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AEC RESEARCH AND DEVELOPMENT REPORT

AUTOMATED INSTRUMENTATION FOR IN VIVO
RADIATION MONITORING

H. H. Cromwell

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

OAK RIDGE Y-12 PLANT
P. O. Box Y
OAK RIDGE, TENNESSEE 37830

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UNION CARBIDE CORPORATION
Nuclear Division

Y-12 PLANT

Contract W-7405-eng-26
With the US Atomic Energy Commission

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ABSTRACT

An in vivo spectrometer utilizes a small digital computer to collect, store, and process radiation data obtained from monitoring the internal body burdens of gamma-emitting radioisotopes. A significant feature of the instrumentation is the storage of differential rather than absolute spectra.

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SUMMARY

A small digital computer has been incorporated in an in vivo spectrometer system. In addition to performing the function of a multichannel analyzer, the computer calculates body burdens and makes the results immediately available to the operator. It also facilitates system calibration and maintenance and can be reprogrammed for other functions.

INTRODUCTION

In vivo analysis is becoming a very popular method for determining internal body burdens of gamma-emitting radioisotopes. An in vivo analysis facility requires instrumentation to collect and store gamma radiation data. Data processing is of such magnitude that use of a computer is necessary. Thus, if the facility does not include a computer, the data must be sent to a time-shared computer facility for processing. Besides the inconvenience, this step causes a delay in obtaining the results. Both these problems are magnified if the facility is for mobile and/or emergency use. Instrumentation for an in vivo analysis facility has been constructed around a small digital computer. Besides processing data, the computer performs the functions of a multi-channel analyzer and output controller.

Two sodium iodide crystals are used to detect gamma radiation. Electrical impulses from these detectors are mixed, amplified, and converted to digital signals for storage. Readout is in the form of typed copy and/or perforated tape; the accumulated spectra are continuously displayed on an oscilloscope. A significant feature of the instrumentation is the storage of a differential rather than absolute spectrum. This makes possible the use of a smaller computer than would be required for an absolute spectrum storage.

INSTRUMENTATION

DESCRIPTION

A front view of the instrumentation console and a block diagram of the system are presented in Figures 1 and 2, respectively. Interfacing circuits and programs allow the computer to coordinate data conversion, storage, and processing as specified by the operator. Schematics and logic diagrams of the interfacing circuits are given in Appendix A; the computer programs are listed in Appendix B. The equipment is operated from a separate control panel (see Figure 3) which is monitored by the computer and which allows the operator to select the data mode (background

121205

Figure 1. INSTRUMENTATION CONSOLE.

Figure 2. BLOCK DIAGRAM OF THE IN VIVO SPECTROMETER.

121202

Figure 3. CONTROL PANEL AND DISPLAY.

or body), storage mode (dual or single), and operate mode (readin, analyze, or read-out). The readin mode reads a background spectrum from perforated tape or body information (eg, age and weight) from the keyboard. The analyze mode initiates the spectrum accumulation as specified by the data-mode and body-mode switches. During this operation, the current accumulated spectrum is displayed on the oscilloscope. Live count time is specified by the operator at the beginning of a background run. When the specified time is reached, the computer automatically stops the analysis and signals the operator. Finally, the readout mode performs operations as specified by the computer switch register, shown in Figure 4. The system consists primarily of five operations: particle detection, pulse amplification and mixing, analog-to-digital conversion, data storage, and data processing.

Detection is accomplished with two 9-inch-diameter by 4-inch-thick sodium iodide crystals, each having a cluster of four 3-inch photomultiplier tubes. These units are mounted in a shielded room, shown in Figure 5, to permit low background counting. One detector is placed near the subject's chest and the other near the

123726

Figure 4. COMPUTER SWITCH REGISTER.

123727

Figure 5. RADIATION DETECTORS.

back. These detectors convert nuclear events into voltage pulses of an amplitude that is directly proportional to the particle energy. Thus, two groups of four signals each are available from the detectors.

Each group of four signals is mixed into a single signal and amplified in a preamp mixer. The preamp mixers are also located in the shielded room to reduce the effects of electrical noise picked up by the long signal lines. The two resulting outputs are fed into two linear amplifiers with variable gain. These amplifiers, shown in Figure 6, enable the system to be calibrated for different full-scale energies. The amplified signals are fed into two mixers. The output of one mixer is a fixed amplitude pulse on one of two lines to indicate which detector originated the analog pulse. This mixer also issues a pulse to indicate the time coincidence of the two

121204

Figure 6. EQUIPMENT RACK.

inputs. These three outputs are utilized in data storage. The other mixer converts the two input lines into a single analog output for conversion to digital form.

The output of the analog-to-digital converter (ADC) consists of a burst of fixed-amplitude pulses. The number of pulses in the burst is directly proportional to the peak amplitude of the analog input pulse. The ADC incorporates a variable zero-energy intercept; full-scale conversion gains of 128, 256, and 512 channels; and a clock-pulse generator for determining the live count time. A reset signal (RSCO) is generated in the ADC and sent to the interfacing circuits approximately two microseconds after an input pulse is received. Pulses (ACS) from the ADC are counted by the address register in the computer interface circuits in preparation for storage. At the end of conversion, the ADC issues a signal to initiate storage. Actual data storage is accomplished by the interfacing circuits using the computer data-break facility to transfer information into computer memory. Data storage starts in Memory Location 3000g for background and Location 2000g for body data. Spectra from the two detectors can be stored separately in two 256-channel groups

or together in a single 512-channel group by using the storage switch on the control panel. In any case, data are stored as a differential rather than an absolute spectrum. This storage is accomplished in four consecutive data-break cycles. During the first cycle, the location specified by the address register is incremented by one count; during the second and third cycles, the contents of the next higher memory location is jammed into the exchange register and decremented by one count. Finally, the contents of the exchange register are transferred back into memory during the fourth break cycle. A signal (A·P4) is then sent back to the ADC to indicate completion of the storage. Timing of the various signals during the data break is shown in Appendix C. Thus, each channel except the first contains the difference count between itself and the next lower channel. Absolute count for any channel can be obtained by adding the contents of that channel and all lower channels. The clock detector circuit causes clock pulses only to be stored in channel zero of the spectrum. Since the differential count between channels can be either positive or negative and each memory location has twelve bits, the maximum allowable differential is 2048 counts. An overflow detector circuit senses this condition and causes a computer program interrupt. The interrupt program then identifies the channel. If it is Channel zero or Channel one, the overflow is recorded; if not, the analysis is stopped and "OVERFLOW" is typed.

Data processing is initiated by the operator with the readout operation mode switch. When in the body data mode, the background is automatically subtracted to produce a net body spectrum. Body burdens of uranium, thorium, cesium, and potassium are calculated from these data and printed by the teletype. A sample format is shown in Figure 7. The readout mode also has provision for listing the entire spectrum, checking sensitivity, and locating spectrum peaks to aid in calibration.

RN: 12345
WT: 150
CT: 7.5
U(UG)=+0.6218721E+02
T(MG)=+0.1451478E+01
C(NC)=+0.3333277E+01
P(G)=+0.7791012E+02

Figure 7. SAMPLE BODY BURDEN FORMAT.

OPERATION

Only the overall system operation and controls are discussed, since detailed operating manuals for the computer, analog-to-digital converter, and amplifier controls are supplied by the manufacturer.

The storage mode switch performs the same function regardless of the data and operation modes. In the dual mode, spectra from the two detectors are stored separately; in the single mode, data from the two detectors are stored as a single spectrum. This operation is equivalent to a channel-by-channel addition of the two separate spectra.

Functions performed by a combination of an operate mode and a data mode are as follows:

1. Readin operate and background data modes read a previously punched background data tape into the computer memory. This tape, which is obtained with a readout-background-list combination contains the specified live count time. The tape can be loaded and the tape reader turned on either before or after the readin switch is actuated. The reader should be turned off when the readin operation is completed.
2. Readin operate and body data modes read the run number, subject weight, and subject chest thickness from the teletype keyboard. When the readin switch is actuated, the computer types "RN:". The operator should then type the run number followed by a carriage return which, in turn, causes "WT:" to be typed, and so forth.
3. Analyze operate and background data modes accumulate background data. When the analyze switch is actuated, the computer types "T = ". The operator should then type the desired live count time followed by a carriage return. This step provides the only opportunity to specify live count time since programming forces the body analysis time to equal that of the background. Analysis begins immediately after the carriage return and runs for four times as long as the specified live time. However, the background data are divided by four during the subsequent readout operation. The tape reader must be off.
4. Analyze operate and body data modes accumulate body data for a time specified by the background tape. Analysis begins immediately upon actuation of the analyze switch. The tape reader must be off.

The readout operation is almost the same for both background and body modes. However, the first readout following a background analysis divides the actual background by four to correspond to the specified live time. Similarly, the first readout following a body analysis subtracts the background data to yield a net body spectrum. Specific readout functions are selected by using the computer switch register, as shown on the decal, Figure 4.

The first three teletype readout functions (UR, TH, C-P) calculate and type the uranium, thorium, cesium, and potassium body burdens. The LST switch selects a

program which lists the run number, live time, and contents of each channel in the spectra. To put this information on perforated tape (for instance, to save a background spectrum), simply turn the punch on before starting the readout. The SEN switch selects a program that types the sum (counts/min) of three segments of the spectra: uranium (S1), cesium (S2), and cobalt (S3). Records of these results can be kept as a means of checking the sensitivity. The last teletype readout function, CAL, serves a dual purpose. Normally, CAL is used in calibration to determine the channel location of a peak in an interval specified by the operator. The computer types "CH:". The operator then types the lower channel, a comma, the upper channel, and a space. Following this step, the computer types the peak channel, indicates the peak by an arrow on the scope display, and returns for the next interval. However, a general calculation program may be read into the computer to replace the calibration program. This program solves the following equation:

$$\frac{C_1 (\sum \text{ch } A, B) - C_2 (\sum \text{ch } D, E)}{C_3} .$$

A, B, D, and E are channel numbers ($A < B$, $D < E$); C_1 , C_2 , and C_3 are constants. The computer types " $C_1 =$ " and the operator types the desired value followed by a carriage return. After all variables have been specified in this manner, the answer is typed. Any combination of the teletype readout functions can be selected simultaneously and will be performed in a left-to-right sequence.

If none of the teletype readout functions are selected, the spectrum or spectra are displayed on the oscilloscope. Any logical combination of quarters (100-channel groups) can be displayed with corresponding parts of each half either side by side or over each other. This step is accomplished by operating the last five switches in the computer's switch register.

The operational procedure consists of the following steps:

Startup

1. Turn computer, control panel, and oscilloscope power on.
2. Allow a minimum ten-minute warmup period.
3. Set the computer's switch register to 4000g.
4. Press the load address switch.
5. Press the start switch. (READY should be displayed on the oscilloscope.)

Operate

1. See that the teletype is on "line", reader "free", and punch "off".
2. Set the appropriate data-mode and storage-mode switches on the control panel.
3. Set the switch register and teletype switches as noted before selecting an operation mode. With the exception of scope display only and calibration readout functions, the system will return to the "ready" state upon completion of each operation cycle. Exit from these two functions is accomplished by selecting a different function.

Shutdown

1. Press the stop switch.
2. Turn computer, control panel, and oscilloscope power off.

MAINTENANCE

Since detailed instructions for maintenance of the standard equipment are provided by the manufacturer, only maintenance of the overall system and nonstandard equipment will be discussed. Preventative maintenance for the system consists of performing periodic calibration and sensitivity checks, as described earlier. A record of these results should be kept for comparison purposes.

