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**Plutonium Isotopic Analysis System for Plutonium
Samples Enriched in ^{238}Pu in EP 60/61 Containers
Volume 1
Users Manual**

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June 1, 1990

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Laboratory

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Plutonium Isotopic Analysis System for Plutonium Samples Enriched in ^{238}Pu in EP 60/61 Containers

Volume 1 Users Manual

Wayne D. Ruhter

June 1, 1990

PREFACE

This user's manual is addressed to the Savannah River Site personnel (routine operators and supervisors) who perform measurements with the Pu-238 isotopic analysis system. Each chapter begins with a table of contents that lists the section titles, illustrations, and tabular data presented in that chapter.

The first chapter in this manual is an introduction to the system. Chapter 2 lists required settings for the system's commercial nuclear instrument modules. System operating procedures are given in Chapter 3. Chapter 4 contains routine and supervisorial operator interactions. Chapter 5 describes the system's short- and long-printout output formats. Chapter 6 gives instructions for changing system parameters. Error messages are listed and described in Chapter 7. Chapter 8 contains a reference article on measuring relative plutonium isotopics in plutonium samples enriched in Pu-238.

In addition to this manual, two other manuals complete the description of the Pu-238 isotopic analysis system. The Pu-238 Isotopic Analysis Hardware Manual (UCRL-CR-103923, Vol. 2) describes the system components and provides service and maintenance information. In that volume are detailed instructions on required settings for the nuclear instrument modules. The Pu-238 Isotopic Analysis Software Manual (UCRL-CR-103923, Vol. 3) is presented in two parts. Part 1 describes the computer codes that control the instrument, analyze the spectral data, and determine the relative plutonium abundances. Part 2 contains the software listings of the isotopics codes.

All commercial items mentioned in this manual are assumed to be functioning correctly for the purposes of system operation. Users are referred to individual equipment manufacturers' manuals for details of operation, trouble-shooting, and maintenance of this commercial equipment.

This manual contains cautions and notes set apart from the text by solid or dashed lines, respectively. A CAUTION precedes an operation in which the equipment is at risk. A NOTE provides important supplementary information to the reader.

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Fig. 1-1. Block diagram of the Pu-238 isotopic analysis system.

Chapter 1

INTRODUCTION

This manual provides instructions and procedures for using the Lawrence Livermore National Laboratory's Pu-238 isotopic analysis system to measure plutonium samples for relative Pu-238, Pu-239, Pu-241, Am-241 isotopic abundances, and sample specific power by gamma-ray spectrometry. The computer program that controls the system and analyzes the gamma-ray spectral data is driven by a menu of one-, two-, or three-letter options chosen by the operator. Provided in this manual are descriptions of these options and their functions, plus detailed instructions (operator dialog) for choosing among the options. Also provided are general instructions for monitoring the Pu-238 isotopic analysis system's performance as well as detailed instructions for using the system's PU238_CHNG program to edit the default parameter file.

1.1 SYSTEM PURPOSE

The inventory measurement of a sample's total plutonium content is determined by two nondestructive measurements. One is a calorimetry measurement of the sample's heat or power output, and the other is a gamma-ray spectrometry measurement of its relative isotopic abundances of plutonium. The isotopic measurements needed to interpret the observed calorimetric power measurement are the relative abundances of various plutonium isotopes and americium-241. The Pu-238 isotopic analysis system carries out these measurements.

1.2 SYSTEM OPERATION

Figure 1-1 is a block diagram of the Pu-238 isotopic analysis system. The equipment is controlled by a Digital Equipment Corporation (DEC) Micro-VAX II computer with which the operator interacts through a remote DEC Letterwriter 100 terminal/printer. Data are acquired on a Canberra Series 90 multichannel analyzer from a large, 20% efficient, coaxial-type (COAX) detector. The sample rotates and moves up and down inside the detector shield (sample cave) while the detector shield lid is closed. The computer senses the rotation and scanning motion and suspends data acquisition if the sample stops rotating or moving up and down.

