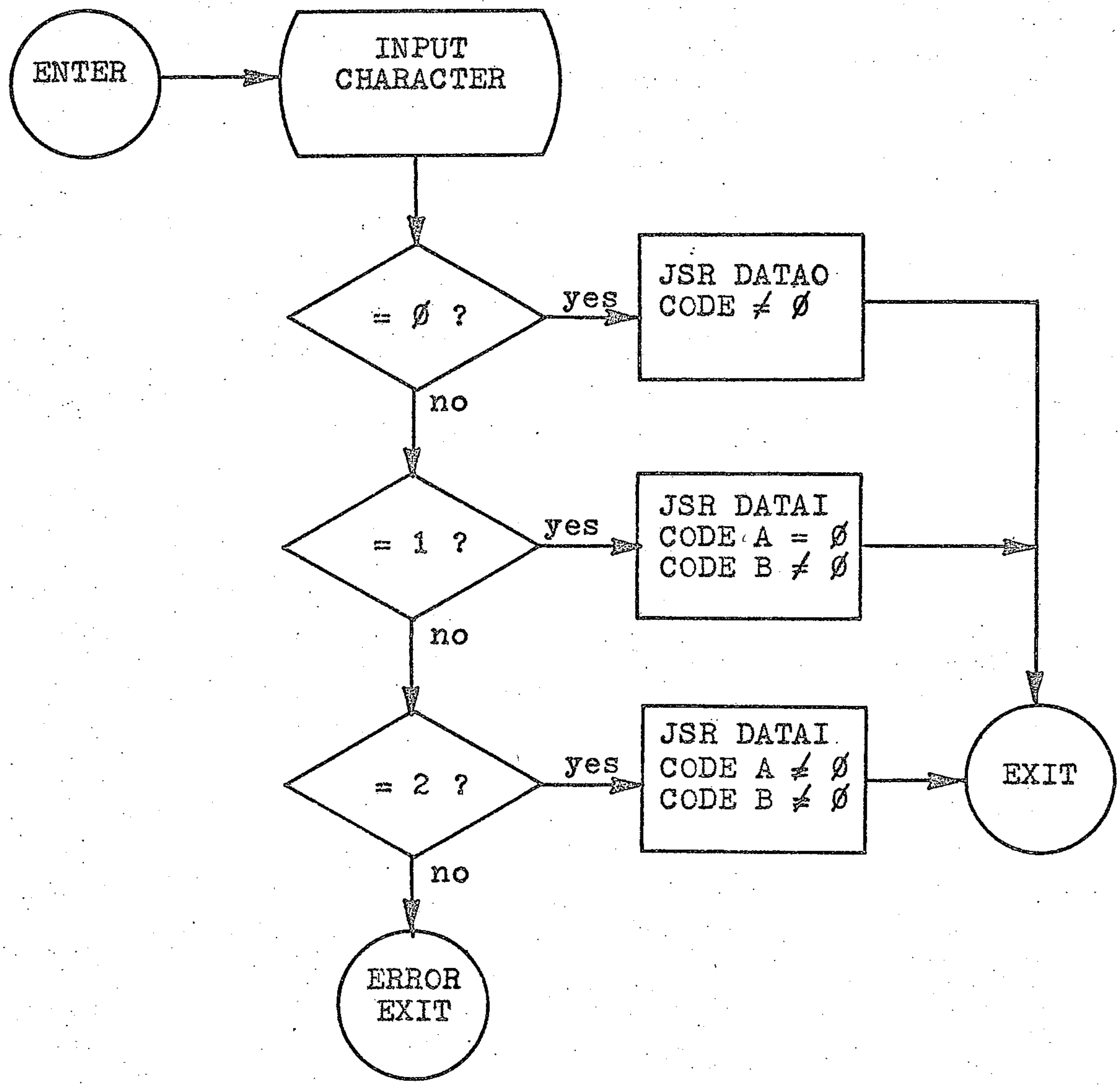


Fig. 13. Flow Chart of D@ Routine

Once the specified file is found, long or short versions of the descriptive data buffer are listed. Output continues until the last file on tape is reached or the operator presses CNTL D on the Teletype. A flow chart of the R@C-@ routine is given in Fig. 14.

Spectra Input-Output

Once the descriptive data has been entered and the spectrum accumulated in the pulse height analyzer, the data may be written on magnetic tape. Before this may occur, two things must be done. First, the analyzer must be placed in the external memory mode so that the data may be accessed by the computer. The method for doing this will vary depending on the type of analyzer used. Software for this operation is supplied in the basic program package of the analyzer - mini-computer combination. The programmer must locate this routine and determine its call sequence. The starting address should be located in page 0 of the mini-computer memory. The second thing which must be done before the spectrum may be written on magnetic tape is to locate the first blank file on the tape.

Write Command

The spectrum write command is called by typing R@W@ on the Teletype. The program then proceeds to find the first blank file on the magnetic tape by using a subroutine called FFBF. This subroutine reads the tape and determines

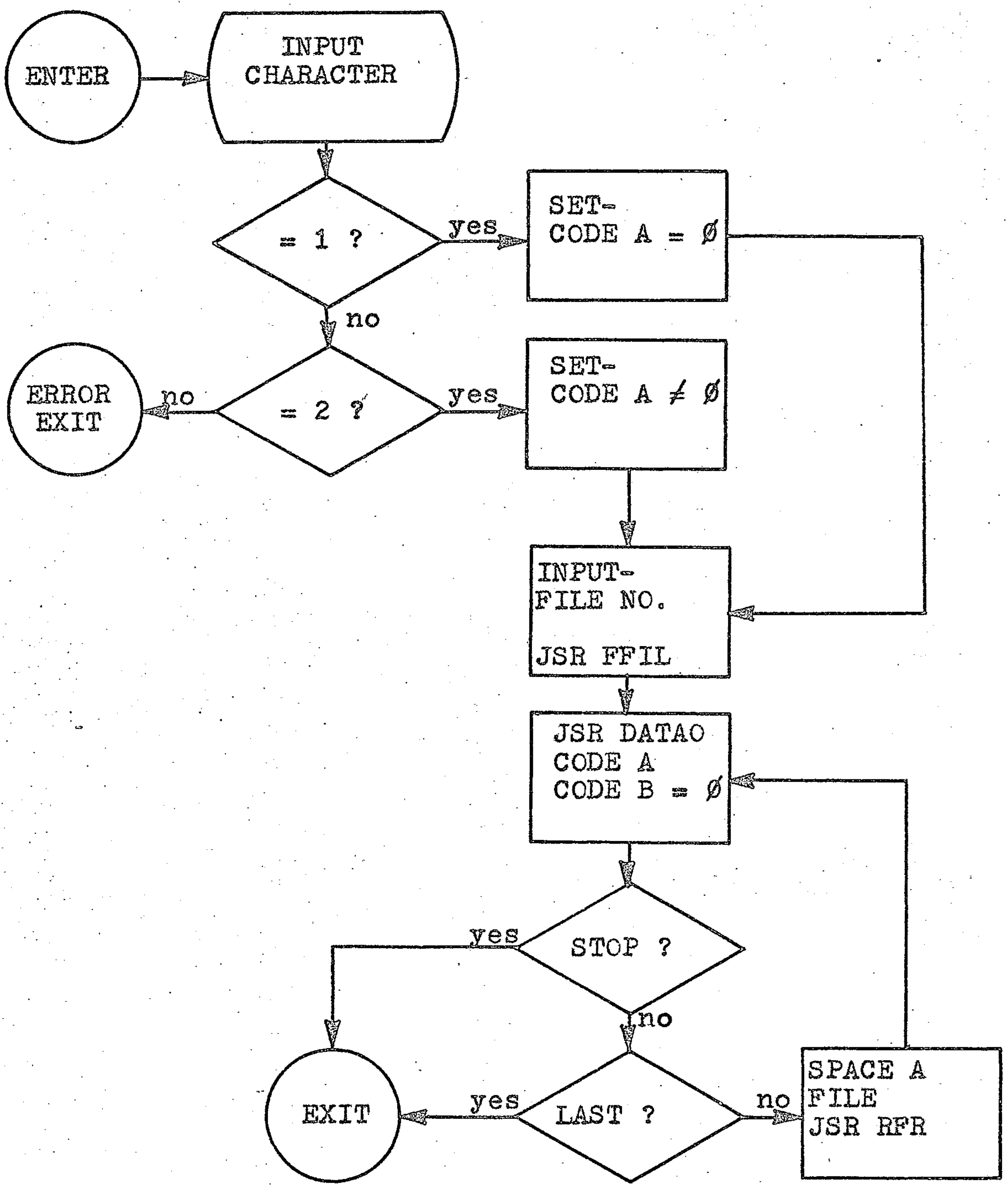


Fig. 14. Flow Chart of C@ Routine

the file number of the present file. It then speces forward until it senses a blank file. Details of the operation of this subroutine are given in Appendix B.

Spectra which have already been written on magnetic tape should be protected from accidential erasure or the writing of new spectra over them. Data recorded in this manner should not be subject to erasure even though it is thought to be useless at the time. This is the philosophy behind the laboratory logbook. All data should be recorded and saved for later analysis or use. Therefore, the R@W@ command will write the new spectrum in the first blank file on tape and will not write over any spectra already stored there. This action should not cause any problems since the tape is capable of storing almost one thousand spectra.

When the first blank file is found, the program writes the new descriptive data block and the calibration table in the first record. The spectrum is then written in the following records. An end-of-file mark is then written on the tape. Finally, the program will type out the file number into which the spectrum has been written. A flow chart of the R@W@ routine is shown in Fig. 15.