Schematics and logic diagrams of the individual circuits built at Y-12 along with a block diagram are contained in Appendix A. All circuits except the mixer and control panel are wired in the card racks shown in Figure 8. Numbers in the logic symbols refer to the card type and location. The racks are designated 1A, 1B, 2A, and 2B from top to bottom. Module connectors within the racks are numbered consecutively from left to right. These racks have marginal checkout provisions similar to the computer. Since the variable power supply in the computer is used in margining, care should be taken to prevent margining the computer and external racks simultaneously. The circuits can be margined while performing calibration and sensitivity checks, and records can be kept of the voltage at failure for each rack. In this manner, marginal cards can be replaced before absolute failure. Failure can usually be detected by observing the oscilloscope display while collecting data. For instance, if part of the display suddenly separates, bits are probably being dropped or picked up during storage. An extender board with separate power leads is provided to allow margining a single module. All major signals are connected to test points on the control panel for easy access. These signals are identified and described in Table 1.

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Figure 8. COMPUTER INTERFACE CARD RACK.

Three separate computer programs (MIVS-MNTN; CPL, DAC, and DS) are provided for detailed troubleshooting of the control panel, digital-to-analog converters, and device selector circuits. These programs are on binary coded perforated tape and are loaded into the computer in the normal manner. All three programs start at Octal Location 4000. The control panel program simply types the data mode, storage mode, and operate mode after an operate mode is selected. The DAC program repetitively generates a sawtooth waveform (-10 to 0 volts) with both X and Y circuits. The device-selector program repetitively generates all device-selector commands. A brief description of the individual circuits follows.

Device Selector Circuits

These circuits decode the computer memory buffer (BMB) and input-output pulses (IOP) to generate an exclusive output pulse from a program command. A list of the device-selector commands and a description of each is given in Table 2.

Table 1
SIGNAL TEST POINTS

TP Number	Signal Designation	Description
<u>Logic Power Supply</u>		
1		+ 10 VDC
2		- 15 VDC
<u>Device Selector Commands</u>		
3	CLDA	Standard Negative Pulse, 400 ns
4	LODX	Standard Positive Pulse, 400 ns
5	LODY	Standard Positive Pulse, 400 ns
6	RCPS	Standard Negative Pulse, 400 ns
7	ANLN	Standard Positive Pulse, 400 ns
8	ANLF	Standard Positive Pulse, 400 ns
9	INTN	Standard Positive Pulse, 400 ns
10	RADR	Standard Negative Pulse, 400 ns
11	OFSF	Standard Negative Pulse, 400 ns
12	OFCF	Standard Positive Pulse, 400 ns
<u>Oscilloscope Display</u>		
13	X Output	0 to - 10 V, - 10 V When Clear
14	Y Output	0 to - 10 V, - 10 V When Clear
15	Intensify Trace	Negative Pulse, 0 to - 15 V, 15 μ seconds
<u>ADC</u>		
16	RCSO	Standard Negative Pulse, 2.5 μ seconds
17	ACS	Standard Square Wave, 4 MHz

Control Panel

State of the control panel switches is strobed into accumulator bits 0 - 4 with a device selector command. The computer programs strobe this circuit periodically but do not take any action unless an operate-mode switch is actuated. Operate-mode switches are momentary and are used only by the programs. However, the data-mode and storage-mode switches are latching type and are used in the address counter circuit as well as by the programs. The control panel also supplies power to the interface circuit card rack.

ADC and Data Break Control

This circuit consists of numerous smaller circuits which coordinate the ADC and computer data-break facility during data storage. The reset circuit generates a general-purpose reset signal from three sources as shown. Next, the break-request circuit initiates the data break from the storage signal generated by the ADC. The

Table 2
DEVICE SELECTOR COMMANDS

Mnemonic	Octal	Function
ANLF	6504	Disables data storage and generates reset signal.
ANLN	6502	Enables data storage.
CLDA	6051	Clears both X and Y digital-to-analog converters (DAC).
INTN	6064	Intensifies oscilloscope trace.
LODX	6052	Loads X DAC from accumulator bits 0 - 8.
LODY	6062	Loads Y DAC from accumulator bits 0 - 8.
OFCF	6514	Clears overflow flag.
OFSF	6512	Skips if overflow flag clear.
RADR	6511	Reads contents of address register into accumulator.
RCPS	6501	Reads control panel switch states into accumulator bits 0 - 4.
	6054	For future expansion.
	6061	For future expansion.

increment-address circuit counts the address register up one count. Miscellaneous circuits generate signals to increment the computer memory buffer, strobe data from the memory buffer to the exchange register, count the exchange register down one count, and specify the direction of data transfer. The reject circuit inhibits the storage when pulses are in time coincidence or are too closely spaced. Finally, the storage-complete circuit generates a signal to the ADC when storage is finished. These circuits are synchronized with the computer by the 4-bit synchronizing circuit and buffered-timing pulses (BT1 and BT2). The synchronizing circuit is a rotating-bit register driven by the computer address accepted signals. This circuit is used to indicate each of the four data-break cycles. A data-break timing diagram is included in Appendix C.

Address Counter

The address counter is used as the data address for the computer data break during storage. It is counted up by pulses from the ADC unit. The two most significant

bits are controlled by the data-mode and storage-mode switches on the control panel. Contents of the address counter can be strobed into the computer accumulator register by a device selector command.

Exchange Register

This register is utilized in data storage to subtract one count from the contents of a memory location. The contents of the location are automatically strobed into the exchange register and counted down one count during the second break cycle. No information is transferred during the third break cycle which allows for carry propagation. During the fourth break cycle, the contents of the exchange register are transferred back into the computer memory.

Clock Detector

This circuit forces clock pulses to be stored in channel zero of the spectrum (3000g for a background and 2000g for a body). It also prevents any other data from being stored in this channel.

Overflow Detector

This circuit causes a program interrupt when the difference between any two adjacent channels reaches 2000g either positive or negative. This interrupt is accomplished by sampling the transitions of bit zero of the memory buffer and the most significant bit of the exchange register at the appropriate times. A computer program processes the interrupt by reading the address counter and determining which channel overflowed. Channel zero and channel one overflows are recorded. However, if any other channel overflows, the analysis is terminated.

Digital-to-Analog Converter

The system contains two 9-bit digital-to-analog converters with a common reference supply. These converters are controlled by the computer programs through device selector commands. Bits in the converter boards are set by parallel transferring bits 0 through 8 of the computer accumulator register into the DAC register. Both converters share a common clear line. The DAC's are used as vertical and horizontal inputs to the oscilloscope to generate a display.

Miscellaneous Circuits

Miscellaneous circuits consist of the analog pulse mixer, high-voltage filter and distribution box, and the crystal simulator. The mixer consists of two transistors connected in a common-load emitter-follower configuration.

The zero balance control is used to compensate for differences in the base biasing resistor strings and transistor input characteristics. The control must be adjusted for the same voltage at both emitters to prevent one transistor from acting as a discriminator for the other. A standard VOM (volt-ohm-milliamp) can be connected between the emitters to facilitate the adjustment. The high-voltage distribution boxes are used to filter and distribute the high voltage to the photomultiplier tubes. The crystal simulator is used to check for noise sources in the system. It presents approximately the same load to the high-voltage circuit as one detector assembly and has approximately the same output impedance. Thus, it simulates a detector in a zero radiation environment.

Note: Due to temperature effects at high count rates, the ADC has been modified. A blower was mounted on the rear of the cabinet to cool the ADC printed circuit board. Transistors 1-2 and 6-7 were replaced with dual transistors, Type 2N3806. Also, the LGO signal was brought out to Pin A of the 50-pin connector.

PERFORMANCE

The automated instrumentation for radiation monitoring has been operated in parallel with the Y-12 In Vivo Facility in normal monitoring. Although the equations and constants derived for the Y-12 facility were used, the results for cesium and potassium were in excellent agreement. The uranium and thorium runs were not in close agreement, but they were well below the maximum permissible lung burden. These differences are attributed to slight differences in calibration of the two systems accentuated by poor statistics, a consequence of a low count rate. New constants will be derived from further use of the instrumentation.

APPENDIX A

SCHEMATICS AND LOGIC DIAGRAMS

Standard logic levels for the digital circuits are 0 and -3 volts. These levels are designated on the logic diagrams, as:

- ◇ Positive Level
- ◆ Negative Level
- ▷ Positive Pulse or Transition
- ▶ Negative Pulse or Transition

Two alphanumeric designators are included in each logic symbol. The module location designator is shown in parenthesis as:

The other designator indicates the module type. Logic functions and module types are listed in alphanumeric order in Table A-1.

Schematics and logic diagrams of the interfacing circuits are shown in Figures A-1 through A-14.

Figure A-1. INTERFACE BLOCK DIAGRAM.

Figure A-2. LOGIC MODULE LOCATIONS.

Table A-1
MIVS LOGIC MODULES

Type	Function
A601	Digital-to-Analog Converter, 3 Bit
A702	Reference Power Supply, - 10 VDC
B200	Flip Flop, 10 MHz
B602	Pulse Amplifier, 10 MHz
R002	Diode Network, Dual
R107	Inverter
R113	Diode Gate
R201	Flip Flop, 5 DCD Gates
R202	Flip Flop, 2 DCD Gates
R203	Flip Flop, 1 DCD Gate
R205	Flip Flop, 3 DCD Gates
R302	Delay (one shot)
W005	Clamped Load, 5 Ma
W051	Indicator and Relay Driver, 100 Ma
W103	Device Selector
W510	Positive Input Converter
W600	Negative Output Converter
W602	Bipolar Output Converter
W700	Mechanical Switch Input Filter

Figure A-3. CONTROL PANEL WIRING.

Figure A-4. INTERCONNECTION DIAGRAM.

Figure A-6. CONTROL PANEL LOGIC.

Figure A-7. ADDRESS COUNTER LOGIC DIAGRAM.

Figure A-8. EXCHANGE REGISTER LOGIC DIAGRAM.

Figure A-9. DIGITAL-TO-ANALOG CONVERTER LOGIC DIAGRAM.

Figure A-10. DEVICE SELECTOR LOGIC DIAGRAM.

Figure A-11. CLOCK DETECTOR LOGIC DIAGRAM.

Figure A-12. OVERFLOW DETECTOR LOGIC DIAGRAM.

Figure A-13. RACK AND MARGINAL CHECK WIRING DIAGRAM.

Figure A-14. MISCELLANEOUS CIRCUITS.

APPENDIX B

COMPUTER PROGRAMS

Software for the system consists of the operating program and three maintenance programs. The maintenance programs perform functions as described in the maintenance section (Page 16). The operating program consists of twenty separate subprograms and subroutines. A flow diagram and a memory usage chart for the operating program are presented in Figures B-1 and B-2, respectively. As shown in the flow diagram, the executive program interprets the control panel and coordinates the other subroutines accordingly. Since page zero is directly addressable from any memory location, it is used primarily as a common storage field. The floating-point package, oscilloscope-character generator, and teletype-output package are supplied by the computer manufacturer. Complete listings of all other programs are presented in Figures B-3 through B-14.

Figure B-1. OPERATING PROGRAM FLOW DIAGRAM.

	0000	1000	2000	3000	4000	5000	6000	7000
0000	Page Zero (Figure B-3)	Readin (Figure B-4)	Body Data Field, Lower	Background Data Field, Lower	Executive (Figure B-7)	Segment Sum (Figure B-11)	"	"
0200	Oscilloscope Character Generator	Display, Part I (Figure B-5)	"	"	Char Strings Calc Segments FP Total FP Subtotal Sub Background (Figure B-8)	(1) Calibrate Normalize (Figure B-12)	"	"
0400	"	Display, Part II (Figure B-5)	Body Data Field, Upper	Background Data Field, Upper	Interrupt Read Time (Figure B-9)	Sensitivity Burden Const Mod Background (Figure B-13)	"	"
0600	Teletype Output Package	Calculate (Figure B-6)	"	"	List (Figure B-10)	Floating Point Arithmetic Package (8-5-S-Bin)	"	Bin Loader (8-2-U-Rim) Rim Loader

(1) A general calculation program can be substituted here (Figure B-14).

Figure B-2. MEMORY USAGE CHART.