If the sample stops rotating or moving up and down for any reason during a measurement--if for example the sample cave lid is opened--a message to that effect is printed on the operator terminal. Once the fault is corrected, the measurement can be resumed by pressing the carriage-return key on the operator terminal.

The system control program also monitors the liquid nitrogen level in the detector dewar, using liquid nitrogen level monitor (ORTEC 729A) interfaced to the computer. Monitoring occurs only when the system is waiting for a user to enter a menu option. If a low liquid-nitrogen level is detected, a warning message is printed on the operator terminal.

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Chapter 2

INITIAL SYSTEM SETTINGS

This chapter contains a checklist of initial settings for most components of the Pu-238 isotopic analysis system. The reader should be aware that actual settings on the various electronic modules for the detector may vary from those specified when it was first installed in 1990 at the Savannah River Site. Contact the Laboratories Department supervisor before making any changes.

The checklists in this chapter should be adequate for experienced personnel (routine operators and supervisors) to prepare the Pu-238 isotopic analysis system components for operation. If in doubt, refer to the Pu-238 Isotopic Analysis System Hardware Manual (UCRL-CR-103923 Vol. 2, Chapter 3) and to the manufacturers' manuals for detailed instructions.

Fig. 2-1. Rack-mounted oscilloscope.

2.1 ROUTINE PREOPERATIONAL SETUP

Preoperational setup requires that controls be set and preliminary operations be performed on commercial components of the Pu-238 isotopic analysis system: Tektronix rack-mounted oscilloscope, nuclear instrument module (NIM) bin components, Canberra Series 90 multichannel analyzer, Digital Equipment Corporation (DEC) MicroVAX II computer, and DEC Letterwriter 100 terminal/printer. Perform routine preoperational setup in accordance with the following checklist.

ROUTINE PREOPERATIONAL SETUP

Equipment	Control	Position
<u>OSCILLOSCOPE</u> (See Fig. 2-1.)	POWER ON/OFF pushbutton	ON (observe green POWER LED on)
	TRIGGER SOURCE switch	Vert Mode
	TRIGGER MODE switch	NORM
	TRIGGER SLOPE switch	Up
	TIME BASE SEC/DIV rotary switch	2 microseconds
	VOLTS/DIV rotary switches for 1X PROBE	2
	AC/GND/DC switches	DC
	CH 1/DUAL MODE/CH 2 pushbuttons	CH 1

Fig. 2-2. Nuclear instrument module (NIM) bin modules.

Fig. 2-3. High-energy region of the plutonium gamma-ray spectrum, taken with the COAX detector at 0.25 keV per channel. Note relative positions of the 152.7- and 766.4-keV peaks.

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position
<u>NIM BIN MODULES (SEE FIG. 2-2)</u>		
<u>Canberra 2020</u> <u>AMPLIFIER</u> (See UCRL-CR-103923, Vol. 2, paragraph 3.3.1, for further information.)	<p>-----</p> <p>NOTE: For proper operation, amplifier gain should be set to give 0.25 keV/channel. The initial settings given below assume correct pileup rejector adjustment, which is important to good high-count-rate energy resolution.</p> <p>-----</p>	
	COARSE GAIN rotary switch	100
	FINE GAIN potentiometer	Approx. 490
	<p>-----</p> <p>NOTE: Amplifier fine gain should be set such that the plutonium-238 152.7-keV peak is at channel 612 and the plutonium-238 766.4-keV peak is at channel 3063 (see Fig. 2-3). This may require some adjustment of the ZERO potentiometer on the analog-digital converter.</p> <p>-----</p>	
	INPUT POLARITY toggle switch	- (negative)
	SHAPING MULTIPLIER switch	X1 (pushbutton out)
	SHAPING TIME μ SEC rotary switch	1.0 μ s
	(P/Z) (pole zero)	See UCRL-CR-103923 Vol. 2, paragraph 3.3.2, for setup.
	RESTORER RATE toggle switch	AUTO
	RESTORER MODE toggle switch	ASYM
	THRESHOLD toggle switch	AUTO
	PUR (pileup rejector) toggle switch	ON (observe red PUR LED on). See UCRL-CR-103923 Vol. 2, paragraph 3.3.3, for setup.