Tape Erase Command

Provision has been made to allow for the erasure of a tape. This action may be used to initialize a magnetic tape which was used for other program storage or erase all

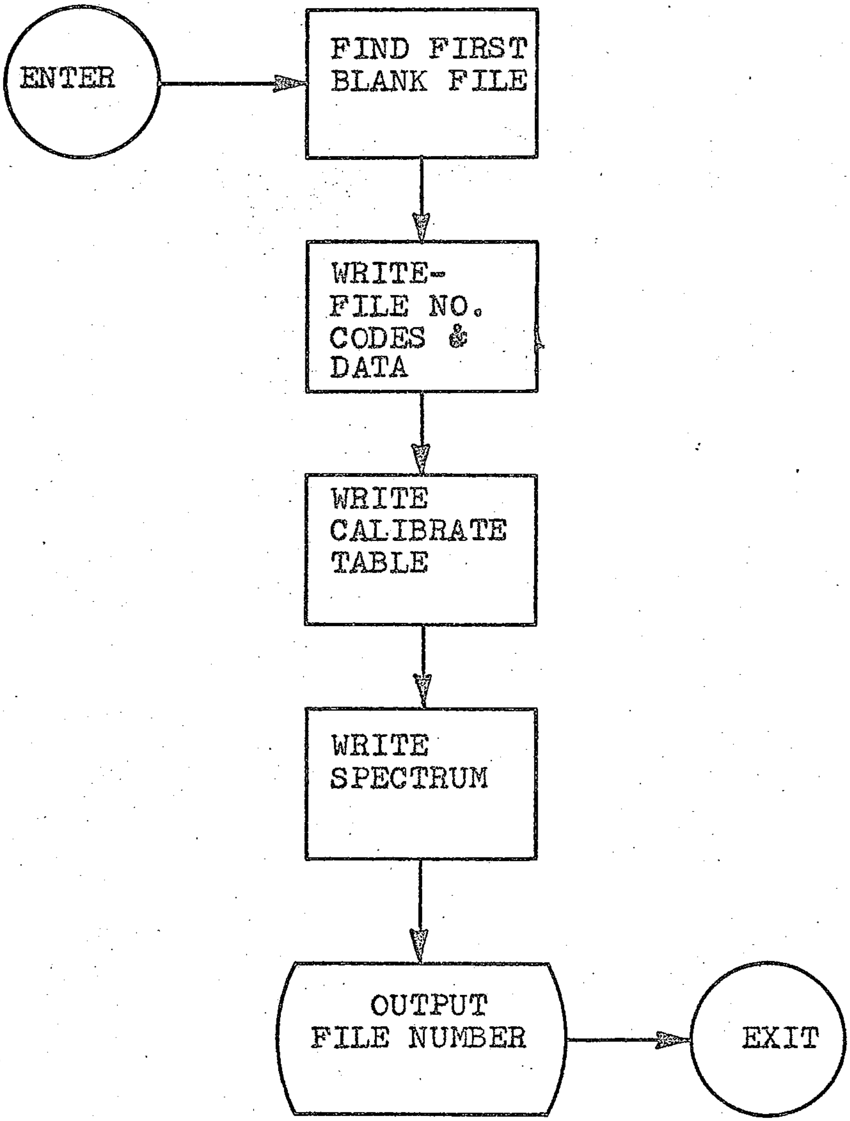


Fig. 15. Flow Chart of W@ Routine

spectra on a tape so that it may be reused. Entry to the erase routine is made by typing R@E@ on the Teletype. The computer then asks for verification of the erase command. This is necessary since all of the R@ command letters are located near each other on the keyboard, and accidential entry into the erase routine is possible. The user must type the letter C to continue the erase sequence. Pressing any other key will return control to the main program.

If the character C has been typed, the tape is rewound to the BOT mark and zero records are written. Writing continues until the EOT mark is sensed or the operator types CNTL D on the Teletype. After either of these actions, the tape is rewound to the BOT and the message TAPE ERASED is typed out. It takes about 24 minutes to erase an entire 2400 foot magnetic tape. The CNTL D termination provision makes it possible to save much time if it is known that only a few spectra have been previously written on the tape. The flow chart of the R@E@ routine is shown in Fig. 16.

Spectrum Read Command

A spectrum may be read from the analyzer back into the analyzer memory by typing R@R-@. The analyzer must be placed in the external memory mode, as for the write sequence. The program will ask for the spectrum file number which must be entered on the Teletype. Subroutine FFIL is used to find the specified file number. This is the same

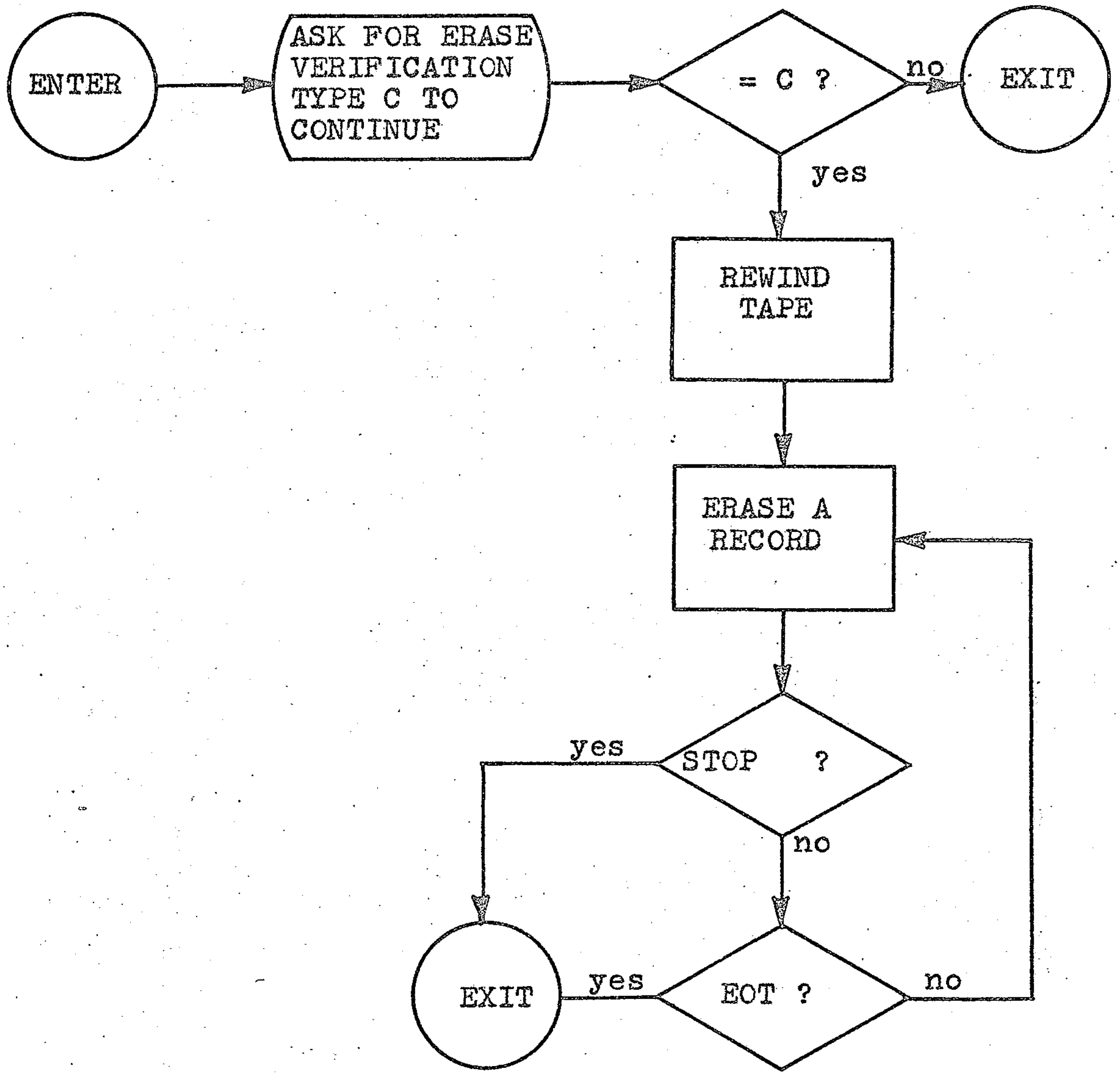


Fig. 16. Flow Chart of E@ Routine

subroutine which was used to locate a specific file for the contents list routine, and is explained in Appendix B.

Two types of descriptive data transfer are possible during a read operation. The first one transfers all data from the first record on tape into the data buffer. This includes transfer of the calibration table. During testing of a prototype version of the read routine, it was found that it may be desirable to suppress the transfer of the calibrate table. This suppression is useful if an error is detected in the calibration table stored on tape. If there are many spectra stored with the same incorrect calibrate table, it is very time consuming to reenter the table after each magnetic tape read. By typing R@R2@ it is possible to transfer the descriptive data and the spectrum without effecting the present calibration table which is stored in the mini-computer memory. A flow chart of the R@R-@ routines is given in Fig. 17.

Complex Functions

Magnetic tape is an excellent on-line mass memory for the storage of spectra. Various spectra may be recalled at any time for further examination or analysis. This capability leads directly to several user-interactive routines which may be used to manipulate data. Since the spectra are stored on tape, retries are possible and no original data is lost.