/ PAGE ZERO				/ SUBROUTINE ADDRESSES			
/ COMMON ADDRESSES, CONSTANTS, STORAGE, SUBROUTINES				*0114			
/				0114	5364	NOAM,	5364
/ SYMBOLS				0115	1200	DSPLC,	1200
CLDA=6051			/ CLEAR DAC REGISTERS	0116	0200	CIAN,	0200
LODX=6052			/ LOAD X REGISTER FROM AC 0-8	0117	0215	ASIR,	0215
CLDX=6053			/ COMBINATION +	0120	0232	PIRA,	0232
LODY=6062			/ LOAD Y REGISTER FROM AC 0-8	0121	0375	XVAL,	0375
INTN=6064			/ INTENSIFY SCOPE	0122	0376	YVAL,	0376
LDYI=6066			/ COMBINATION +	0123	4000	EXFLOC,	4000
KCPS=6501			/ READ CONTROL PANEL INTO AC	0124	0600	TYI,	0600
ANLN=6502			/ ENABLE ANALYSIS	0125	0605	TYP,	0605
ANLF=6504			/ DISABLE ANALYSIS AND RESET	0126	0617	TCK,	0617
READR=6511			/ READ ADDRESS REGISTER INTO AC	0127	0627	TSP,	0627
OFSF=6512			/ SKIP IF OVERFLOW FLAG = 0	0130	0634	TYT,	0634
OFCF=6514			/ CLEAR OVERFLOW FLAG	0131	0645	TDIC,	0645
/				0132	0660	TSC,	0660
/ 0000,1,2,3,4, AND 0112 USED BY INTXPT				0133	0746	OLY,	0746
/				0134	5000	SLMSFG,	5000
/ GATEWAY TO FLOATING POINT				/			
*0005				/ LIVE COUNT TIME STORAGE			
0005	7400	7400	/ INPUT	0135	0000	LCT,	0
0006	7200	7200	/ OUTPUT	0136	0000		0
0007	5600	5600	/ INITIALIZER	0137	0000		0
/				/			
/ INITIALIZE OSC CHAR GENERATOR				/ READ CONTROL PANEL, SET STORE AND DATA MODES.			
*0020				/ IF NOP RETURN TO CALL+1			
0020	0000	0	INTL,	/ IF OPR RETURN TO CALL+2			
0021	7200	CLA		*0140			
0022	1104	TAD OSC-4		0140	0000	KCPL,	0
0023	3521	DCA I Z XVAL		0141	7200	CLA	
0024	1105	TAD OSCVB		0142	6501	KCPS	
0025	3522	DCA I Z YVAL		0143	3172	DCA CPL	
0026	5420	JMP I INTL		0144	1172	TAD CPL	
/				0145	7104	CLL KAL	
/ BODY DATA				0146	7104	CLL KAL	
*0027				0147	7104	CLL KAL	
0027	0000	KUNNO,	0	0150	7104	CLL KAL	
0030	0000		0	0151	3171	DCA STRMD	
0031	0000		0	0152	7010	RAK	
0032	0000	UFICH1,	0	0153	3170	DCA DATA	
0033	0000		0	0154	1172	TAD CPL	
0034	0000		0	0155	0070	AND C7K	
0035	0000	CHESI,	0	0156	7640	SZA CIA	
0036	0000		0	0157	2140	ISZ KCPL	
0037	0000		0	0160	5540	JMP I KCPL	
/				/			
/ CONSTANTS				/ STORAGE REGISTERS			
*0062				*0161			
0062	1000	C1K,	1000	0161	0000	VMOD,	0
0063	2000	C2K,	2000	0162	0000	PKLOF1,	0
0064	0010	C10,	0010	0163	0000	PKLOF2,	0
0065	7777	CV1,	7777	0164	0000	TTENS,	0
0066	7776	C2,	7776	0165	0000	TUNIS,	0
0067	7774	C4,	7774	0166	0000	TTNS,	0
0070	7000	C7K,	7000	0167	0000	HINC,	0
0071	0400	C4C,	0400	0170	0000	DATMD,	0
0072	7764	CV12D,	7764	0171	0000	STRMD,	0
0073	7765	CV11D,	7765	0172	0000	CPL,	0
0074	7634	CM1CD,	7634	0173	0000	BDLOF1,	0
0075	7766	CM10D,	7766	0174	0000	BDLOF2,	0
0076	7770	CM10,	7770	0175	0000	CH1LOF,	0
0077	3000	C3K,	3000	0176	0000	CH1UOF,	0
0100	7001	CM511D,	7001	0177	0000	IC,	0
0101	3634	CC,	3634	/			
0102	0000	TV,	0000	/ VERTICAL MODIFIER, SCOPE DIR			
0103	0207	BELL,	0207	/ BKEND OVERFLOW, LOWER			
0104	2500	OSCHB,	2500	/ UPPER			
0105	7000	OSCVB,	7000	/ MINUTES X 10			
0106	0013	C11D,	0013	/ MINUTES X 1			
0107	0026	C22D,	0026	/ MINUTES X 1			
0110	0260	C260,	0260	/ HORIZONTAL INCREMENT			
/				/ DATA MODE			
/				/ STORAGE MODE			
/				/ CONTROL PANEL WORD			
/				/ BODY OVERFLOW, LOWER			
/				/ UPPER			
/				/			
/				/ ABSOLUTE LIVE TIME COUNTER			

Figure B-3. PAGE ZERO PROGRAM.

/ READIN				1074	4405	JMS I Z 5	/ GET TIME
/ SUBROUTINES TO READ BODY AND BKGND				1075	4407	JMS I Z 7	
/ INFORMATION INTO THE COMPUTER.				1076	6135	FPUT Z LCT	
/				1077	0000	FEXT	
/ BODY				1100	4514	JMS I Z NORM	
*1000				1101	3102	DCA Z TM	
1000	4526	ABODA,	JMS I Z TCR	1102	4251	LOOK, JMS READ	
1001	4526		JMS I Z TCR	1103	1233	TAD LNFD	
1002	1245		TAD IDINT	1104	7450	SNA	/ LINE FEED ?
1003	3011		DCA Z 11	1105	5302	JMP LOOK	/ YES
1004	1232		TAD STINT	1106	1234	TAD RET	
1005	3242		DCA STLOC	1107	7450	SNA	/ RETURN ?
1006	1231		TAD CM3	1110	5302	JMP LOOK	/ YES
1007	3243		DCA ENUF	1111	1235	TAD SPAC	
1010	1411	AGN,	TAD I Z 11	1112	7450	SNA	/ SPACE ?
1011	4525		JMS I Z 1Y2	1113	5302	JMP LOOK	/ YES
1012	1230		TAD CMCH	1114	1236	TAD MONY	
1013	4525		JMS I Z 1Y2	1115	7450	SNA	/ \$ (END) ?
1014	4405		JMS I Z 5	1116	5523	JMP I Z EXELOC	/ YES, RETURN.....
1015	4533		JMS I Z OTY	1117	1237	TAD ASTK	
1016	4407		JMS I Z 7	1120	7440	SZA	/ * (OVFL) ?
1017	7000		FNOR	1121	5335	JMP DATA	/ NO, MUST BE DATA
1020	6642		FPUT I STLOC	1122	4251	JMS READ	
1021	0000		FEXT	1123	4341	JMS PROC	
1022	2242		ISZ STLOC	1124	2241	ISZ ASTCTR	/ FIRST * ?
1023	2242		ISZ STLOC	1125	5333	JMP DATA-2	/ YES
1024	2242		ISZ STLOC	1126	3163	DCA Z BKLOF2	
1025	2243		ISZ ENUF	1127	1077	TAD Z C3K	
1026	5210		JMP AGN	1130	1071	TAD Z C4C	
1027	5523		JMP I Z EXELOC	1131	3010	DCA Z 10	
/ FINISHED ?				1132	5302	JMP LOOK	
/ NO				1133	3162	DCA Z BKLOF1	
/ YES, RETURN.....				1134	5302	JMP LOOK	
/ CONSTANTS				1135	1240	DATA, TAD RPL	
1030	7240	CMCH,	7240	1136	4341	JMS PROC	
1031	7775	CM3,	7775	1137	3410	DCA I Z 10	
1032	0027	STINT,	0027	1140	5302	JMP LOOK	
1033	0212	LNFD,	0212	/ PROCESS 4 DATA CHAR			
1034	0003	RET,	0003	1141	0000	PROC, 0	
1035	0023	SPAC,	0023	1142	1110	TAD Z C260	
1036	0004	MONY,	0004	1143	7041	CMA IAC	
1037	0006	ASTK,	0006	1144	3244	DCA CNTS	
1040	7526	RPL,	7526	1145	1231	TAD CM3	
/ STORAGE				1146	3243	DCA ENUF	
1041	0000	ASTCTR,	0	1147	1244	TAD CNTS	
1042	0000	STLOC,	0	1150	7104	MOR, CLL RAL	
1043	0000	ENUF,	0	1151	7006	RTL	
1044	0000	CNTS,	0	1152	3244	DCA CNTS	
/ IDENT CHAR STRINGS				1153	4251	JMS READ	
1045	1045	IDINT,	.	1154	1110	TAD Z C260	
1046	2216		2216	1155	7041	CMA IAC	
1047	2724		2724	1156	1244	TAD CNTS	
1050	0324		0324	1157	2243	ISZ ENUF	/ THRU ?
/ READ ONE CHAR				1160	5350	JMP MOR	/ NO
1051	0000	READ,	0	1161	5741	JMP I PROC	
1052	6031		KSF	/			
1053	5252		JMP --1	/ CESIUM CONSTANTS			
1054	6036		KRB	*1164			
1055	7041		CMA IAC	1164	7773	CC1,	7773
1056	5651		JMP I READ	1165	3730		3730
/				1166	0137		0137
/ BKGND				1167	7771	CC2,	7771
*1057				1170	3675		3675
1057	1066	ABKDA,	TAD Z CM2	1171	6360		6360
1060	3241		DCA ASTCTR	/			
1061	1077		TAD Z C3K	/ URANIUM CONSTANTS			
1062	3010		DCA Z 10	*1172			
1063	4251	RN,	JMS READ	1172	0005	UC1,	0005
1064	1233		TAD LNFD	1173	4430		4430
1065	7640		SZA CLA	1174	2436		2436
1066	5263		JMP RN	1175	0001	UC2,	0001
1067	4405		JMS I Z 5	1176	2617		2617
1070	4407		JMS I Z 7	1177	2703		2703
1071	6027		FPUT Z RUNNO				
1072	0000		FEXT				
1073	4251		JMS READ				
/ LINE FEED ?							
/ NO							
/ YES, GET RUN NO							

Figure B-4. READ-IN PROGRAM.