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position
<u>Canberra 8075</u>		
<u>ANALOG-DIGITAL</u>	Inner GAIN rotary switch	4K
<u>CONVERTER (ADC)</u>		
(See UCRL-CR-103923, Vol. 2, paragraph 3.4, for further information.)	Outer RANGE rotary switch	4K
	OFFSET toggle switches (6)	Down
	LLD potentiometer	Approx. 0.10.
	ZERO potentiometer	Assuming that the amplifier gain is set properly, ad- just so that chan- nel zero is near zero energy: i.e., set the plutonium- 238 152.7-keV peak at channel 612 and the plutonium-238 766.4-keV peak at channel 3063.
	PEAK DETECT toggle switch	AUTO
	PHA/SVA toggle switch	PHA
	COINC/ANTI toggle switch	ANTI

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position
<u>Canberra 8232</u>		
<u>GAIN/ZERO</u>	ZERO/GAIN toggle switch	ZERO [enter ZERO PEAK value (612)]
<u>STABILIZER</u>		
(See UCRL-CR-103923, Vol. 2, paragraph 3.5, for further information.)	ZERO/GAIN toggle switch	GAIN [enter GAIN PEAK value (3063)]
	ZERO/GAIN toggle switch	ZERO [enter ZERO WINDOW value (13)]
	ZERO/GAIN toggle switch	GAIN [enter GAIN WINDOW value (21)]
	ZERO/GAIN toggle switch	ZERO [enter ZERO ANALOG RNG. value (0.125)]
	ZERO/GAIN toggle switch	GAIN [enter GAIN ANALOG RNG. value (0.125)]
	STABILIZATION ZERO ON/HOLD/OFF toggle switch	ON
	STABILIZATION GAIN ON/HOLD/OFF toggle switch	ON
	REMOTE/MANUAL toggle switch	MANUAL

ORTEC 729A
LIQUID NITROGEN
MONITOR

There are no required initial control settings for the
LN monitor.

-C A U T I O N-

During system operation, do not ignore liquid nitrogen
monitor low-nitrogen alarm. The detector high voltage
should be shut down automatically, but the detector
will be damaged if this does not happen, resulting in
expensive repairs.

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position
<u>ORTEC 459 HIGH-VOLTAGE SUPPLY</u> (See UCRL-CR-103923, Vol. 2, paragraph 3.7.2, for further information.)	----- -C A U T I O N- Be absolutely sure that NEG (negative polarity) light is on. Incorrect high-voltage polarity may blow out input FET in preamplifier. Also make sure that OUTPUT VOLTAGE potentiometer is set to zero before turning on the high-voltage supply. Excessive voltage may damage or destroy germanium detector. Excessive voltage will surely blow out input FET. -----	
	HIGH-VOLTAGE ON/OFF toggle switch	ON (Observe power indicator on.)
	OUTPUT VOLTAGE potentiometer	3.00 (-3000 V)
----- NOTE: The correct voltage for the detector initially supplied to WSRC was -3000V. If it becomes necessary to replace the detector, check the manufacturer's recommended voltage and change the corresponding value above and in the hardware manual. -----		