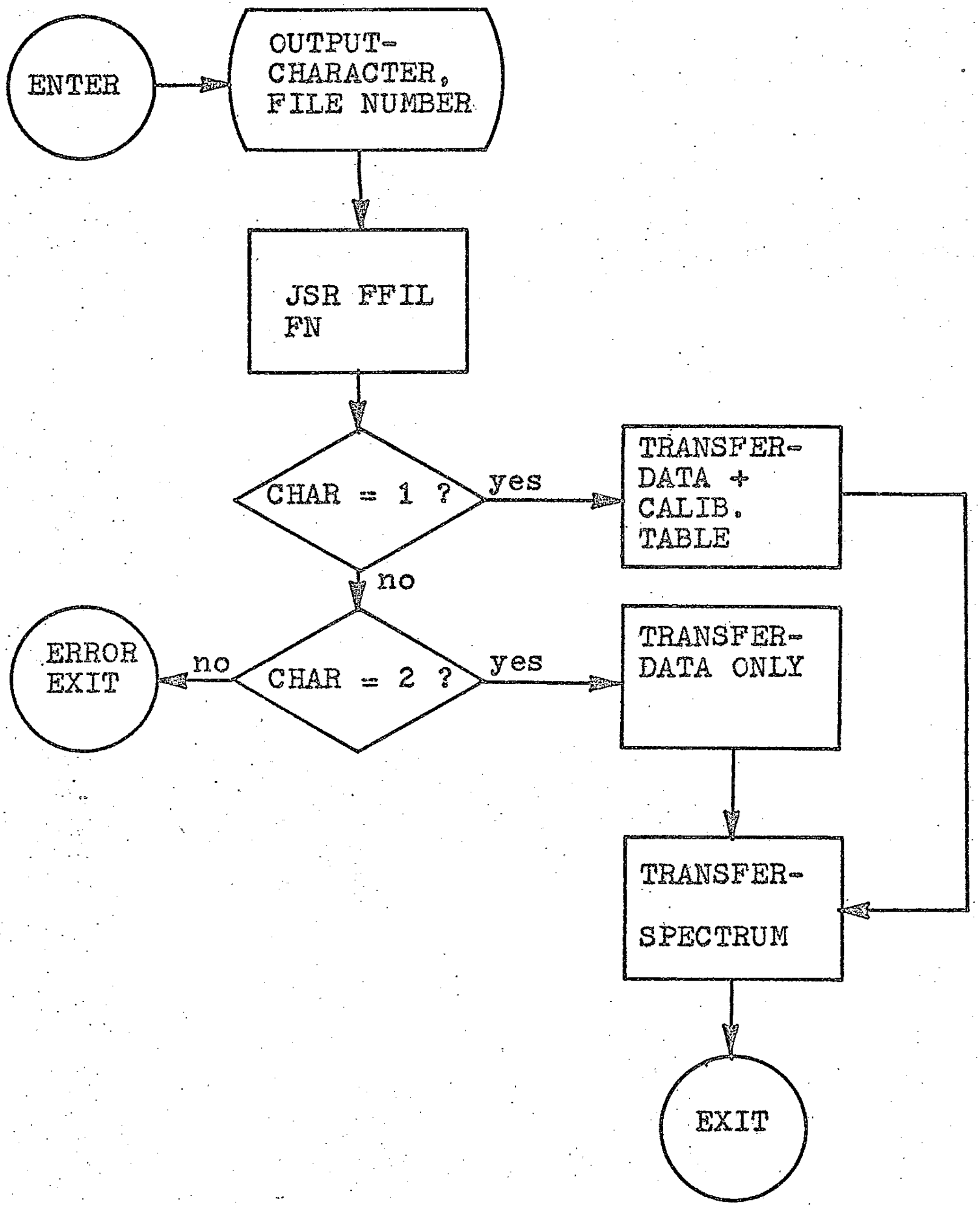


Fig. 17. Flow Chart of R@ Routine

Spectrum Compare

The first user-interactive routine described will allow the user to compare two spectra. The first one is read into the analyzer by use of the R@R-@ command. The second spectrum is then asked for after entry into the compare routine. This is initiated by typing R@M@. Subroutine FFIL is then used to locate the specified file.

The program then asks for several parameters. The first is the multiplication factor. This is the number which the spectrum on tape will be multiplied by before it is entered into the analyzer for comparison. This allows the user to compare two spectra which have vastly different count times or which were made of samples of different activity. Other analyzer routines may be used to obtain the multiplication factor directly. Routines exist for integrating the counts under a photopeak. Taking the ratio of these areas may be used to calculate the multiplication factor. This factor is important in the stripping routine which will be described later.

Limits may be placed on the region to be compared. The program tests to make sure that the limits specified are within the limits of the analyzer and are not in the reverse order. A shift factor may then be entered. Either a left or right shift may be made. This allows corrections for drift in the amplifier and analog-to-digital converter. Tests are made to see that the shift plus limits are not out of bounds of the analyzer memory. Subroutine MSD is used to input the file number and other data. A description of subroutine MSD appears in Appendix C.

Once the data has been entered, subroutine SETW is called to locate the starting address of the record and first word which are to be transfered to the analyzer. The appropriate shift factor is also introduced. A detailed description of subroutine SETW is given in Appendix C.

All intensification is removed from the spectrum in the analyzer. The spectrum on tape is then stored in every other channel in the analyzer. Each bit of the comparison spectrum is intensified. The result is a display on the analyzer CRT which shows the original spectrum in odd numbered channels and the new spectrum, shifted, scaled by the multiplication factor, and intensified in the even numbered channels. As mentioned earlier, this routine is useful for determining the shift and multiplication factor necessary for use in the strip routine. A flow chart of the compare routine is shown in Fig. 18.

Spectrum Strip

Typing R@S@ initiates the spectrum strip routine. The file number and input parameters are input just as in the spectrum compare routine. Subroutines MSD and SETW are used. Intensification is removed from the spectrum in the analyzer. Each channel of data which makes up the spectrum

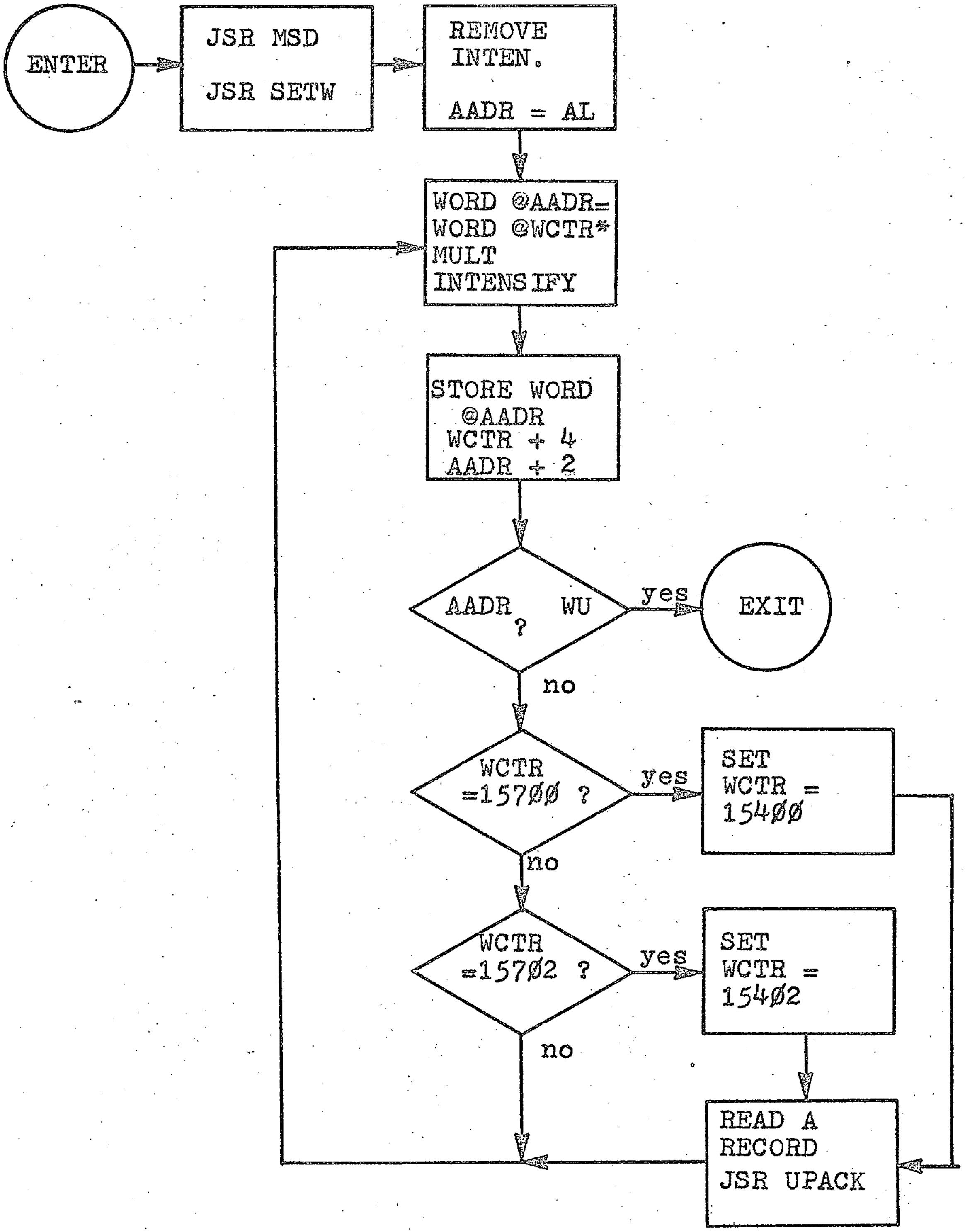


Fig. 18. Flow Chart of M@ Routine

on tape is then read, shifted, scaled, and subtracted from the corresponding channel in the analyzer. Underflows are set to zero and intensified. Care should be taken to round off numbers and make sure that no shifts are introduced during successive reads. A good test of this routine is to subtract a spectrum from itself. The result should be zero in each channel. A further test is to subtract half the spectrum twice, or one third the spectrum three times. In each case, the result should be zero or, in the presence of round off errors, a one left. A flow chart of the spectrum stripping routine is shown in Fig. 19.

The uses of the stripping routine are numerous. It may be used to subtract peaks which interfere with other peaks nearby. This is particularly useful when a NaI detector is used. Stripping may also be used to remove background radiation and other interfering counts.