/DSPLY /DISPLAYS ABSOLUTE SPECTRUM ON SCOPE /ACCORDING TO CONTROL PANEL AND SWITCH /REGISTER.			
1200	0000	DSPLY, 0	/ENTRY
1201	7300	INILZ, CLA CLL	/ INITIALIZE
/SET DATA ADDRESS			
1202	1170	TAD Z DATMD	
1203	7104	CLL RAL	
1204	1063	TAD Z C2K	
1205	7430	SZL	/BODY OR BKEND ?
1206	1062	TAD Z C1K	/BKEND
1207	3010	DCA Z 10	/SET ADDRESS
/ SET CH1 OVERFLOWS			
1210	1162	TAD Z BKLOF1	
1211	3175	DCA Z CH1LOF	
1212	1163	TAD Z BKLOF2	
1213	3176	DCA Z CH1UOF	
1214	7430	SZL	/ BKEND OR BODY?
1215	5222	JMP .+5	/ BKEND
1216	1173	TAD Z BDLOF1	
1217	3175	DCA Z CH1LOF	
1220	1174	TAD Z BDLOF2	
1221	3176	DCA Z CH1UOF	
/SET HORIZONTAL INCREMENT			
1222	7604	LAS	
1223	0342	AND C37	
1224	7450	SNA	/NORMAL DISPLAY?
1225	1347	TAD C33	/YES
1226	3365	DCA PL10	
1227	1365	TAD PL10	
1230	7450	SNA	/00?
1231	5264	JMP HX1	
1232	1343	TAD CM33	
1233	7450	SNA CLA	/33?
1234	5264	JMP HX1	
1235	1365	TAD PL10	
1236	1344	TAD CM3	
1237	7450	SNA CLA	/03?
1240	5263	JMP HX2	
1241	1365	TAD PL10	
1242	1345	TAD CM30	
1243	7450	SNA CLA	/30?
1244	5263	JMP HX2	
1245	1365	TAD PL10	
1246	1350	TAD CM11	
1247	7450	SNA CLA	/ 11?
1250	5263	JMP HX2	
1251	1365	TAD PL10	
1252	1351	TAD CM22	
1253	7450	SNA CLA	/ 22?
1254	5263	JMP HX2	
1255	1365	TAD PL10	
1256	1346	TAD CM37	
1257	7450	SNA CLA	/37?
1260	5263	JMP HX2	
1261	1064	HX4, TAD Z C10	
1262	1064	TAD Z C10	
1263	1064	HX2, TAD Z C10	
1264	1064	HX1, TAD Z C10	
1265	3167	DCA Z RINC	
/ DISPLAY TIME			
1266	4334	JMS TMRIAS	
1267	1164	TAD Z TIMEAS	
1270	1352	TAD C272	
1271	4520	JMS I Z FIRA	
1272	1165	TAD Z TIMEAS	
1273	1352	TAD C272	
1274	4520	JMS I Z FIRA	
1275	1353	TAD DFNI	
1276	4520	JMS I Z FIRA	
1277	1166	TAD Z TIMEAS	
1300	1352	TAD C272	
1301	4520	JMS I Z PIRA	
/ DISPLAY SCALE FACTOR			
1302	4334	JMS TIMEAS	
1303	1354	TAD LFD	
1304	4516	JMS I Z FIAN	
1305	1161	TAD Z VMOD	
1306	7040	CMA	
1307	3366	DCA ENUF	
1310	7120	CLL CML	
1311	7004	RAL	
1312	2366	ISZ ENUF	
1313	5311	JMP .-2	
1314	1110	TAD Z C260	
1315	4520	JMS I Z PIRA	
1316	1360	TAD K	
1317	4520	JMS I Z PIRA	
/ PLOT FULL SCALE MARKER			
1320	1363	TAD ZBIAS	
1321	6053	CLDX	
1322	6066	LDYI	
1323	7000	NOF	
1324	6053	CLEX	
1325	7240	CLA CMA	
1326	6066	LDYI	
/ CHECK FOR NEW OPK			
1327	4140	JMS Z RCPL	
1330	7410	SKP	
1331	5523	JMP I Z EXELOC	
1332	4764	JMS I SPTDSP	/DISPLAY SPEC
1333	5600	JMP I DSPLY	/RETURN TO CALLING PGM
/ LOCATE SCOPE DISPLAY SUBROUTINE			
1334	0000	TMRIAS, 0	
1335	1361	TAD CV	
1336	3522	DCA I Z YVAL	
1337	1362	TAD CH	
1340	3521	DCA I Z XVAL	
1341	5734	JMP I TMRIAS	
/CONSTANTS			
1342	0037	C37, 0037	
1343	7745	CM33, 7745	
1344	7775	CM3, 7775	
1345	7750	CM30, 7750	
1346	7741	CM37, 7741	
1347	0033	C33, 0033	
1350	7767	C. 11, 7767	
1351	7756	CM22, 7756	
1352	0272	C272, 0272	
1353	0256	DFN1, 0256	
1354	1355	LFF, .+1	
1355	0012	CM12, 0012	
1356	0000	0000, 0000	
1357	0001	0001, 0001	
1360	0313	K, 0313	
1361	7400	CV, 7400	
1362	5400	CM, 5400	
1363	0137	ZBIAS, 0137	
/ADDRESSES			
1364	1400	SPIDSP, 1400	/DISPLAY SPEC ROUTINE
/SLOPAGE			
*1365			
1365	0000	PL10, 0	/SR PLOT WORD
1366	0000	ENUF, 0	
/			
/ UNANIUM CONSTANTS			
*1367			
1367	7774	UC3, 7774	
1370	3146		3146
1371	3147		3147
1372	7773	UC4, 7773	
1373	4121		4121
1374	7270		7270
1375	7776	UC5, 7776	
1376	3075		3075
1377	3412		3412

(a) Part I

Figure B-5. DISPLAY PROGRAM.

/PLOT ENTIRE ABSOLUTE SPEC ONE TIME			
*1400			
1400	0000	SPTESP, 0	/ENTRY FOR SPEC PLOT
1401	7200	CLA	
1402	1774	TAD I PLTLOC	
1403	3364	DCA PLT0	/STORE SK PLOT WORD
1404	1066	TAD Z CM2	
1405	3372	DCA HLFCTR	/SET HLAIF COUNTER
1406	1066	TAD Z CM2	
1407	3365	DCA QTRCTR	/SET QUARTER COUNTER
1410	1461	TAD Z VMOD	
1411	1362	TAD CM3	
1412	7500	SMA	
1413	7240	CLA CMA	
1414	3373	DCA MVMOD	
1415	1175	TAD Z CH1LOF	
1416	4333	JMS HIMOD	/MOD LOWER OVERFLOW
1417	1356	TAD ZBIAS	/STAK1 EACH OVER HALF
1420	3370	DCA HORZ	/SET HORIZONTAL
1421	1074	TAD Z CM1CD	/STAK1 EACH GTR & NON-OVER HE
1422	3371	DCA DATCTR	/SET DATA COUNTER
/ DETERMINE PLOT STATUS			
1423	1364	TAD PLT0	
1424	7112	CLL RTR	
1425	7700	SMA CLA	/ PLOT ?
1426	5234	JMP NOPE	/ NO
1427	1357	TAD CMD1	
1430	3274	DCA STRH	
1431	1360	TAD CMD2	
1432	3276	DCA PLT	
1433	5240	JMP ECHPT	
1434	1361	TAD CLAA	
1435	3274	DCA STRH	
1436	1361	TAD CLAA	
1437	3276	DCA PLT	
1440	1373	TAD MVMOD	
1441	3366	DCA ENUF	
1442	1410	TAD I Z 10	
1443	7510	SPA	
1444	5264	JMP NEG	
1445	4350	JMS LOMOD	
1446	7100	CLL	
1447	1367	TAD VERT	
1450	7420	SNL	/ OVERFLOW ?
1451	5270	JMP PLOT	/ NO
1452	7200	CLA	/ YES, MOD VMOD IF IN ANALYSIS
1453	1776	TAD I SUBSW	
1454	7700	SMA CLA	/ BKEND SUBTRACTED ?
1455	5270	JMP PLOT	/ YES
1456	1161	TAD Z VMOD	
1457	1066	TAD Z CM2	
1460	7650	SNA CLA	/ SCALE 4K ?
1461	5270	JMP PLOT	/ YES
1462	2161	ISZ Z VMOD	/ NO, MULT BY 2
1463	5775	JMP I INTLZ	
1464	7041	CMA IAC	
1465	4350	JMS LOMOD	
1466	7041	CMA IAC	
1467	1367	TAD VERT	
1470	3367	DCA VERT	
1471	1167	TAD Z HINC	
1472	1370	TAD HORZ	
1473	6053	CLDX	
1474	3370	DCA HORZ	/ CHANGED TO CLA FOR NO PLOT
1475	1367	TAD VERT	
1476	6066	LDYI	/ CHANGED TO CLA FOR NO PLOT
1477	7200	CLA	
1500	2371	ISZ DATCTR	/ FINISHED QUARTER ?
1501	5240	JMP ECHPT	/ NO
1502	1364	TAD PLT0	/ YES, MOD PLOT
1503	7110	CLL RAR	
1504	3364	DCA PLT0	
1505	2372	ISZ HLFCTR	/FINISHED HALF ?
1506	5221	JMP SPTM+2	/NO
1507	1066	TAD Z CM2	
1510	3372	DCA HLFCTR	/KERET HALF COUNTER
1511	2365	ISZ QTRCTR	/FINISHED ALL DATA
1512	7410	SKP	/NO
1513	5600	JMP I SPTDSP	/RETURN TO CALLING PGM
1514	1171	TAD Z STRMD	
1515	7700	SMA CLA	/ DUAL OR SINGLE ?
1516	5325	JMP OVR	/SINGLE
1517	1010	TAD Z 10	
1520	0070	AND Z C7K	
1521	1071	TAD Z C4C	
1522	3010	DCA Z 10	/SET ADDRESS FOR 2ND HALF
1523	1176	TAD Z CH1UOF	
1524	4333	JMS HIMOD	/MOD UPPER OVERFLOW
1525	1364	TAD PLT0	
1526	7110	CLL RAR	
1527	3364	DCA PLT0	
1530	7420	SNL	/OVER OR NONOVER?
1531	5221	JMP SPTM+2	/NONOVER
1532	5217	JMP SPTM	
1533	0000	HIMOD, 0	/MODIFY OVERFLOW
1534	3363	DCA TEMP	
1535	1373	TAD MVMOD	
1536	7000	NOP	
1537	3366	DCA ENUF	
1540	1363	TAD TEMP	
1541	7110	CLL RAR	
1542	7010	RAR	
1543	2366	ISZ ENUF	
1544	5342	JMP .-2	
1545	1356	TAD ZBIAS	
1546	3367	DCA VERT	
1547	5733	JMP I HIMOD	
1550	0000	LOMOD, 0	/ MODIFY DIFFERENTIAL
1551	2366	ISZ ENUF	
1552	7410	SKP	
1553	5750	JMP I LOMOD	
1554	7104	CLL RAL	
1555	5351	JMP LCMOD+1	
/CONSTANTS			
1556	0137	ZBIAS, 0137	/ ZERO OFFSET FOR SCOPE DISPL
1557	3370	CMD1, DCA HORZ	
1560	6066	CMD2, LDYI	
1561	7200	CLAA, CLA	
1562	7775	CM3, 7775	
/STORAGE			
1563	0000	TEMP, 0	
1564	0000	PLT0, 0	
1565	0000	QTRCTR, 0	
1566	0000	ENUF, 0	
1567	0000	VERT, 0	
1570	0000	HORZ, 0	
1571	0000	DATCTR, 0	
1572	0000	HLFCTR, 0	
1573	0000	MVMOD, 0	
/ADDRESSES			
1574	1365	PLTLOC, 1365	/ LOC OF PLOT WORD ON FIRST PB
1575	1201	INTLZ, 1201	/LOC INTL ON FIRST PAGE
1576	4177	SUBSW, 4177	

(b) Part II

Figure B-5. (Continued)