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position												
<u>CANBERRA SERIES 90</u> <u>MULTICHANNEL</u> <u>ANALYZER (Fig. 2-4)</u> (See UCRL-CR-103923, Vol. 2, paragraph 3.8, for further information.)	----- NOTE: Data collection parameters are set by the computer program. No preliminary actions are required except routine setup unless the Series 90 "loses its memory." If so, the setup is more complex (see paragraph 2.2). -----													
Setup configuration for Series 90	1 EXTENDED User (User #1) User #1 assigned to host computer Group #1 assigned to Unit (ADC) #1 Group #1 memory = 4K													
Verify setup configuration	Set CONTROL/STATUS key switch to SUPERVISOR. Touch <u>MENU</u> to get executive menu. Touch <u>SUPERVISOR</u> to get next line in menu. Touch <u>USER SUMMARY</u> and observe:													
	<table><thead><tr><th><u>USER</u></th><th><u>TYPE</u></th><th><u>GROUP</u></th><th><u>MEMORY</u></th><th><u>INPUTS</u></th><th><u>PASSWD</u></th></tr></thead><tbody><tr><td>H1*</td><td>EXTENDED</td><td>1</td><td>4K</td><td></td><td>0000</td></tr></tbody></table>	<u>USER</u>	<u>TYPE</u>	<u>GROUP</u>	<u>MEMORY</u>	<u>INPUTS</u>	<u>PASSWD</u>	H1*	EXTENDED	1	4K		0000	
<u>USER</u>	<u>TYPE</u>	<u>GROUP</u>	<u>MEMORY</u>	<u>INPUTS</u>	<u>PASSWD</u>									
H1*	EXTENDED	1	4K		0000									
	<u>RETURN</u> -----													
	NOTE: Above asterisk after H1 denotes that Series 90 is enabled to communicate with the computer. If asterisk is not displayed, perform the following: Touch <u>MENU</u> . Touch <u>CURRNT USER</u> . Observe that box labeled <u>HOST ASSIGN</u> is set to [YES]. If not, touch <u>HOST ASSIGN</u> to set it from [NO] to [YES]. -----													
	Touch <u>MENU EXIT</u>

Fig. 2-4. Canberra Series 90 display showing detector gamma-ray spectrum in Group 1.

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position								
<u>CANBERRA SERIES 90</u> <u>MULTICHANNEL</u> <u>ANALYZER</u> (CONTINUED)	Set CONTROL/STATUS key switch to	ON LINE (Observe ON LINE LED on.)								
Verify Group-Unit setting (GROUP SUMMARY method)	----- NOTE: Group-Unit setting can be verified by either the GROUP SUMMARY method or the ACQ. SUMMARY method. -----									
	Set CONTROL/STATUS key switch to	SUPERVISOR.								
	Touch <u>MENU</u> to get executive menu.									
	Touch <u>CURRENT USER</u> to get next line in menu.									
	Touch <u>CONFIG GROUPS</u> to get next line in menu.									
	Touch <u>GROUP SUMMARY</u> and observe:									
	<table><tr><th><u>GROUP</u></th><th><u>SIZE</u></th><th><u>ACO. UNIT</u></th><th><u>PRESET</u></th></tr><tr><td>1</td><td>4K</td><td>1 PHA+</td><td>T(True) = XX.X</td></tr></table>	<u>GROUP</u>	<u>SIZE</u>	<u>ACO. UNIT</u>	<u>PRESET</u>	1	4K	1 PHA+	T(True) = XX.X	
<u>GROUP</u>	<u>SIZE</u>	<u>ACO. UNIT</u>	<u>PRESET</u>							
1	4K	1 PHA+	T(True) = XX.X							
	Touch <u>MENU EXIT</u>									
Verify Group-Unit setting (ACQ. SUMMARY method)	Set CONTROL/STATUS key switch to	SUPERVISOR.								
	Touch <u>MENU</u> to get executive menu.									
	Touch <u>SYSTEM</u> to get next line in menu.									
	Touch <u>ACQ. SUMMARY</u> and observe:									
	<table><tr><th><u>UNIT #</u></th><th><u>DESCRIPTION</u></th><th><u>USER</u></th><th><u>GROUP</u></th></tr><tr><td>1</td><td>Single-input C.I. Bd #1 ADC</td><td>1</td><td>1</td></tr></table>	<u>UNIT #</u>	<u>DESCRIPTION</u>	<u>USER</u>	<u>GROUP</u>	1	Single-input C.I. Bd #1 ADC	1	1	
<u>UNIT #</u>	<u>DESCRIPTION</u>	<u>USER</u>	<u>GROUP</u>							
1	Single-input C.I. Bd #1 ADC	1	1							
	Touch <u>MENU EXIT</u>									
	Set CONTROL/STATUS key switch to	ON LINE (Observe ON LINE LED on.)								