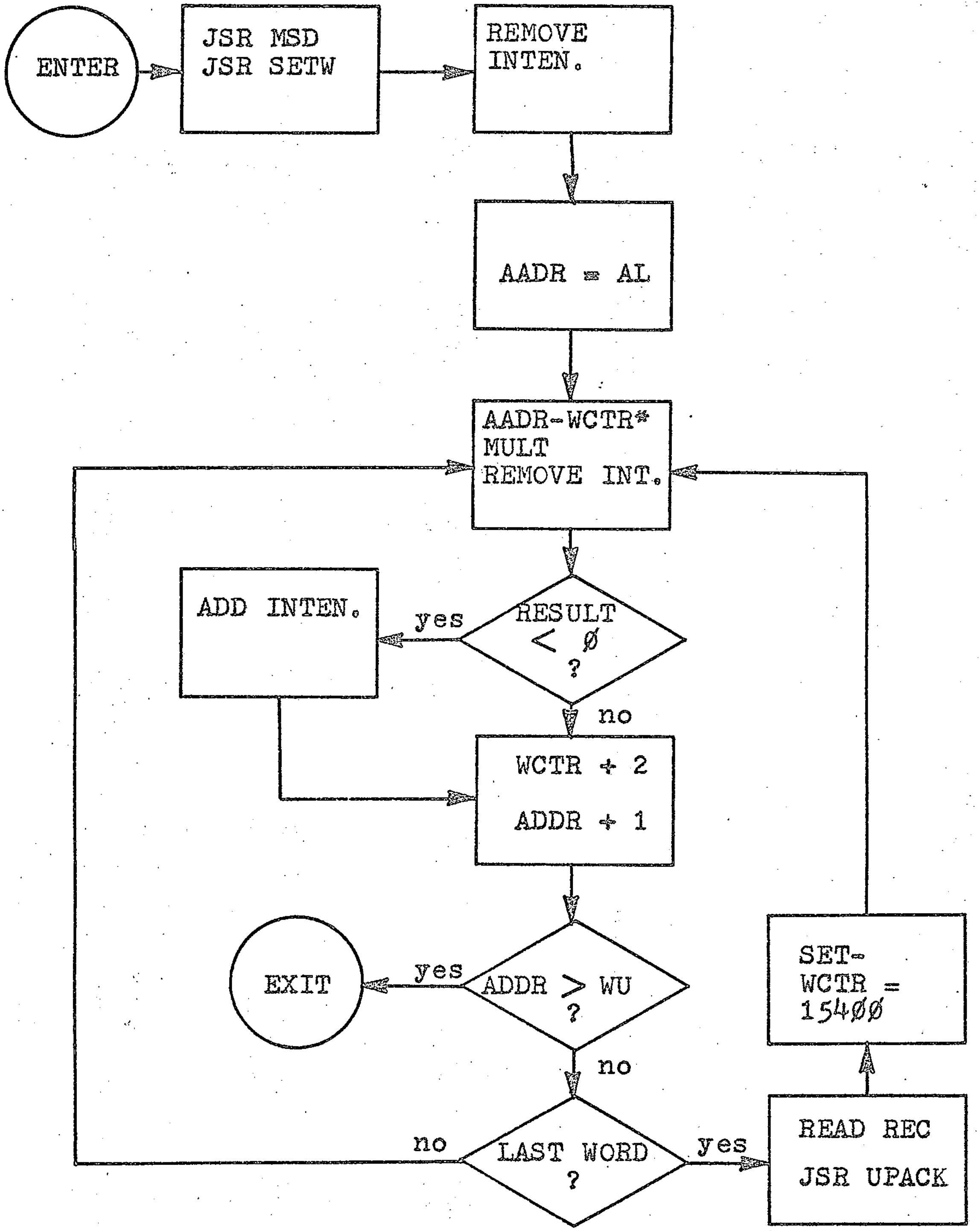


Fig. 19. Flow Chart of S@ Routine

CHAPTER 5

PROGRAM STORAGE ON MAGNETIC TAPE

Magnetic tape has proven to be a fast, reliable, storage medium for the large amounts of data collected during the course of gamma-ray spectroscopy experiments. The many advantages of magnetic tape over Teletype and high speed paper tape have been delineated. Magnetic tape also parvides an efficient method of storing and recalling program material.

A rapid means of storing and recalling programs is particularly useful when new programs are assembled or existing programs are updated. The basic analyzer and assembler programs require about 8K of mini-computer memory, about the same amount as a spectrum from the pulse height analyzer. It would be very time consuming to read in the assembler program from paper tape, read in the old analyzer program, and then punch out an update version. Each of the above operations requires over a half an hour to execute on the Teletype, but less than 5 seconds on the magnetic tape drive.

As with all computer systems, occasional program failures will occur, wither due to hardware problems or operator error. Rapid system recovery is essential to efficient utilization of the analyzer system. Under most circumstances, the software required to read from magnetic tape is not destroyed by operator errors; and, since it is relatively short, is less prone to mechanical failures. It is faster to read in the magnetic tape handlers from paper tape and then the main program from magnetic tape than it is to read in the entire analyzer program from paper tape. If the particular mini-computer in use does not have magnetic core memory, any power outage will cause a complete loss of all data in memory. The use of magnetic tape is particularly useful in these instances.

The magnetic tape handlers were kept as short and simple as possible to speed up their loading and lessen the probability of their loss due to mechanical problems. All control functions of the magnetic tape handlers are initiated from the front panel of the mini-computer; no interface with the Teletype is made. A typical user instruction set is shown in Fig. 20.

PRESS STOP

PRESS RESET

SET 000000 IN THE DATA SWITCHES

PRESS DEPOSIT AC0

SET 60 IN SWITCHES

PRESS DEPOSIT AC1

SET FN IN DATA SWITCHES

PRESS DEPOSIT AC2

SET ADDRESS IN DATA SWITCHES

PRESS START

(program will load mini-computer memory)

SET MAIN PROGRAM STARTING ADDRESS

PRESS RESET

PRESS START

Fig. 20. Sequence of Steps to be Followed for Manual Operation of the Magnetic Tape Drive

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Standard hard copy equipment was found to be the factor which limited the overall system efficiency in an otherwise state-of-the-art gamma-ray spectroscopy system. With proper planning, magnetic tape was shown to be a fast, high density, portable mass storage medium for gamma-ray spectroscopy data. It allows user-interactive operations such as spectrum strip and prevents accidential loss of data. All spectra may be permanently recorded for future study. Reactor time may be used more efficiently since short half lived isotopes may be counted and their spectra stored on magnetic tape before analysis in a relatively short time. Reactor personnel no longer have to wait for long data output operations to be completed before the next sample may be irradiated.

Much of the same software used to write gamma-ray spectra on magnetic tape may be used to store program material there also. This greatly increases the speed at which program modification may take place and makes system recovery after a program failure fast and simple.

Recommendations

Several operations are possible once the magnetic tape operating system has been installed and tested. One requires the addition of a real time clock. With the addition of this equipment, automatic functions are possible. That is, various counting operations and sequences may be initiated automatically and the data stored on tape. This allows the system to operate without user interaction. This would be useful for counting large numbers of samples or a single sample a large number of times for half-life determination.

It is also possible to transport spectra to larger computers by use of magnetic tape. All that is required is a review of the magnetic tape handling software used in the large computer. Programs to remove the spectrum data may be written using the same algorithms as used in the mini-computer system. Special number conversion routines may have to be included to change the number forms from the mini-computer representation into forms recognizable by the large computer.

APPENDIX A

SUBROUTINES DATAI AND DATAO

Data essential to the understanding of the spectra is stored in the first record of the spectrum file. This descriptive data block must be read in and output by several different magnetic tape operating routines. Efficient use of time also dictates that long and short versions of the data block be possible. Subroutines DATAI and DATAO were written to input and output data respectively.

Subroutine DATAI

Subroutine DATAI is used by the A@D-@ and R@D-@ routines to input the information to be stored in the descriptive data record of the spectrum file. Subroutine DATAI has two modes which are initiated by the number typed after the letter D. The character "1" is used to denote that the short version of the data list should be input. A "2" indicates that the complete data set should be entered. After entry, the subroutine asks:

SAMPLE NAME?

The user may then type a single line on the Teletype which describes the spectrum to be written. The line may be terminated at any time by typing a carriage return. The sample name may contain any characters except the carriage return.

The program then asks:

SAMPLE ID NUMBER?