/ CALC			1677	5757	FGT I S5
/ SUBROUTINES TO CALCULATE URANIUM, THORIUM,			1700	4760	FDIV I S6
/ AND CESIUM-POTASSIUM BURDENS.			1701	1754	FADD I S2
/			1702	1753	FADD I S1
/ START URANIUM			1703	2776	FSUB I C3.23
*1600			1704	3777	FMPY I C8.82
1600	0000	UPDN, 0	1705	0000	FEXT
1601	1345	TAD UH0	1706	4406	JMS I Z 6
1602	4532	JMS I Z 1SC	1707	4526	JMS I Z TCR
1603	1351	TAD USEG	1710	5663	JMP I TBDN
1604	4534	JMS I Z SUMSEG	/ START CESIUM-POTASSIUM		
1605	4407	JMS I Z 7	*1711		
1606	5754	FGT I S2	1711	0000	CPDN, 0
1607	3765	FMPY I UC2	1712	1343	TAD CHD
1610	6754	FPUT I S2	1713	4532	JMS I Z TSC
1611	5755	FGT I S3	1714	1347	TAD CSEG
1612	3766	FMPY I UC3	1715	4534	JMS I Z SUBSEG
1613	6755	FPUT I S3	1716	4407	JMS I Z 7
1614	5756	FGT I S4	1717	5754	FGT I S2
1615	3767	FMPY I UC4	1720	3762	FMPY I CC2
1616	6756	FPUT I S4	1721	6754	FPUT I S2
1617	5032	FGT I Z WFIHQ1	1722	5753	FGT I S1
1620	3770	FMPY I UC5	1723	3761	FMPY I CC1
1621	1756	FADD I S4	1724	2754	FSUB I S2
1622	1755	FADD I S3	1725	0000	FFX1
1623	1754	FADD I S2	1726	4406	JMS I Z 6
1624	1764	FADD I UC1	1727	4526	JMS I Z TCR
1625	6754	FPUT I S2	1730	1344	TAD PHD
1626	5035	FGT I Z CHFS1	1731	4532	JMS I Z TSC
1627	3772	FMPY I UC7	1732	1350	TAD PSEG
1630	6755	FPUT I S3	1733	4534	JMS I Z SUBSEG
1631	3755	FMPY I S3	1734	4407	JMS I Z 7
1632	6756	FPUT I S4	1735	5753	FGT I S1
1633	3755	FMPY I S3	1736	4763	FDIV I PC1
1634	6757	FPUT I S5	1737	0000	FFX1
1635	3755	FMPY I S3	1740	4406	JMS I Z 6
1636	4775	FDIV I C6.00	1741	4526	JMS I Z TCR
1637	4774	FDIV I C2.00	1742	5711	JMP I CPDN
1640	6760	FPUT I S6	/ IDENTIFICATION ADDRESSES		
1641	5757	FGT I S5	1743	4242	CHD, 4242
1642	4775	FDIV I C6.00	1744	4246	PHD, 4246
1643	6757	FPUT I S5	1745	4232	UH0, 4232
1644	5756	FGT I S4	1746	4236	THD, 4236
1645	4774	FDIV I C2.00	/ SPECTRUM SEGMENT ADDRESSES		
1646	1760	FADD I S6	1747	4252	CSEG, 4252
1647	1757	FADD I S5	1750	4257	PSEG, 4257
1650	1755	FADD I S3	1751	4262	USEG, 4262
1651	1773	FADD I C1.00	1752	4273	1SEG, 4273
1652	3771	FMPY I UC6	/ INTERCOM REGISTERS FOR SUMS		
1653	6755	FPUT I S3	1753	5154	S1, 5154
1654	5753	FGT I S1	1754	5161	S2, 5161
1655	2754	FSUB I S2	1755	5164	S3, 5164
1656	3755	FMPY I S3	1756	5167	S4, 5167
1657	0000	FFX1	1757	5172	S5, 5172
1660	4406	JMS I Z 6	1760	5175	S6, 5175
1661	4526	JMS I Z TCR	/ FP CONSTANT ADDRESSES		
1662	5600	JMP I UBDN	1761	1164	CC1, 1164
/ START THORIUM			1762	1167	CC2, 1167
*1663			1763	5475	PC1, 5475
1663	0000	TRDN, 0	1764	1172	UC1, 1172
1664	1346	TAD THD	1765	1175	UC2, 1175
1665	4532	JMS I Z 1SC	1766	1367	UC3, 1367
1666	1352	TAD TSEG	1767	1372	UC4, 1372
1667	4534	JMS I Z SUMSEG	1770	1375	UC5, 1375
1670	4407	JMS I Z 7	1771	4572	UC6, 4572
1671	5753	FGT I S1	1772	4575	UC7, 4575
1672	1754	FDIV I S2	1773	5456	C1.00, 5456
1673	6753	FPUT I S1	1774	5461	C2.00, 5461
1674	5755	FGT I S3	1775	5464	C6.00, 5464
1675	4756	FDIV I S4	1776	5467	C3.23, 5467
1676	6754	FPUT I S2	1777	5472	C8.82, 5472

Figure B-6. CALCULATE PROGRAM.

/ EXEC			/ EXECUTIVE CONTROL OF DATA			/ INTERPRETS CONTROL PANEL AND COORDINATES SUBROUTINES		
*4000								
4000	6002	EXEC,	IOF	/ INITIALIZE				
4001	6504		ANLF					
4002	6514		OFCE					
4003	6046		ILS					
4004	7300		CLA CLL					
4005	1103		TAD Z BELL					
4006	4533		JMS I Z OLY	/ SIGNAL OPERATOR				
4007	4020	ACV,	JMS Z INIL					
4010	1357		TAD BY					
4011	4516		JMS I Z CIAV	/ DISPLAY READY MESSAGE				
4012	2140		JMS Z KCPL	/ OPERATE ?				
4013	5077		JMP ACV	/ NO				
4014	6501		KOPS					
4015	0070		AND Z C7<					
4016	7640		S/A CLA	/ SWITCH TELETYPE ?				
4017	5014		MP .-3	/ NO				
4020	1172		LOF Z CPL					
4021	7002		HAL					
4022	7430		SZL	/ FAIL ?				
4023	5353		JF TEN	/ YES				
4024	7002		AI					
4025	7430		AI	/ ANALYZE ?				
4026	5000		JMP ANL	/ YES				
4027	7002		AI					
4030	7600		ANI CLA	/ FAULT ?				
4031	5007		JF ACV	/ NO				
4032	1374		TAD KPCS					
4033	7710		SFA CLA	/ RECONV. QUALIFIED ?				
4034	4765		JMS I CPHC	/ NO				
4035	3374		DCA RKC					
4036	117		IAI Z TALI					
4037	7710		JF CLC	/ REPLY ?				
4038	5044		AI	/ NO				
4041	2077		ISZ S S	/ RECONV. ?				
4042	5044		AI	/ RECONV. ?				
4043	4771		AI	/ YES				
4044	4506		JMS I Z IC					
4045	4515		ISZ I Z PL C					
4046	7602		LS					
4047	075		AI C374					
4050	7450		AI	/ SCAL ?				
4051	5044		JF IO+1	/ YES				
4052	710		AI					
4053	00		AI					
4054	74		AI					
4055	476		ISZ I	/ YES				
4056	4076		JMS IT					
4057	7400		SL	/ YES				
4060	4763		JMS I I I	/ YES				
4061	4076		JMS IOI					
4062	743		SZL	/ C-2 ?				
4063	4764		JMS IOI	/ YES				
4064	4076		JMS IOI					
4065	7430		SL	/ YES				
4066	4764		JMS I I I	/ YES				
4067	4076		JMS IOI					
4070	743		SZL	/ SENSITIVITY ?				
4071	4770		JMS I SENSIV	/ YES				
4072	4076		ISZ IOI					
4073	7400		SZL	/ CLIP ?				
4074	4767		JMS I CAI	/ YES				
4075	5000		JMP EXFC					
4076	000	CI,	AI					
4077	1373		TAD EXFC					
4100	7104		CLL HAL					
4101	3373		DCA EXFC					
4102	5676		AI	/ STA 1 ANALYSIS				
4103	724		CLA CLA					
4104	3377		DCA SUBS	/ REPLY ?				
4105	3161		DCA Z V CD					
4106	117		TAD Z LATI					
4107	3374		DCA KPCS					
4110	1170		IAI Z DAT D					
4111	7710		SFA CLA	/ COPY ?				
4112	1062		TAD Z CII	/ REPLY ?				
4113	1003		TAD Z COK					
4114	1065		TAD Z C I					
4115	3010		DCA Z I					
4116	1100		IAI Z CYSIII					
4117	3373		DCA EXFC					
4120	1101		IAI Z CC					
4121	3410		DCA I I					
4122	1075		TAD Z C I					
4123	3166		DCA Z I I I					
4124	1075		TAD Z C I					
4125	3165		DCA Z I I I					
4126	1075		IAI Z C I I					
4127	3164		DCA Z I I I					
4130	1102		IAI Z I I					
4131	741		AI					
4132	3177		DCA I I					
4133	117		IAI Z I I I					
4134	771		SFA CLA	/ YES ?				
4135	4770		JMS I I I	/ YES ?				
4136	3170		DCA Z I I I					
4137	3171		DCA Z I I I					
4140	341		DCA Z I I					
4141	2373		ISZ EXFC					
4142	5320		AI					
4143	6502		ANI					
4144	6042		ICF					
4145	630		ICC					
4146	6001		ICN					
4147	4515		JMS I I I	/ DISPLAY SPEC AND TIME HILE ANALYZE C				
4148	4140		ISZ Z KCPL					
4149	5327		JMP DSP	/ REPLY ?				
4150	5000		JMP EXFC					
4153	117		IAI Z DAT D	/ COPY ?				
4154	7710		SFA CLA	/ COPY ?				
4155	5761		IAI Z I I I					
4156	5760		JMP I I I					
4157	420		AI	/ YES				
4160	1000		AI					
4161	1057		AI					
4162	100		AI					
4163	1663		AI					
4164	1711		AI					
4165	55		AI					
4166	460		AI					
4167	500		AI					
4170	540		AI					
4171	4323		AI					
4172	4546		AI					
4173	200		AI					
4174	0000		AI					
4175	3740		AI					
4177	0000		AI					

Figure B-7. EXECUTIVE PROGRAM.

/ CHARACTER STRINGS				4272	4200	4000	
/				4273	0033	TSEG,	0033 / 27
/ RFADY				4274	0005		0005 / 5
*4200				4275	0001		0001 / 1
4200	2205	2205		4276	0005		0005 / 5
4201	0104	0104		4277	0001		0001 / 1
4202	3100	3100		4307	0014		0014 / 12
4203	0000	0000		4301	0001		0001 / 1
4204	0001	0001		4302	0022		0022 / 18
/ TURN READER OFF				4303	0037		0037 / 31
*4205				4304	0023		0023 / 19
4205	0015	0015		4305	0001		0001 / 1
4206	0000	0000		4306	0022		0022 / 18
4207	0000	0000		4307	4000		4000
4210	0000	0000		/			
4211	0000	0000		/ FP SUBROUTINE			
4212	2425	2425		/ NORMALIZES CONTENTS OF ADDRESS SPECIFIED			
4213	2216	2216		/ BY LOC Z 10 AND ADDS TO CONTENTS OF			
4214	0027	0027		/ SUBTOTAL REGISTER ON PAGE ZERO.			
4215	0000	0000		*4310			
4216	2205	2205		4310	0000	SUBTL,	0
4217	0104	0104		4311	7200		CLA
4220	0522	0522		4312	1106		TAD Z C11D
4221	0000	0000		4313	3044		DCA Z 44
4222	1706	1706		4314	1410		TAD I Z 10
4223	0600	0600		4315	3045		DCA Z 45
4224	0001	0001		4316	3046		DCA Z 46
/ OVERFLOW				4317	4407		JMS I Z 7
*4225				4320	7000		FNOR
4225	1726	1726		4321	1325		FADD SUB
4226	0522	0522		4322	6325		FPUT SUB
4227	0614	0614		4323	0000		FFXT
4230	1727	1727		4324	5710		JMP I SUBTL
4231	0001	0001		*4325			
/ BUFFER IDENT				4325	0000	SUB,	0
*4232				4326	0000		0
4232	2550	2550	/ U(UG)=	4327	0000		0
4233	2507	2507		/			
4234	5175	5175		/ FP TOTAL SUBROUTINE			
4235	0001	0001		/ ADDS CONTENTS OF SUBTOTAL REGISTER ON PAGE ZERO			
4236	2450	2450	/ T(MG)=	/ TO CONTENTS OF TOTAL REGISTER ON PAGE ZERO.			
4237	1507	1507		*4330			
4240	5175	5175		4330	0000	TOTL,	0
4241	0001	0001		4331	7200		CLA
4242	0350	0350	/ C(AC)=	4332	4407		JMS I Z 7
4243	1603	1603		4333	5340		FGET TTL
4244	5175	5175		4334	1325		FADD SUB
4245	0001	0001		4335	6340		FPUT TTL
4246	2050	2050	/ P(G)=	4336	0000		FFXT
4247	0751	0751		4337	5730		JMP I TOTL
4250	7500	7500		*4340			
4251	0100	0100		4340	0000	TTL,	0
/				4341	0000		0
/ CALCULATION SECFEN1 ARRAY				4342	0000		0
*4252				/			
4252	0112	0112	/ 74	/ SUBRG			
4253	0023	0023	/ 19	/ SUBTRACT BACKGROUND SUBROUTINE			
4254	0122	0122	/ P2	*4343			
4255	0030	0030	/ P4	4343	0000	SUBRG,	0
4256	4000	4000		4344	1162		TAD Z BKLOF1
4257	0257	0257	/ 175	4345	7041		CMA IAC
4260	0030	0030	/ 24	4346	1173		TAD Z BDLOF1
4261	4000	4000		4347	3173		DCA Z BDLOF1
4262	0025	0025	/ 21	4350	1163		TAD Z BKLOF2
4263	0005	0005	/ 5	4351	7041		CMA IAC
4264	0010	0010	/ 8	4352	1174		TAD Z BDLOF2
4265	0005	0005	/ 5	4353	3174		DCA Z BDLOF2
4266	0044	0044	/ 36	4354	1100		TAD Z CMS11D
4267	0022	0022	/ 10	4355	3372		DCA FNUF
4270	0122	0122	/ 42	4356	1077		TAD Z C3K
4271	0030	0030	/ 24	4357	3010		DCA Z 10
				4360	1063		TAD Z C2K
				4361	3373		DCA RODADD
				4362	2373	AGN,	ISZ RODADD
				4363	1410		TAD I Z 10
				4364	7041		CMA IAC
				4365	1773		TAD I RODADI
				4366	3773		DCA I RODADD
				4367	2372		ISZ FNUF
				4370	5362		JIP AGN
				4371	5743		JMP I SUBRG
				/ STORAGE			
				4372	0000	ENUF,	0
				4373	0000	RODADD,	0