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position
<u>CANBERRA SERIES 90</u> <u>MULTICHANNEL</u> <u>ANALYZER</u> (CONTINUED)	<p>-----</p> <p>NOTE: Canberra Series 90 is now ready for operation by computer control. Set up soft keys and user-assigned fields, if desired, in accordance with paragraph 2.3. Implement x-axis display calibration, if desired, in accordance with paragraph 2.4. Consult Canberra Series 90 <u>Operator's Manuals</u>, Extended User Section, pp. 1-26, if a new MCA has to be installed. (Also see UCRL-CR-103923, Vol. 2, paragraph 3.8.2, for further information.)</p> <p>-----</p>	
<u>MICROVAX II COMPUTER</u>	ON/OFF switch	ON (Observe green DC OK LED and green LED in Ready push-button on; verify green LED in Write Protect <u>not</u> on.)
<u>Digital Equipment Corporation LED</u> <u>Letterwriter 100</u> <u>TERMINAL/PRINTER</u>	ON/OFF switch	ON (Observe POWER and LINE LED on.)
	<p>-----</p> <p>NOTE: Verify that supply and feed of printer paper at the terminal/printer are adequate. (Red-bordered paper means that the supply is running out.)</p> <p>-----</p>	

2.2 NEW (FACTORY-DEFAULT) CANBERRA SERIES 90 SETUP

When a multichannel analyzer from the factory is powered up, it starts in a factory default status. This gives users a standard acquisition configuration by which to begin operation, but the touch screen does not display the usual fields. Before proceeding, users should familiarize themselves with the Canberra Series 90 manufacturer's manual, possibly starting with the tutorial section. Assuming that the multichannel analyzer is turned on and normal display is available on the screen, perform preoperational setup as follows:

Equipment	Control	Position
Obtain factory default summary	Set CONTROL/STATUS key switch to Touch <u>MENU</u> to get executive menu. Touch <u>SUPERVISOR</u> to get next line in menu. Touch <u>FACTRY DEFAULT</u> . Touch <u>CNFIRM</u> . Touch blinking dots to calibrate touch screen. Touch <u>USER SUMMRY</u> to get factory default summary: 1 EXTENDED User (User #1) User #1 assigned to host computer Group #1 assigned to Unit (ADC) #1 Group #1 memory = 4K	SUPERVISOR.
Enter correct date and time	Touch TIME/DATE and observe: YEAR MONTH DAY HOUR MINUTE Enter appropriate numbers using console numeric keypad and STORE key. Touch <u>MENU EXIT</u> . Set CONTROL/STATUS key switch to	ON LINE (Observe ON LINE LED on.)

2.3 CANBERRA SERIES 90 SOFT KEYS AND USER-ASSIGNED FIELDS SETUP

At this point the Canberra 90 soft keys and user-assigned fields have not been designated. Consulting the Series 90 Operator's Manuals, Extended Users Sections 2.0 and 3.0-3.2, for details, set up the soft keys and user-assigned fields as follows:

Equipment	Control	Position
Setting up soft keys	Touch <u>MENU</u> to get executive menu.	
	Touch <u>CURRNT USER</u> to get next line in menu.	
	Touch <u>ASSIGN SOFKEY</u> to assign key functions:	