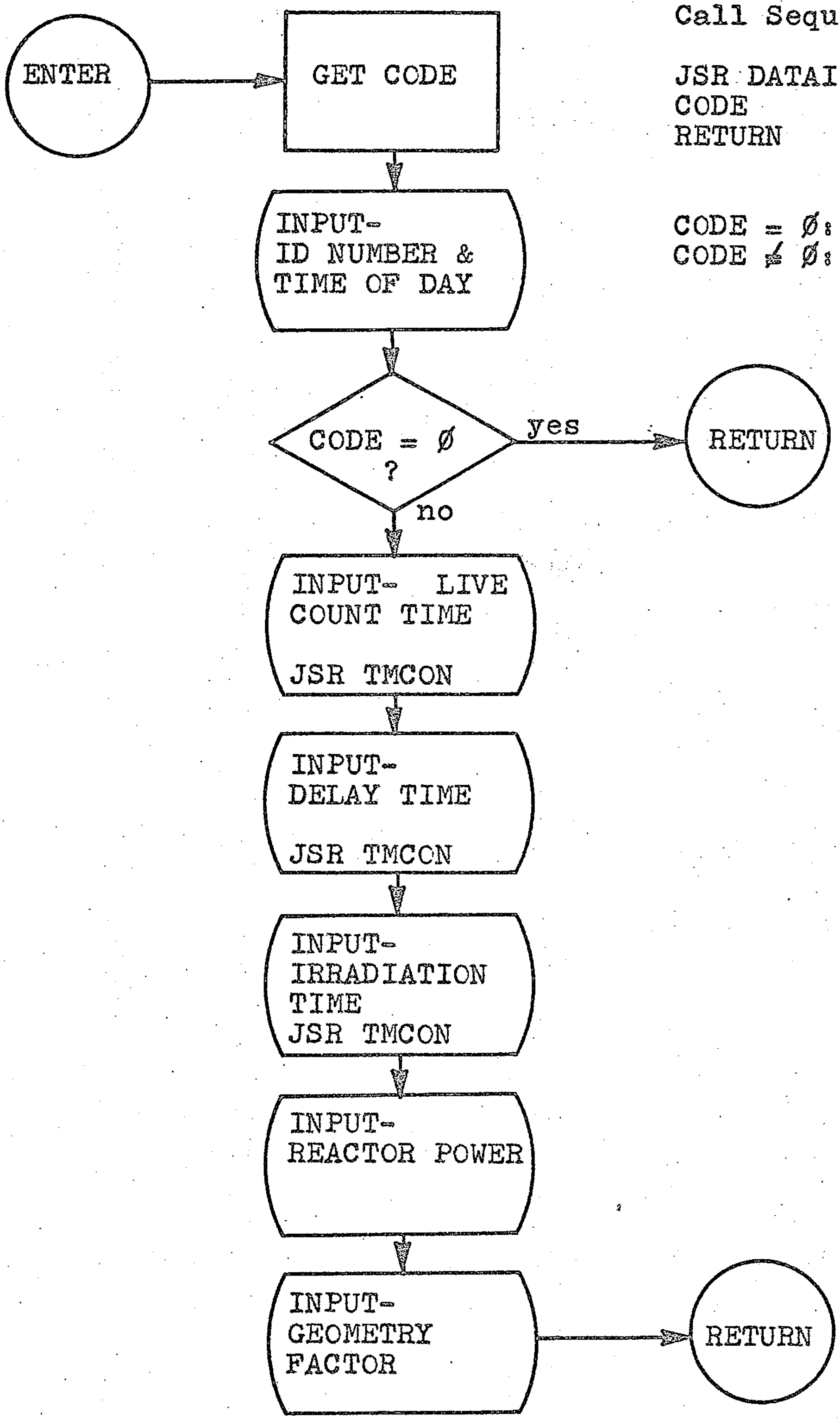
The user must type eight characters on the Teletype. These eight characters are usually broken up into four two digit numbers representing the day, month, year, and sample count number. After the eighth character is typed, the program asks:

TIME OF DAY?

Four digits must be typed. The time of day should be entered in 24-hour format.

If a one has been typed, the program now sets all remaining data to zero. Otherwise, the program continues to input data. The program now asks for three times, the live count time, irradiation time, and delay time. Following each time entry, the user must type a letter S, M, H, or D. This allows the user to input the time requested in the most practical units. The time entered is converted to seconds before it is stored in the data buffer. Subroutine TMCON is used to convert the times to seconds from the indicated units. This is done to maintain a degree of uniformity in the data.

Finally, the program asks for the reactor power in kilowatts and the detector geometry factor. Both of these numbers are entered in the floating point format used to represent the various times. Flow charts of subroutines DATAI and TMCON are shown in Fig. 21 and Fig. 22.



Call Sequence:

JSR DATAI
CODE
RETURN

CODE = 0: Short Data
CODE ≠ 0: Long Data

Fig. 21. Flow Chart of Subroutine DATAI

Call Sequence:

JSR TMCON
RETURN

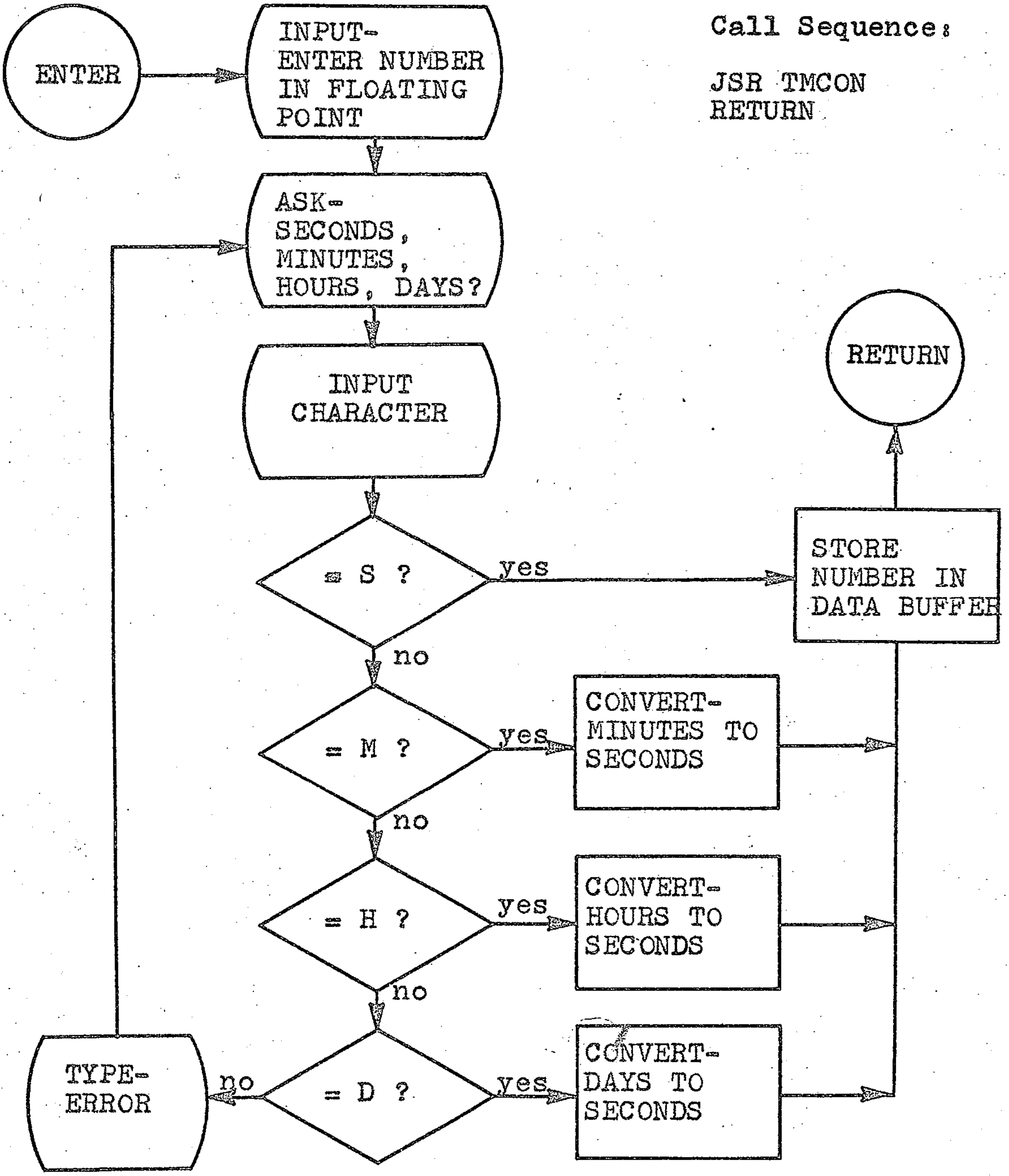
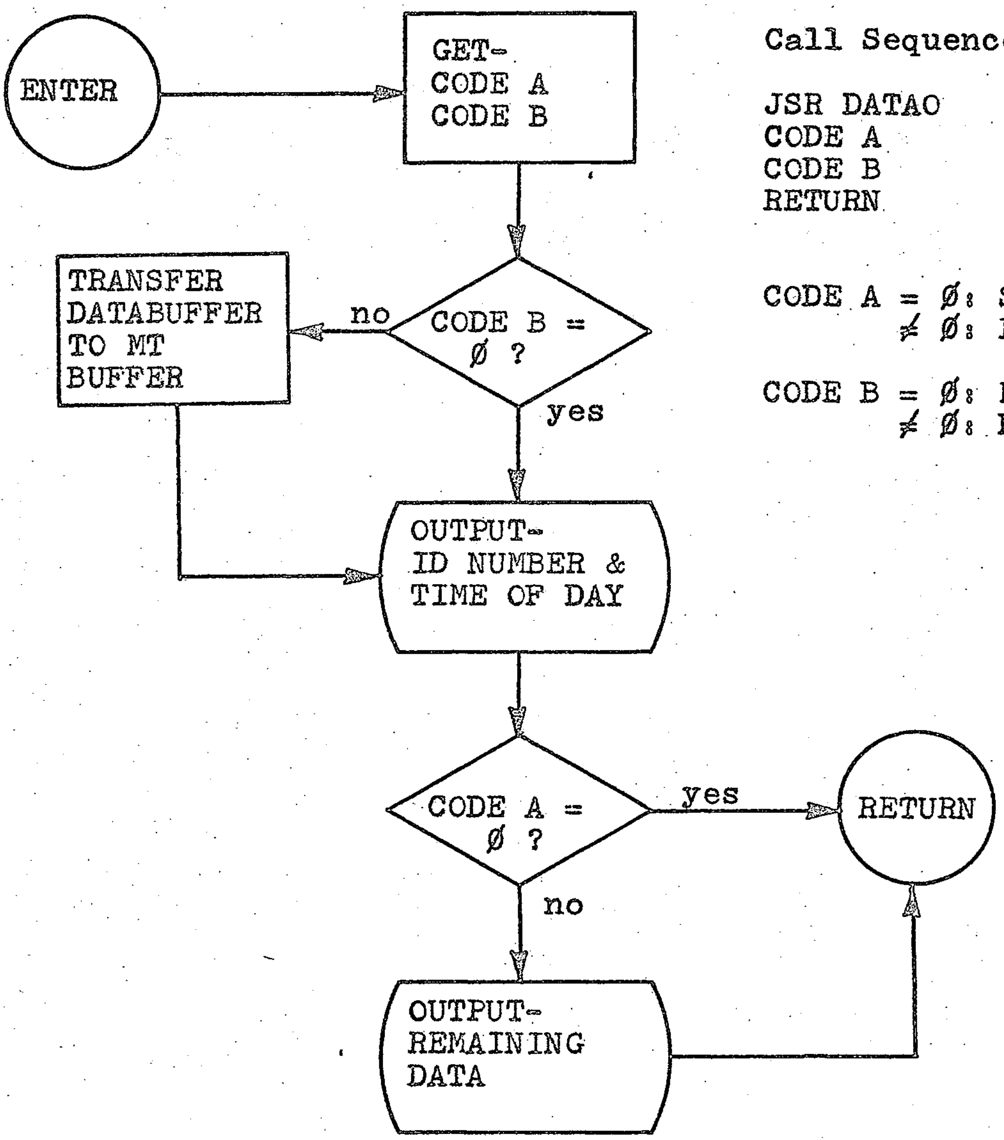


Fig. 22. Flow Chart of Subroutine TMCON

Subroutine DATAO

Subroutine DATAO is used by the A@D-@, R@C-@, and R@R-@ routines to output the data in the descriptive data block. As with the subroutine DATAI, long and short versions of the data may be output. The subroutine may output data from either the data buffer or the magnetic tape buffer.