Figure B-9. INTERRUPT AND READ-TIME SUBROUTINES

/ LIST			/ TYPE ONE LINE SUBROUTINE		
/ LISTS DIFFERENTIAL SPECTRUM (OCTAL)					
/ WHILE DISPLAYING ABSOLUTE SPECTRUM					
*4600					
4600 0000	LIST,	0 / ENTRY, INITIALIZE	4701 0000	TYPLIN,	0
4601 4350		JMS LEDR	4702 1412		TAD I Z 12
4602 4526		JMS I Z 1CK	4703 4317		JMS CHNL
4603 1170		TAD Z DATMD	4704 2377		ISZ DATCTR / FINISHED LINE ?
4604 7710		SPA CLA / BODY OR BKGND ?	4705 7410		SKP / NO
4605 1062		TAD Z C1K	4706 5312		JMP .+4
4606 1063		TAD Z C2K	4707 1365		TAD SPAC
4607 3012		DCA Z 12	4710 4337		JMS TYPDSP
4610 1066		TAD Z CM2	4711 5302		JMP TYPLIN+1
4611 3373		DCA HLFCTR	4712 1363		TAD RET
4612 4407		JMS I Z 7	4713 4337		JMS TYPDSP
4613 5027		FCET Z RUNNO	4714 1364		TAD LNFD
4614 0000		FEET	4715 4337		JMS TYPDSP
4615 4406		JMS I Z 6	4716 5701		JMP I TYPLIN / RETURN
4616 4533		JMS I Z 01Y	/ TYPE ONE CHANNEL SUBROUTINE		
4617 4407		JMS I Z 7	4717 0000	CHNL,	0
4620 5135		FCET Z LCI	4720 3375		DCA DATA
4621 0000		FEET	4721 1067		TAD Z CM4
4622 4406		JMS I Z 6	4722 3374		DCA CHCTR
4623 4533		JMS I Z 01Y	4723 1375	AGN,	TAD DATA / START EACH CHAR
4624 1367		TAD ASTK	4724 7104		CLL RAL
4625 4533		JMS I Z 01Y	4725 7006		RAL
4626 1170		TAD Z DATMD	4726 3375		DCA DATA
4627 7710		SPA CLA / BODY OR BKGND ?	4727 1375		TAD DATA
4630 5233		JMP .+3 / BKGND	4730 7004		RAL
4631 1173		TAD Z BKLOF1	4731 0366		AND C7
4632 7410		SKP	4732 1110		TAD Z C260
4633 1162		TAD Z BKLOF1	4733 4337		JMS TYPDSP
4634 4317	HLF,	JMS CHNL / START EACH HALF	4734 2374		ISZ CHCTR / FINISHED CHANNEL ?
4635 1361		TAD CM19D	4735 5323		JMP AGN / NO
4636 3372		DCA LINCTR	4736 5717		JMP I CHNL / YES, RETURN
4637 1360		TAD CM9D	/ TYPE ONE CHAR AND DISPLAY SUBROUTINE		
4640 3377		DCA DATCTR	4737 0000	TYPDSP,	0
4641 4301		JMS TYPLIN	4740 3376		DCA CHAR
4642 1075	NXT,	TAD Z CM10D	4741 4515		JMS I Z DSPLOC
4643 3377		DCA DATCTR	4742 6041		TSF
4644 4301		JMS TYPLIN	4743 5341		JMP TYPDSP+2
4645 2372		ISZ LINCTR / FINISHED HALF ?	4744 1376		TAD CHAR
4646 5242		JMP NXT / NO	4745 6046		ILS
4647 2373		ISZ HLFCTR / YES, WHICH HALF ?	4746 7200		CLA
4650 5255		JMP .+5 / FIRST, DO SECOND	4747 5737		JMP I TYPDSP / RETURN
4651 1362		TAD MONY	/ TYPE LEADER		
4652 4337		JMS TYPDSP	4750 0000	LEDR,	0
4653 4350		JMS LEDR	4751 1370		TAD CM50D
4654 5600		JMP I LIS1 / LAST, EXIT.....	4752 3374		DCA CHCTR
4655 1171		TAD Z STKMD	4753 1371		TAD C2C
4656 7700		SPA CLA / DUAL OR SINGLE ?	4754 4533		JMS I Z 01Y
4657 5275		JMP SGL / SINGLE	4755 2374		ISZ CHCTR
4660 1367		TAD AS1K	4756 5353		JMP .-3
4661 4337		JMS TYPDSP	4757 5750		JMP I LEDR
4662 1012		TAD Z 12	/ CONSTANTS		
4663 0070		AND Z C7K	4760 7767	CM9D,	7767
4664 1071		TAD Z C4C	4761 7755	CM19D,	7755
4665 3012		DCA Z 12	4762 0244	MONY,	0244
4666 1170		TAD Z DATMD	4763 0215	RET,	0215
4667 7710		SPA CLA / BODY OR BKGND ?	4764 0212	LNFD,	0212
4670 5273		JMP .+3 / BKGND	4765 0240	SPAC,	0240
4671 1174		TAD Z BKLOF2	4766 0007	C7,	0007
4672 7410		SKP	4767 0252	ASTK,	0252
4673 1163		TAD Z BKLOF2	4770 7716	CM50D,	7716
4674 5234		JMP HLF / DO SECOND HALF	4771 0200	C2C,	0200
4675 7240	SGL,	CLA CM4	/ STORAGE		
4676 1361		TAD CM19D	4772 0000	LINCTR,	0
4677 3372		DCA LINCTR	4773 0000	HLFCTR,	0
4700 5242		JMP NXT	4774 0000	CHCTR,	0
			4775 0000	DATA,	0
			4776 0000	CHAR,	0
			4777 0000	DATCTR,	0

Figure B-10. LIST PROGRAM.

/ SFGSUM			5076	2343	ISZ SUMMARY
/ FF SEGMENT SUM SUBROUTINE			5077	2343	ISZ SUMMARY
/ FNTR WITH ADDRESS OF SEGMENT ARRAY			5100	2343	ISZ SUMMARY
/ STORES SUMS IN S1, S2, ..., S6			5101	4407	JMS I Z 7
*5000			5102	5751	FEET I TTL
5000	0000	SFGSUM, 0	5103	4135	FDIV Z LC1
5001	3342	DCA SEGADD	5104	1743	FADD I SUMMARY
5002	1337	TAD ADDR / CLEAR SUM ARRAY	5105	6743	FPLT I SUMMARY
5003	3010	DCA Z 10	5106	0000	FEXT
5004	1340	TAD CM18D	5107	2344	ISZ SEC
5005	3341	DCA LINCTR	5110	1744	TAD I SFC
5006	3410	DCA I Z 10	5111	7700	SMA CLA / FINISHED ALL SEGMENTS ?
5007	2341	ISZ LINCTR	5112	5244	JMP AGN / NO
5010	5206	JMP --2	5113	2341	ISZ LINCTR / FINISHED ALL DATA ?
5011	1170	TAD Z DATND	5114	7410	SKP / NO
5012	7710	SPA CLA / BODY OK BKEND ?	5115	5600	JMP I SFGSUM / YES, RETURN.....
5013	1062	TAD Z C1K / PKEND	5116	1010	TAD Z 10
5014	1063	TAD Z C2K	5117	0070	AND Z C70
5015	3010	DCA Z 10	5120	1071	TAL Z C4C
5016	1162	TAD Z BKLOF1	5121	3010	DCA Z 10
5017	3175	DCA Z CH1LOF	5122	1176	TAD Z CH1UCF
5020	1163	TAD Z BKLOF2	5123	5237	J P RGN / RECYCLE FOR DUAL
5021	3176	DCA Z CH1LOF	5124	0000	HINOK, C / SET SUP TO OVERFLOW
5022	1170	TAD Z DATND	5125	3045	DCA Z 45
5023	7710	SPA CLA / BODY OK BKEND ?	5126	1107	TAD Z C22D
5024	5231	JMP ++5 / BKEND	5127	3044	DCA Z 44
5025	1173	TAD Z BDLOF1	5130	3046	DCA Z 46
5026	3175	DCA Z CH1LOF	5131	4407	JMS I Z 7
5027	1174	TAD Z BDLOF2	5132	7000	FNOK
5030	3176	DCA Z CH1UCF	5133	6747	FPUT I SUP
5031	1171	TAD Z STRND	5134	0000	FFXI
5032	7710	SPA CLA / DUAL OR SINGLE ?	5135	5724	JMP I HIND / RETURN
5033	1065	TAD Z CM1 / DUAL	/ CONSTANTS		
5034	1065	TAD Z CM1	5136	5153	SUMADD, 5153
5035	3341	DCA LINCTR	5137	5155	ADDR, 5155
5036	1175	TAD Z CH1LOF	5140	7756	CM18D, 7756
5037	4324	JMS HINOK / START EACH SFG/FF, T	/ STORAGE		
5040	1336	TAD SUMADD	5141	0000	LINCTR, 0
5041	3343	DCA SUMMARY	5142	0000	SFGADD, 0
5042	1340	TAD SFGADD	5143	0000	SUMARY, 0
5043	3344	DCA SEC	5144	0000	SFC, 0
5044	1171	TAD Z STRND / START EACH SUP	5145	0000	CHCTR, 0
5045	7700	SMA CLA / DUAL OR SINGLE ?	/ INTERCOM RECEIPTS FOR TOTAL AND S-TOTAL		
5046	1744	TAD I SEG / SINGLE	5146	4310	SUBTL, 4310
5047	1744	TAD I SEG	5147	4325	SUB, 4325
5050	7041	C A IAC	5150	4330	TOTL, 4330
5051	7450	SMA / SENSE ZERO INTERVAL	5151	4340	TTL, 4340
5052	5257	JMP ++5	/ SUM STORAGE DATA		
5053	3345	DCA CHCTR	*5156		
5054	4746	JMS I SUBTL	5156	0000	S1, 0
5055	2345	ISZ CHCTR / FINISHED SEGMENT ?	5157	0000	0
5056	5254	JMP --2 / NO	5160	0000	0
5057	4407	JMS I Z 7	5161	0000	S2, 0
5060	5747	FEET I SUB	5162	0000	0
5061	6751	FPUT I TTL	5163	0000	0
5062	0000	FFXI	5164	0000	S3, 0
5063	2344	ISZ SEC	5165	0000	0
5064	1171	TAD Z STRND	5166	0000	0
5065	7700	SMA CLA / DUAL OR SINGLE ?	5167	0000	S4, 0
5066	1744	TAD I SEG / SINGLE	5170	0000	0
5067	1744	TAD I SFC	5171	0000	0
5070	7041	CMA IAC	5172	0000	S5, 0
5071	3345	DCA CHCTR	5173	0000	0
5072	4746	JMS I SUBTL	5174	0000	0
5073	4750	JMS I TOTL	5175	0000	S6, 0
5074	2345	ISZ CHCTR / FINISHED SEGMENT ?	5176	0000	0
5075	5272	JMP --3 / NO	5177	0000	0

Figure B-11. SEGMENT SUM SUBROUTINE.