NOTE: The following assignments have been found useful:		
<u>Soft. No.</u>	<u>Assignment</u>	<u>Soft. No.</u> <u>Assignment</u>
1	X-AXIS CALIB.	5 NORMALIZE
2	XFER	6 SMOOTH (3-pt)
3	PEAK SEARCH	7 STRIP
4	SORT ROI	8 DIFFER

	Touch <u>MENU EXIT</u> .	
Setting up user-assigned fields	Touch <u>ASSIGN FIELDS</u> to get next line in menu.	
	Touch <u>OPTION FIELDS</u> and then appropriate key to define function of that key:	

NOTE: The following assignments have been found useful:		
<u>Field No.</u>	<u>Option</u>	<u>Fixed places format</u>
1	AREA	1
2	% ERROR	3
3	PEAK CENTER	3
4	FWHM	3
5	PRESET TIME	1
6	TRUE TIME	1
7	% DEADTIME	2
8	CPS INTEG	3

	Touch <u>MENU EXIT</u>	
	Set CONTROL/STATUS key switch to	ON LINE (Observe ON LINE LED on.)

2.4 CANBERRA SERIES 90 X-AXIS ENERGY CALIBRATION

If the soft keys have been designated (paragraph 2.3) and x-axis (energy) calibration has been chosen as one of the soft keys, this feature may be used to calibrate the Canberra 90 display. Assuming the normal display on the touch screen, implement x-axis calibration as follows:

Equipment	Control	Position
Choosing appropriate calibration peaks	<p>-----</p> <p>NOTE: The usual choices are the plutonium-238 peaks at 152.7 keV and 766.4 keV.</p> <p>-----</p> <p>Place selected peaks in regions of interest (ROI) by positioning cursor window on peak and pressing ENTER ROI key on console.</p> <p>Touch <u>X-AXIS CALIB.</u> soft key to obtain options.</p> <p>Touch <u>COMPUTE COEFFS</u> to get next set of options.</p>	
Entering energy value for each calibration peak	<p>Press INDEX RIGHT key until cursors are on first calibration peak.</p> <p>Touch <u>PEAK</u>; observe that display shows channel position of peak and asks for its energy.</p> <p>Type energy value using console numeric keypad.</p> <p>Press STORE key.</p> <p>If value is correct, touch <u>ACCEPT</u>.</p> <p>Repeat above procedure for other calibration peaks.</p> <p>Touch <u>END</u> if gain and zero values appear to be correct.</p>	

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Fig. 3-1. Pu-238 isotopic analysis system sample cave. The control panel at the right is used to load/unload the sample by opening/closing the sample cave lid and raising/lowering the sample turntable. The count-rate meter indicates the detector count rate to advise the operator in positioning the detector.	3-4
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Chapter 3

SYSTEM OPERATION

3.1 STARTING INSTRUMENT CONTROL PROGRAM

The instrument control program, SRS_ASY238, starts automatically from a startup command file when the system is turned on. The startup command file will load and start the SRS_ASY238 program on the remote terminal.

If the SRS_ASY238 program has been aborted, restart it by logging onto the operator terminal under the SRS_ASY238 account to cause the startup command file to be executed and the SRS_ASY238 program to be started. When the program starts, you are automatically logged off of the SRS_ASY238 account.

When the SRS_ASY238 program is first started on the system, messages similar to the ones shown below will be typed on the remote operator terminal:

```
Reading PARMTR.IS8
PARMTR.IS8   was written 22-MAR-90  14:50:42 by WDR
Reading BACKGR.IS8
BACKGR.IS8   was written 09-NOV-84  15:25:51 by WDR
***** STATUS OF HARDWARE OKAY *****
06-JUN-90  16:30:06   Enter OPTION (H to see Menu) ->
```

At this point, the instrument is ready for action by typing the appropriate option (see Chapter 4 for available options). The Pu-238 isotopic analysis system is in an idle state whenever the previous message is being displayed on the terminal. The sample cave lid cannot be operated unless the SRS_ASY238 program is running or the computer is turned off.