The subroutine is called by the main program by an indirect jump to a page zero location. The JSR DATAO instruction is followed by two code numbers which tell the subroutine how much data to output and where it is located. The first word, CODE A, indicates whether or not the full data record is to be output. A zero stands for the short version, a nonzero causes the entire record to be output. The second word after the JSR instruction, CODE B, is used to indicate the location of the record. A zero indicates that the data is located in the MT buffer. This is used during the R@C-@ routine which lists the contents. The MT buffer is used so that the data in the data buffer is not lost during the contents list operation. A nonzero word for CODE B indicates that the data buffer is to be listed. This is used to check the contents after a DATAI operation. This may be necessary at the end of a lengthy (overnight) count when the data was entered shortly after the count was started. A flow chart of subroutine is shown in Fig. 23.



Call Sequence:

JSR DATAO
CODE A
CODE B
RETURN

CODE A = 0: Short
≠ 0: Long

CODE B = 0: MT
≠ 0: DATA

Fig. 23. Flow Chart of Subroutine DATAO

Data Buffer Map

A chart or map should be made to show the locations and types of numbers used for the descriptive data record. This will insure that the proper numbers are input and output during the DATAI and DATAO operations. The data buffer map used for this thesis is shown in Fig. 24. Note that it is 300_8 words long to match the length of a single record. The calibration table is also included.

Number Representation

Several types of number and character representation are used. The particular form used will depend on the use to which the information will be put. Sample name and ID numbers as well as the time of day are stored in standard ASCII code. This format allows direct input and output of this information of the Teletype. Since the data is not used anywhere else, this representation is sufficient. Programs for input and output of ASCII characters were included in the standard analyzer software package.

Binary integers were used to represent the file number, codes, and spectrum data. This form proved to be convenient since no mathematical operations are required. Input and output routines were supplied as part of the analyzer software. Special routines exist in the floating point interpreter to change binary integers into floating point numbers and back if necessary.

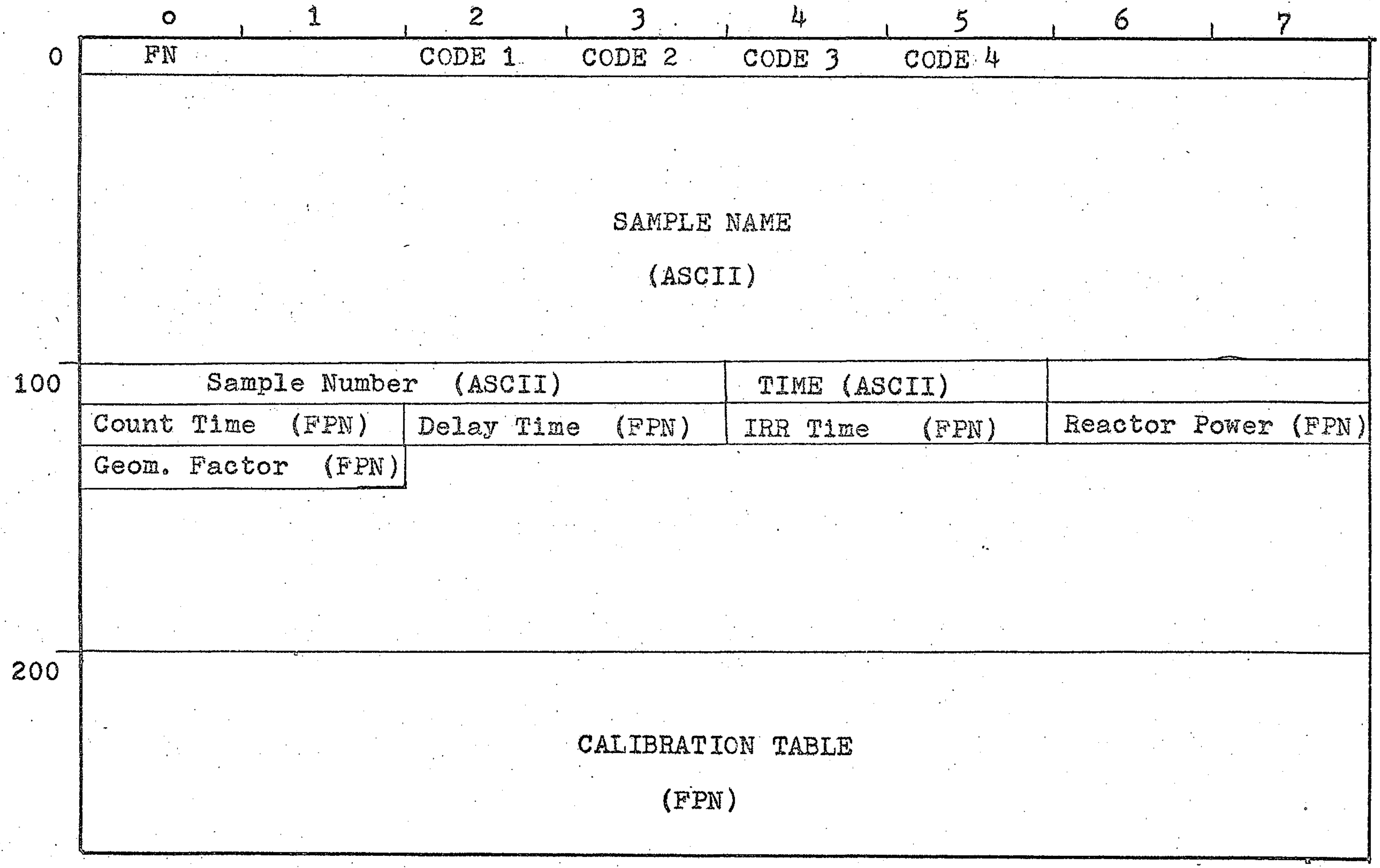


Fig. 24. Data Buffer Map

APPENDIX B

SUBROUTINES FFIL AND FFBF

All routines except the data input-output routines require locating either the first blank file on the magnetic tape or a particular file. Subroutines FFIL and FFBF are designed to do this. Each routine is written to locate the file requested with no assumptions made as to the contents of the tape or its location on the tape drive. Four subprograms are used extensively in these routines. They are CODE, SPF, SFOR, and RFR. Detailed explanations of these subprograms will be given at the end of this Appendix.

Subroutine FFIL

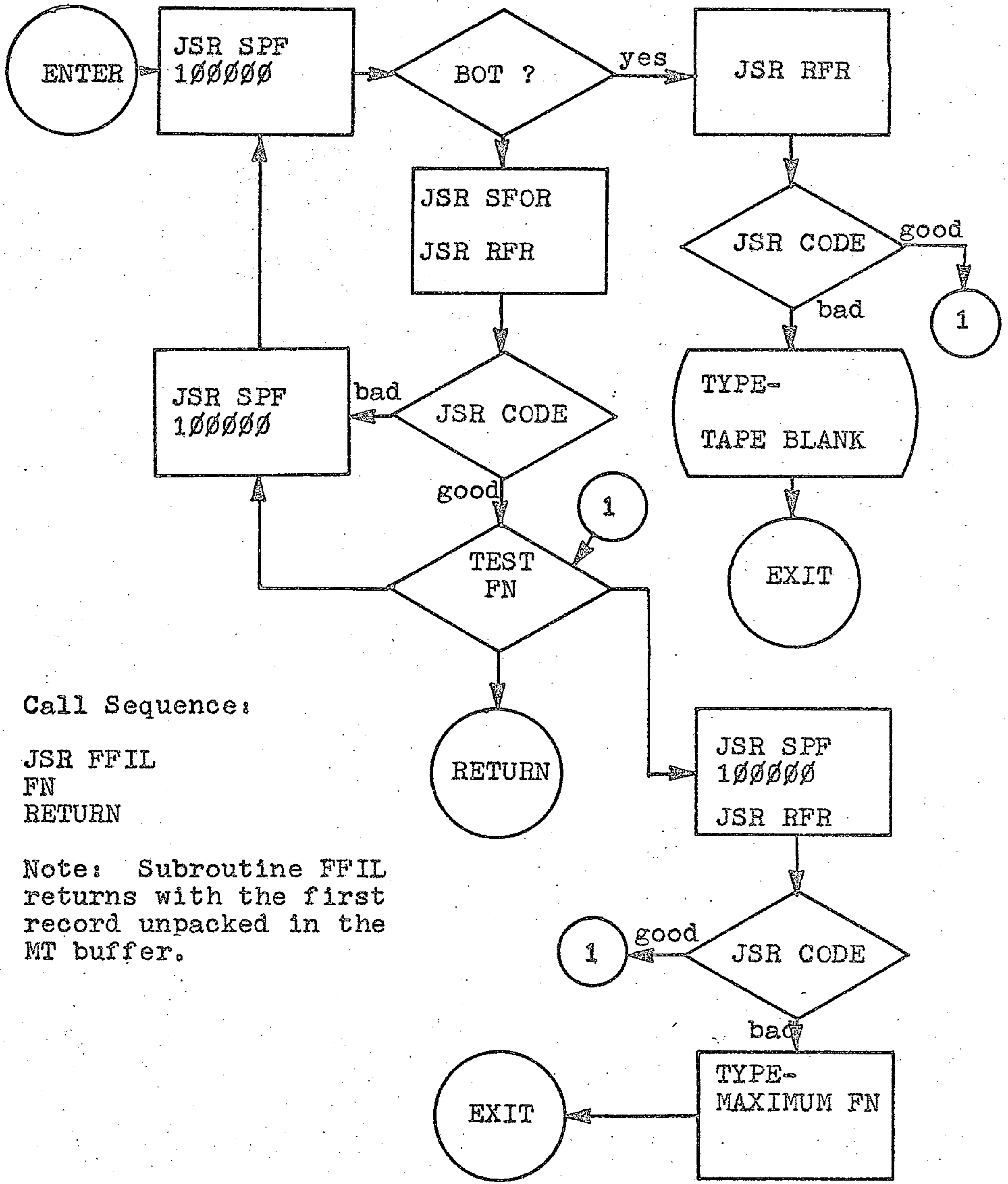
The starting address of the subroutine FFIL is stored in page 0 of the mini-computer memory. A JSR @LOC followed by the file number in binary comprises the call sequence for subroutine FFIL. After entry, the program spaces back one file and checks for a beginning of tape mark. This is done to determine if a space forward one record (SFOR) is necessary. If there is no BOT mark, it is necessary to space over the file mark before any read commands may be given, otherwise an error will occur. Once the tape is positioned at the beginning of tape or beginning of a file, the first record is read. The codes are checked to determine if a file does exist. If no file exists, the tape is spaced back to the beginning of the next file. This process continues until the specified file is found or the BOT is reached. Return to the main program is made if the file is found. If the largest file on tape is less than the specified file, a message to that effect is typed out. If no files are found and the BOT encountered, the subroutine will output a message saying that the tape is blank. Control is then returned to the main analyzer program. A flow chart of subroutine FFIL is shown in Fig. 25.