		/ CALB		5276	1355	TAD SUMM	
		/ CALIBRATION SUBROUTINE		5277	7041	CNA IAC	
		/ TYPES CHANNEL NUMBER OF PEAK IN INTERVAL		5300	1353	TAD MAX	
		/ SPECIFIED ON TTY AND INDICATES (A-F-O)		5301	7700	SNA CLA	/ SUM > MAX ?
		/ ON SCOPE DISPLAY.		5302	5307	JMP .+5	/ NO
		/ END POINTS SHOULD NOT DIFFER IN AMPLITUDE BY		5303	1355	TAD SUMM	
		/ MORE THAN 2000(DEC) COUNTS.		5304	3353	DCA MAX	
		*5200		5305	1011	TAD Z 11	
5200	0000	CALB,	C	5306	3354	DCA CHAL	
5201	4526		JMS I Z 1CR	5307	2350	ISZ FNUF	/ FINISHED ALL CHANNELS ?
5202	1360		TAD CHLOC	5310	5266	JVP TST	/ NO
5203	7001		IAC	/ TYPE CHANNEL NUMBER			
5204	4532		JMS I Z 1SC	5311	1354	TAD CHNL	
		/ DISPLAY SPECTRUM AND POINTER		5312	0346	AND C377	
5205	1354		TAD CHNL	5313	3354	DCA CHAL	
5206	7450		SNA	5314	1352	TAD ADDR	
5207	7001		IAC	5315	7041	CNA IAC	
5210	7041		CNA IAC	5316	1354	TAD CHAL	
5211	3350		DCA ENLF	5317	1351	TAD LOFND	
5212	1167		TAD Z HINC	5320	3354	DCA CHNL	
5213	2350		ISZ FNUF	5321	1354	TAD CHAL	
5214	5212		JMP .-2	5322	3045	DCA Z 45	
5215	1344		TAD CSC	5323	3046	DCA Z 46	
5216	3347		DCA XXX	5324	1106	TAD Z C11D	
5217	1347	AGN,	TAD XXX	5325	3044	DCA Z 44	
5220	3521		DCA I / AVAL	5326	4406	JMS I Z 6	
5221	3522		DCA I Z YVAL	5327	4533	JMS I Z OTY	
5222	1345		TAD AFO	5330	2356	ISZ HLFCTP	/ FINISHED ALL SECTIONS ?
5223	4520		JMS I Z FINE	5331	7410	SKP	/ NO
5224	4515		JMS I Z DSPLOC	5332	5201	JMP CALB+1	
5225	6031		KSF	5333	4527	JMS I Z TSP	
5226	5217		JMP AGN	5334	4527	JMS I Z TSP	
5227	1170		TAD Z DATMD	5335	1011	TAD Z 11	
5232	7710		SPA CLA	5336	0070	AND Z C7K	
5231	1062		TAD Z C1K	5337	1071	TAD Z C4C	
5232	1063		TAD Z C2K	5340	5254	JMP BCN	
5233	3011		DCA Z 11	/ CONSTANTS			
		/ READ LO FR AND LPPFR CHANNELS		5341	7470	CMPCD,	7470
5234	4405		JMS I Z 5	5342	0310	C2CD,	0310
5235	4514		JMS I Z NORF	5343	0070	C5CD,	0070
5236	3352		DCA ADDR	5344	0050	C50,	0050
5237	1352		TAD ADDR	5345	0336	AXOW,	0336
5240	3351		DCA LOFND	5346	0377	C377,	0377
5241	4405		JMS I Z 5	/ STORAGE			
5242	4514		JMS I Z NORF	5347	0000	XXX,	0
5243	7041		CNA IAC	5350	0000	FNUF,	0
5244	1352		TAD ADD	5351	0000	LCEND,	0
5245	3357		DCA DIFF	5352	0000	ADDR,	0
5246	1171		TAD Z STRMD	5353	0000	MAX,	0
5247	7712		SPA CLA	5354	0000	CHNL,	0
5250	1065		TAD Z CM1	5355	0000	SUMM,	0
5251	1065		TAD Z CM1	5356	0000	HLFC1R,	0
5252	3356		DCA HLFCTP	5357	0000	DIFF,	0
		/ FIND PEAK CHANNEL		/ IDENT CHAR STRING			
5253	1011		TAD Z 11	5360	5360	CHLOC,	.
5254	1352	PCN,	TAD ADDR	5361	0310		0310
5255	3011		DCA Z 11	5362	7240		7240
5256	1357		TAD DIFF	5363	0001		0001
5257	3350		DCA FN F	/			
5260	4527		JMS I Z TSP	/ NORMALIZE SUBROUTINE			
5261	4527		JMS I Z TSP	/ CONVERT FP TO OCTAL INTERER			
5262	3353		DCA MAX	*5364			
5263	3355		DCA SUMM	5364	0000	NORVL,	0
5264	1011		TAD Z 11	5365	1073		TAD Z CM11D
5265	3354		DCA CHNL	5366	1044		TAD / 44
5266	7300	TST,	CLA CLL	5367	3375		DCA EXP
5267	1411		TAD I Z 11	5370	1045		TAD Z 45
5270	7100		CLL	5371	7110		CLL EAK
5271	7510		SPA	5372	2375		ISZ EXP
5272	7020		CLL	5373	5371		JMP .-2
5273	7210		KAR	5374	5764		JMP I NORML
5274	1355		TAD SUMM	5375	0000	EXP,	0
5275	3355		DCA SUMM				

Figure B-12. CALIBRATE AND NORMALIZE SUBROUTINE.

/ SENSITIVITY SUBROUTINE			5473	215	215
/ SENSITIVITY IN CHARTS (FCT 1L) 21-26, 75-93,			5474	7534	75 4
/ 140-150 IN CHARTS (FCT 1L) 42-52, 15-166, 206-360			/ POTASSIUM CONCENTRATION		
/ IN SJ OF OF.			*5475		
5400	0000	SENSITIVITY,	5475	0000	PC1,
5401	2526	JAS I 2 10	5476	2436	2436
5402	4526	JAS I 2 10	5477	5606	5606
5403	1246	IAF RCAF	/		
5404	7001	IAC	/ MODIFIER		
5405	4537	JAS I 2 SENSE	/ MODIFY 2X BACKGROUND TO 1X		
5406	7201	CH IAC	*5500		
5407	3245	ICA SACTR	5500	000	0
5408	1222	ICL SACTR	5501	7201	CH IAC
5409	3243	ICA I C	5502	1 77	IAF 2 C3K
5410	1240	IAI C 3	5503	3365	ICA ADDR
5411	3244	ICA ENIF	5504	1066	IAI 2 C 2
5412	1041	IAI S C 4	5505	3366	DCA HIFCTR
5413	4532	JAS I 2 C 1Y	5506	1162	IAI 2 PKI OF 1
5414	1245	IA S C 1	5507	7112	CH IAC
5415	1110	IAI 2 C 26	5508	0364	IAI C 2
5416	2533	IAS I 1	5509	1765	IAI I ADDR
5417	1 7	IAS I 1	5510	1 1	2
5418	2533	IAS I 2 1Y	5511	7110	CH IAC
5419	2707	JAS I 2 7	5512	0365	ICA I ADDR
5420	5623	ICFT I S NCC	5513	1363	IAI C 201
5421	0000	FFI	5514	3244	DCA ENIF
5422	2206	JAS I 2 6	5515	2365	IAS ADDR
5423	2526	IAS I 2 10	5516	7300	ICA CH
5424	2243	IAS S LCC	5517	1765	IAI I ADDR
5425	2243	IAS S LCC	5518	75	2
5426	2245	IAS S C 1X	5519	5031	IAS FOS
5427	2244	IAS S C 1F	5520	1 41	CA IAC
5428	5214	IAS S C 1X	5521	7110	CH IAC
5429	5600	IAS S C 1Y	5522	7110	CH IAC
/ CO SENSITIVITY			5523	5333	ICA IAC
5430	0275	FL,	5524	7110	CH IAC
5431	7775	C 3,	5525	7110	CH IAC
5432	323	CH,	5526	7110	CH IAC
5433	5156	CH,	5527	7 41	CA IAC
/ SENSITIVITY			5528	5333	ICA IAC
5434	0000	SENSITIVITY,	5529	7110	CH IAC
5435	0000	FL,	5530	7110	CH IAC
5436	0000	CH,	5531	3765	ICA IAC
5437	0000	S C 1,	5532	2242	IAS FOS
5438	0000	S C 1,	5533	5317	JAS I 2 1
5439	0000	S C 1,	5534	2366	IAS FOS
5440	0000	S C 1,	5535	5351	IAS FOS
5441	0000	S C 1,	5536	1162	IAS FOS
5442	0000	S C 1,	5537	7110	CH IAC
5443	0000	S C 1,	5538	7110	CH IAC
5444	0000	S C 1,	5539	7110	CH IAC
5445	0000	S C 1,	5540	7110	CH IAC
5446	0000	S C 1,	5541	7110	CH IAC
5447	0000	S C 1,	5542	7110	CH IAC
5448	0000	S C 1,	5543	7110	CH IAC
5449	0000	S C 1,	5544	7110	CH IAC
5450	0000	S C 1,	5545	7110	CH IAC
5451	0000	S C 1,	5546	7110	CH IAC
5452	0000	S C 1,	5547	7110	CH IAC
5453	0000	S C 1,	5548	7110	CH IAC
5454	0000	S C 1,	5549	7110	CH IAC
5455	0000	S C 1,	5550	7110	CH IAC
5456	0000	S C 1,	5551	7110	CH IAC
5457	0000	S C 1,	5552	7110	CH IAC
5458	0000	S C 1,	5553	7110	CH IAC
5459	0000	S C 1,	5554	7110	CH IAC
5460	0000	S C 1,	5555	7110	CH IAC
5461	0000	S C 1,	5556	7110	CH IAC
5462	0000	S C 1,	5557	7110	CH IAC
5463	0000	S C 1,	5558	7110	CH IAC
5464	0000	S C 1,	5559	7110	CH IAC
5465	0000	S C 1,	5560	7110	CH IAC
5466	0000	S C 1,	5561	7110	CH IAC
5467	0000	S C 1,	5562	7110	CH IAC
5468	0000	S C 1,	5563	7110	CH IAC
5469	0000	S C 1,	5564	7110	CH IAC
5470	0000	S C 1,	5565	7110	CH IAC
5471	0000	S C 1,	5566	7110	CH IAC
5472	0000	S C 1,	5567	7110	CH IAC

Figure B-13. SENSITIVITY SUBROUTINE, BURDEN CONSTANTS, AND MODIFY BACKGROUND SUBROUTINE.