Subroutine FFBF

Subroutine FFBF operates in much the same way as subroutine FFIL. The exception is that it spaces forward until the first blank file is found. If the tape is blank, the tape is set to the first file after the BOT mark. The file number found to be the first blank one is returned to the main program. Much use is made of subroutines CODE, SPF, SFOR, and RFR. The flow chart for subroutine FFBF is shown in Fig. 26.

Subprograms CODE, SPF, SFOR, and RFR

Subroutine Code checks to see that the third through sixth words in the first record on the file match a preset group of numbers. The code numbers were selected to test all seven data channels of the read-write electronics in the magnetic tape operating system. Also, the odds of



Call Sequence:

JSR FFIL
FN
RETURN

Note: Subroutine FFIL returns with the first record unpacked in the MT buffer.

Fig. 25. Flow Chart of Subroutine FFIL

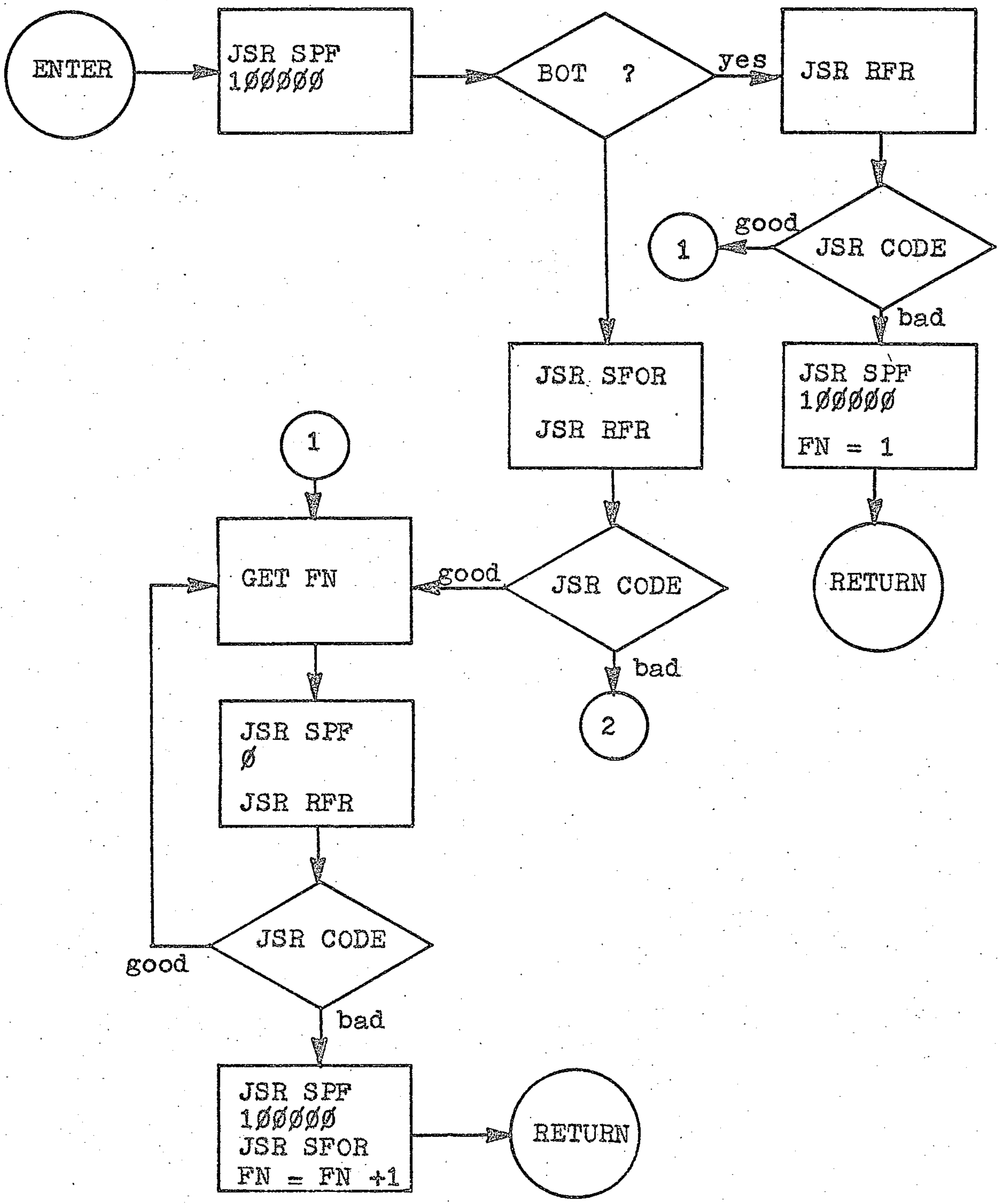


Fig. 26. Flow Chart of Find First Blank File Routine

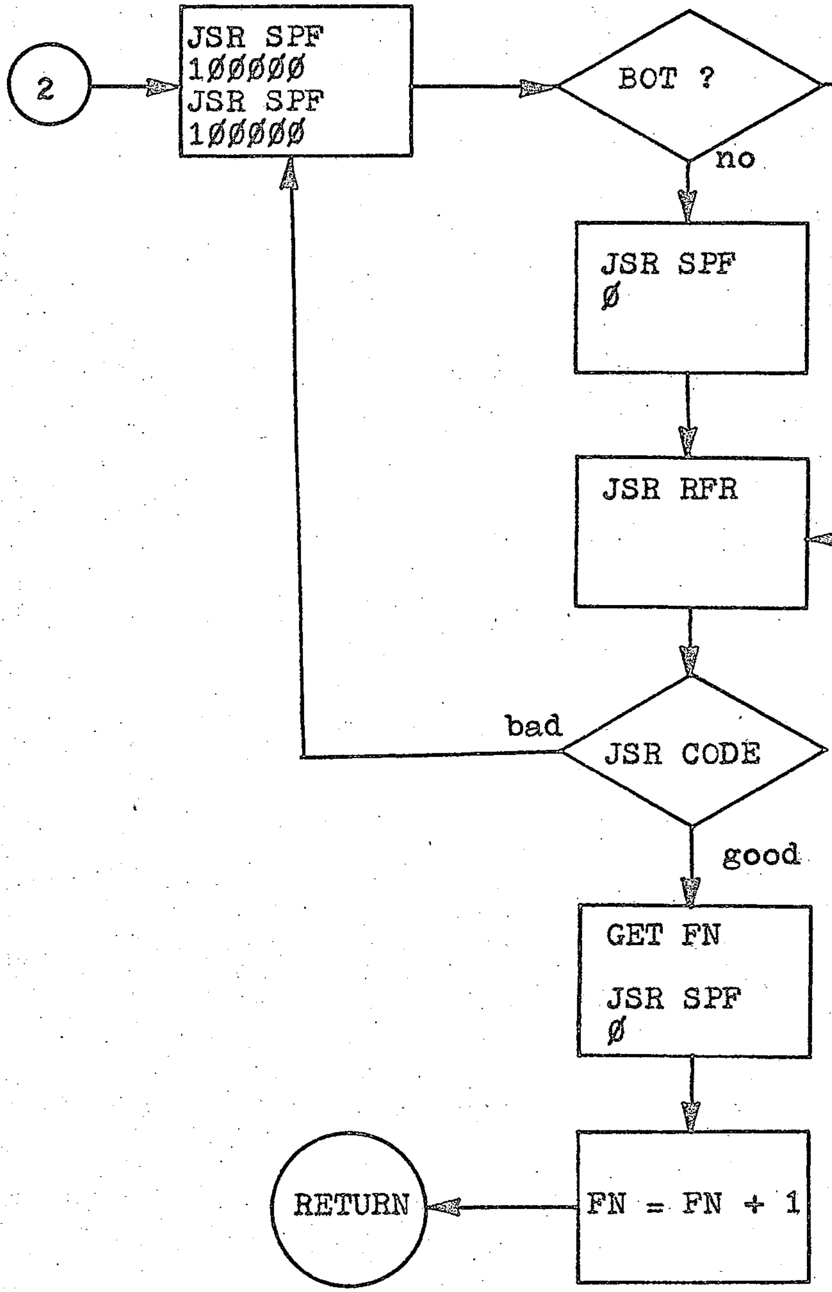


Fig. 26. Continued

finding just this combination of words at random is very small. If the codes are good, the subprogram returns to the subroutine at the call address plus one. If the codes are bad, the return is made at the call address plus two.

Subprogram SFP is used to space the tape forward or backward one complete file. The word at the call address plus one is used to indicate which direction the tape is to be spaced. A zero indicates that a forward space is desired and a large negative number (in twos complement) indicates a space back of one file is required. Return is made to the call address plus two.

SFOR is used after a space back one file to reset the tape position to the beginning of the file. This is required since the space back command sets the tape just ahead of the last end of file mark. Any read command attempted would set an error condition since the read would attempt to read over the end of file mark.

After the tape has been positioned by using the SPF and SFOR commands, the first record is read using the RFR subprogram. This program reads the first record in the file and unpacks the data into the magnetic tape buffer. A call to subprogram CODE is then made to determine whether or not the file is blank.

The starting addresses of these four subprograms are stored in page 0 locations of the mini-computer. A simple JSR @LOC is all that is required to call them.

APPENDIX C

SUBROUTINES MSD AND SETW

Special data is required for operation of the two complex functions included in the new software package. This data includes a shift and multiplication factor and a set of limits. Subroutine MSD is used to input this data for both the R@M@ and R@S@ routines. The main purpose of MSD is to check the limits and shift factor to see that the analyzer memory limits are not exceeded. This would occur if a large shift were entered and the limits specified were near the boundaries of the analyzer memory. The flow chart for subroutine MSD is shown in Fig. 27.

Once the data for R@M@ and R@S@ is entered, it is necessary to find the first number on tape which corresponds to the lower limit. The effective word number is calculated by adding the lower limit and the shift factor. Records are read in succession until the required word is found. The program then returns to the main program. A flow chart for subroutine SETW is given in Fig. 28.

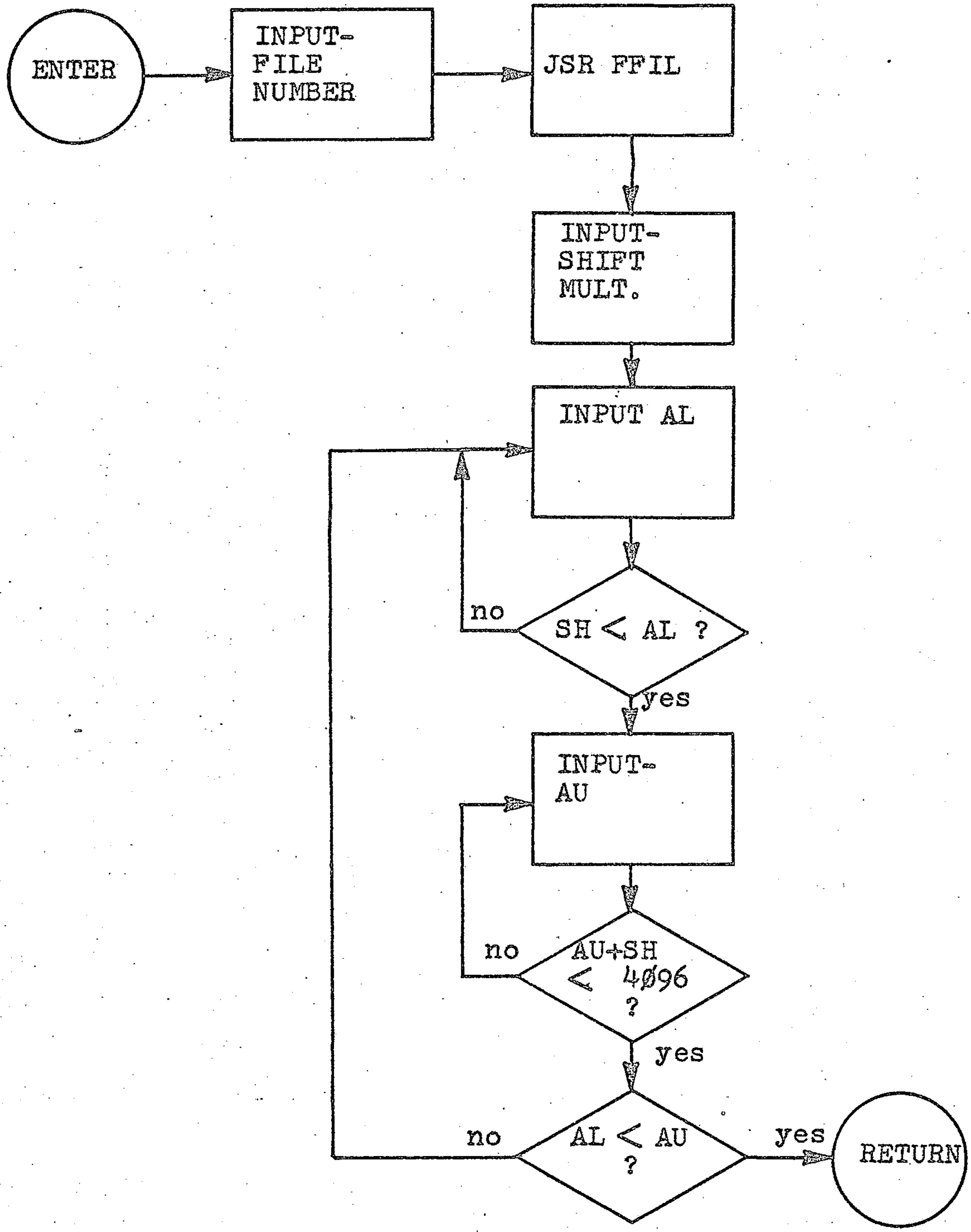


Fig. 27. Flow Chart of MSD Subroutine

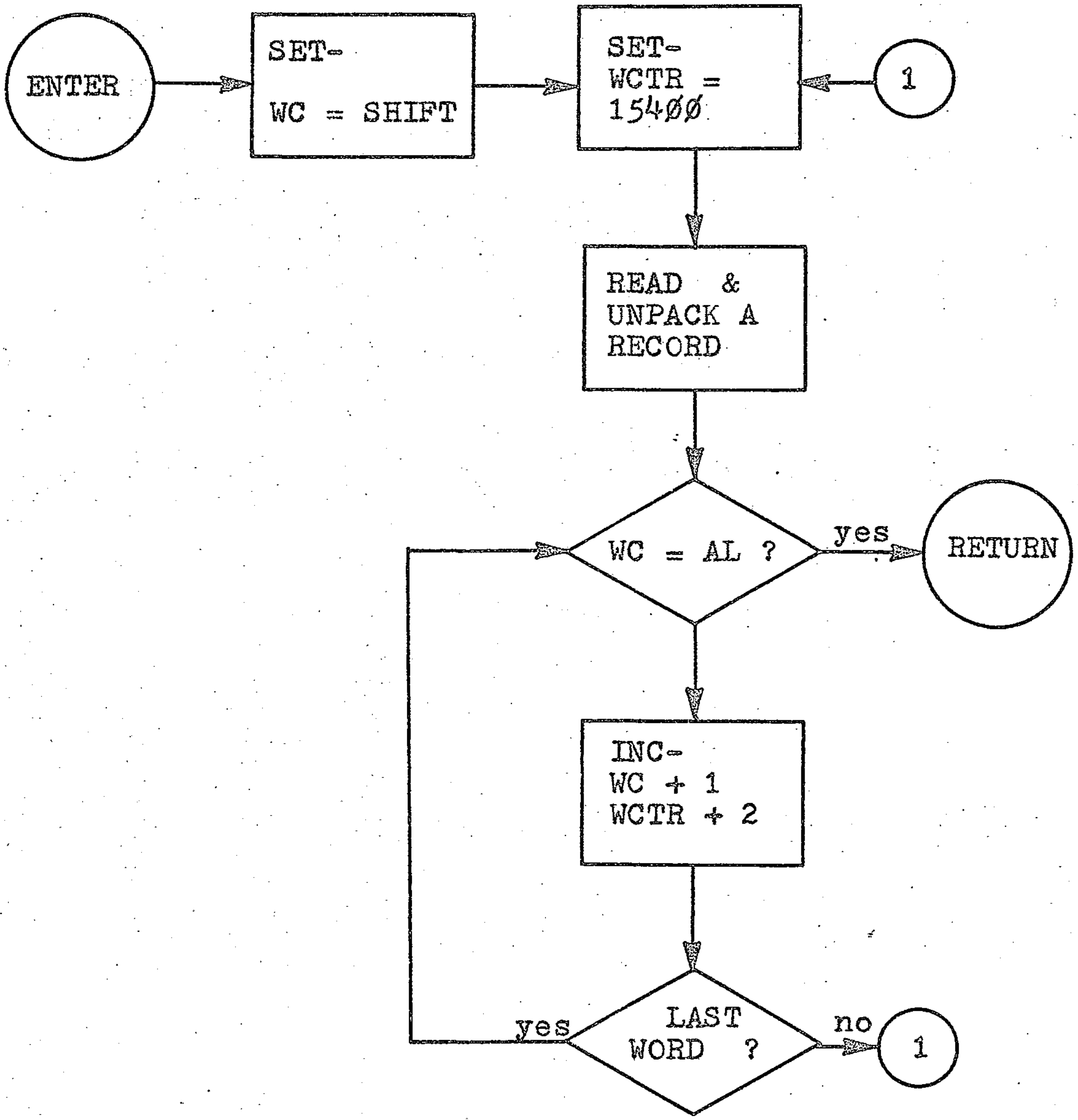


Fig. 28. Flow Chart of SETW Subroutine

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