/ GCAL				5274	4406	JMS I Z 6	/ TYPE RESULT
/ GENERAL CALCULATION SUBROUTINE				5275	4526	JMS I Z TCR	
/ SOLVES :				5276	5600	JMP I GCAL	/ RETURN
/				/ STORAGE			
/				5277	0000	FNUF,	0
/				5300	0000	IDNT,	0
/				5301	0000	CONST,	0
/				5302	0000	NORCON,	0
/				5303	5303	FSTCON,	.
/				5304	0000	C1,	0
/				5305	0000		0
/				5306	0000		0
/				5307	0000	A,	0
/				5310	0000		0
/				5311	0000		0
/				5312	0000	B,	0
/				5313	0000		0
/				5314	0000		0
/				5315	0000	C2,	0
/				5316	0000		0
/				5317	0000		0
/				5320	0000	D,	0
/				5321	0000		0
/				5322	0000		0
/				5323	0000	E,	0
/				5324	0000		0
/				5325	0000		0
/				5326	0000	C3,	0
/				5327	0000		0
/				5330	0000		0
/				5331	5331	NORADD,	.
/				5332	0000	NORC1,	0
/				5333	0000	NORA,	0
/				5334	0000	NORB,	0
/				5335	0000	NORC2,	0
/				5336	0000	NORD,	0
/				5337	0000	NORE,	0
/				5340	0000	NORC3,	0
/				5341	5341	SEG,	.
/				5342	0000		0
/				5343	0000		0
/				5344	0000		0
/				5345	0000		0
/				5346	4000		4000
/				/ CONSTANTS			
/				5347	7771	CM7,	7771
/				5350	0275	EQL,	0275
/				5351	5351	FSTID,	.
/				5352	0361		0361
/				5353	0147		0147
/				5354	0247		0247
/				5355	0362		0362
/				5356	0447		0447
/				5357	0547		0547
/				5360	0363		0363
/				/ ADDRESSES			
/				5361	5156	S1,	5156
/				5362	5161	S2,	5161
/				/ NORML			
/				/ CONVERT FF TO OCTAL INTEGER			
/				*5364			
/				5364	0000	NORML,	0
/				5365	1073	TAD Z CM11D	
/				5366	1044	TAD Z 44	
/				5367	3375	DCA EXP	
/				5370	1045	TAD Z 45	
/				5371	7110	CLL KAR	
/				5372	2375	ISZ EXP	
/				5373	5371	JMP *-2	
/				5374	5764	JMP I NORML	
/				5375	0000	EXP,	0

Figure B-14. GENERAL CALCULATION SUBROUTINE.

/ MIVS-MNTN, GPS				4035	7006	RFL		4143	0302	302
/ CONTROL PANEL MAINTENANCE PROGRAM				4036	7006	RFL		4144	0317	317
/ TYPES STATUS OF CONTROL PANEL SWITCHES				4037	7200	CLA		4145	0304	304
/ AFTER OPERATION MODE HAS BEEN SELECTED.				4040	7420	SNL	/ BKGND OR BODY?	4146	0331	331
/				4041	5244	JMP +3	/ BODY	4147	0254	254
/ TYPEOUT SUBROUTINE				4042	1331	TAD BKG	/ BKGND	4150	0240	240
/ ENTER WITH CHAK STRING ADDR-1 IN AC				4043	7410	SKP		4151	0000	0
/ EXIT WHEN 0000 APPEARS				4044	1342	TAD BODY		4152	4152	DUL, .
*0100				4045	4100	JMS Z TYP		4153	0304	304
0100	0000	TYP,	0 / ENTRY	4046	1264	STOR,	/ TEST STORAGE MODE	4154	0325	325
0101	7001		IAC	4047	7006	RFL		4155	0301	301
0102	3114		DCA ADDR	4050	7006	RFL		4156	0314	314
0103	7200	NXCH,	CLA	4051	7004	RAL		4157	0000	0
0104	1514		TAD I ADDP	4052	7200	CLA		4160	4160	(L, .
0105	7450		SNA	4053	7420	SNL	/ DUAL OR SINGLE?	4161	0323	323
0106	5500		JMP I TYP	4054	5257	JMP +3	/ SINGLE	4162	011	311
0107	6041		TSF	4055	1352	TAD DUL	/ DUAL	4163	0316	316
0110	5107		JMP -1	4056	7410	SKP		4164	011	307
0111	6046		TL5	4057	1360	TAD SGL		4165	0314	314
0112	2114		ISZ ADDR	4060	4100	JMS Z TYP		4166	0305	305
0113	5103		JMP NACH	4061	1265	TAD CRLF		4167	0000	0
0114	0000	ADDR,	0 / CHARACTER ADDRESS REGISTER	4062	4100	JMS Z TYP				
/				4063	5200	JMP BGV	/ RECYCLE	ADDR	0114	
/ SYMBOLS				4064	0000	IE I,	/ TEMPORARY STORAGE	ANL	4103	
CLDA=6051 / CLEAR DAC REGISTERS				4065	4065	CRLF,	/ RETURN LINE FIELD	CNLF	6504	
LDUX=6052 / LOAD X REGISTER FROM AC				4066	0215			CNLF	6502	
CLDX=6053 / COMBINATION 1				4067	0212			CNLF	6506	
LDY=6062 / LOAD Y REGISTER FROM AC				4070	0000			EDL	4142	
INTN=6064 / INTENSIFY SCOPE				4071	4071	NDV,	/ PREADING	EGN	4000	
LDYI=6066 / COMBINATION 1				4072	0322			HAL	4131	
RCPS=6501 / READ CONTROL PANEL TO AC				4073	0305			CLDA	6051	
ANLV=6502 / ENABLE ANALYSIS				4074	0301			CLDX	6053	
ANLF=6504 / DISABLE ANALYSIS				4075	0304			CNLF	4065	
ANLNF=6506 / COMBINATION 1				4076	0311			DEIB	4034	
NADR=6511 / READ ADDRESS REGISTER TO AC				4077	0316			DUL	4152	
UFSF=6512 / SKIP IF OVERFLOW FLAG = 0				4100	0273			INTN	6064	
UFCF=6514 / CLEAR OVERFLOW FLAG				4101	0240			LDYI	6066	
/				4102	0000			LDUX	6052	
/				4103	4103	ANL,	/ ANALYZED	LDY	6062	
/				4104	0301			NACH	0103	
/				4105	0316			UFCF	6514	
*4000				4106	0301			UFSF	6512	
4000	7200	BGN,	CLA / ENTRY	4107	0314			UPR	4004	
4001	6046		TL5 / INITIALIZE TRY FLAG	4110	0331			ADDR	6511	
4002	1265		TAD CRLF	4111	0332			RCPS	6501	
4003	4100		JMS Z TYP	4112	0305			NDN	4071	
4004	7200	UPR,	CLA / TEST OPERATE MODE	4113	0273			NDU	4116	
4005	6501		RCPS	4114	0240			SGL	4160	
4006	3264		DCA TEMP	4115	0000			STOR	4046	
4007	1264		TAD TEMP	4116	4116	NDU,	/ READOUT?	TEMP	4064	
4010	7004		RAL	4117	0322			IEP	0100	
4011	7420		SNL	4120	0305					
4012	5217		JMP +5	4121	0301					
4013	7200		CLA	4122	0304					
4014	1271		TAD RDN	4123	0317					
4015	4100		JMS Z TYP	4124	0325					
4016	5234		JMP DATA	4125	0324					
4017	7004		RAL	4126	0273					
4020	7420		SNL	4127	0240					
4021	5226		JMP +5	4130	0000					
4022	7200		CLA	4131	4131	BKG,	/ DBKGND?			
4023	1303		TAD ANL	4132	0302					
4024	4100		JMS Z TYP	4133	0313					
4025	5234		JMP DATA	4134	0307					
4026	7004		RAL	4135	0316					
4027	7420		SNL	4136	0304					
4030	5204		JMP OFR	4137	0254					
4031	7200		CLA	4140	0240					
4032	1316		TAD RDU	4141	0000					
4033	4100		JMS Z TYP	4142	4142	BODY,	/ DBODY?			
4034	1264	DATA,	TAD TEMP							

Figure B-15. CONTROL PANEL MAINTENANCE PROGRAM.

```

/ MIVS-MNIN, DS
/ DEVICE SELECTOR MAINTENANCE PROGRAM
/ REPETITIVELY GENERATES ALL COMMANDS.
/
/ SYMBOLS
CLDA=6051      / CLEAR DAC REGISTERS
LODX=6052      / LOAD X REGISTER FROM AC
CLDX=6053      / COMBINATION 1
LODY=6062      / LOAD Y REGISTER FROM AC
INTN=6064      / INTENSIFY SCOPE
LDY1=6066      / COMBINATION 1
RCPS=6501      / READ CONTROL PANEL TO AC
ANLN=6502      / ENABLE ANALYSIS
ANLF=6504      / DISABLE ANALYSIS
ANLNF=6506     / COMBINATION 1
NADR=6511      / READ ADDRESS REGISTER TO AC
OFSF=6512      / SKIP IF OVERFLOW FLAG = 0
OFCF=6514      / CLEAR OVERFLOW FLAG
/
/
/
+4000
4000 7200 BGN,      CLA      / ENTRY
4001 6051      CLDA
4002 6052      LODX
4003 6062      LODY
4004 6501      RCPS
4005 6506      ANLN
4006 6064      INTN
4007 6511      NADR
4010 6514      OFCF
4011 6512      OFSF
4012 5200      JMP BGN      / RECYCLE

ANLF 6504
ANLN 6502
ANLNF 6506
BGN 4000
CLDA 6051
CLDX 6053
INTN 6064
LDY1 6066
LODX 6052
LODY 6062
OFCF 6514
OFSF 6512
NADR 6511
RCPS 6501

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Figure B-16. DEVICE SELECTOR MAINTENANCE PROGRAM.

```

/ MIVS-MNIN, DAC
/ DAC MAINTENANCE PROGRAM
/ REPETITIVELY GENERATES SARTOOTH ON BOTH OUTPUTS
/
/ SYMBOLS
CLDA=6051      / CLEAR DAC REGISTERS
LODX=6052      / LOAD X REGISTER FROM AC
CLDX=6053      / COMBINATION 1
LODY=6062      / LOAD Y REGISTER FROM AC
INTN=6064      / INTENSIFY SCOPE
LDY1=6066      / COMBINATION 1
RCPS=6501      / READ CONTROL PANEL TO AC
ANLN=6502      / ENABLE ANALYSIS
ANLF=6504      / DISABLE ANALYSIS
ANLNF=6506     / COMBINATION 1
NADR=6511      / READ ADDRESS REGISTER TO AC
OFSF=6512      / SKIP IF OVERFLOW FLAG = 0
OFCF=6514      / CLEAR OVERFLOW FLAG
/
/
/
+4000
4000 1210 BGN,      FAD C10      / ENTRY
4001 6053      CLDX
4002 7000      NOP
4003 7000      NOP
4004 6066      LDY1
4005 7000      NOP
4006 7000      NOP
4007 5200      JMP BGN      / RECYCLE
4010 0010 C10,      0010

ANLF 6504
ANLN 6502
ANLNF 6506
BGN 4000
CLDX 6053
C10 4010
INTN 6064
LDY1 6066
LODX 6052
LODY 6062
OFCF 6514
OFSF 6512
NADR 6511
RCPS 6501

```

Figure B-17. DAC MAINTENANCE PROGRAM.

APPENDIX C

DATA BREAK TIMING DIAGRAM

APPENDIX D

MAJOR EQUIPMENT

Major Components of the MIVS Instrumentation System are:

<u>Type</u>	<u>Manufacturer and Part Number</u>
ADC	Nuclear Data, Inc, ND-180F
Circuit Modules	Digital Equipment Corporation, Flip Chip Line
Computer	Digital Equipment Corporation, PDP-8
Detector Assembly	Harshaw Chemical Company
Linear Amplifier	Radiation Instrument Development Laboratory, 30-24
Mixer	Radiation Instrument Development Laboratory, 30-26
Oscilloscope	Tektronics, Inc, RM503
Preamplifier	Radiation Instrument Development Laboratory, 31-14
Teletype	Teletype Corporation, 33ASR