3.2 HALTING INSTRUMENT CONTROL PROGRAM

The SRS_ASY238 program may be halted only by a supervisor using the operator terminal with the X option. This option requires a password and halts the execution of the program. Other programs or the system cannot be accessed from the operator terminal.

3.3 ABNORMAL HALTS

When power is restored after a power failure, the computer system will automatically reboot and start the instrument control program. Note that if the power failure occurs in the middle of data acquisition, the data will be lost and the system will not resume the measurement automatically.

If the system does not boot after a power failure, turn computer power off and on to force the computer to reboot. If this fails, consult a VAX systems operator: the system disk may have to be reloaded from the backup tape provided with the instrument.

Fig. 3-1. Pu-238 isotopic analysis system sample cave. The control box (right) is used to load/unload the sample by opening/closing the sample cave lid and raising/lowering the sample turntable. The count-rate meter indicates the detector count rate to advise the operator in positioning the detector

There may be other occasions when the instrument control program halts abnormally because of an error in a calculation, i.e., divide by zero, etc. In such cases, the instrument control program will have to be restarted as described above. Before restarting the program, try to determine the cause of the error. Check such counting parameters as the length of the count, etc. Were sufficient data collected? Was the sample loaded?

3.4 REMOTE OPERATOR TERMINAL

The remote Digital Equipment Corporation Letterwriter 100 is a slave terminal which allows the operator to interact with the instrument through dialog generated by the SRS_ASY238 program. It is not possible to interact with the computer system monitor from this terminal.

3.5 LOADING AND UNLOADING SAMPLES

A control panel at the right side of the sample cave above the detector provides control for loading and unloading samples and for monitoring the detector count rate for positioning of the detector (see Fig. 3-1). Spring-loaded illuminating pushbuttons on this panel have a dual purpose: to initiate selected actions (such as unloading a sample) and, when lit, to signal specific conditions (such as sample counting; system in use).

3.5.1 Loading Sample

Inside the sample cave is a Lucite guide which usually remains inside the cave, its conical opening serving to position the calorimeter canister containing the sample on the circular sample turntable. With the sample cave lid open and sample turntable ready for loading, load the sample as follows:

1. Read the sample bar code (or type the sample ID on the operator terminal) in preparation for assay.
2. Put the sample in the cave, using the Lucite guide to help position the calorimeter canister in the center of the turntable.
3. Simultaneously depress and hold the pushbuttons labeled LOAD. This causes the turntable to descend. As soon as it clears the top of the cave, the sample cave lid shuts. When the lid is fully closed, the LOAD pushbuttons are lit, denoting that the sample is loaded.
4. After loading the sample, check and adjust the detector count rates by positioning the detector as described in paragraph 3.6 (below).

3.5.2 Unloading Sample

The IN USE light is lit during an assay and remains lighted until the data are analyzed, during which time the sample cave lid motor is disabled. All lights but the LOAD lights go out at the end of the analysis, denoting that the sample is ready for unloading. To unload the sample, simultaneously depress and hold the pushbuttons labeled UNLOAD. The sample cave lid opens, and the turntable rises; when the lid is fully open, the sample is elevated about 8 in. The UNLOAD pushbuttons are lit, signalling that the sample can be removed.

3.6 POSITIONING DETECTOR

Correct assays depend on proper positioning of the detector whose associated count-rate meter is on the control panel. Detector position should be checked after the sample is loaded. The detector may be moved manually to obtain the optimum count rate. At an optimum rate, dead time on the analog-digital converter should be about 30% (should never exceed 40%); the needle on the count-rate meter should be in the green area. If the needle is in the yellow area, the count rate is too low and the detector should be moved closer to the sample. If it is in the red area, the count rate is too high and the detector should be moved away from the sample. To move the detector, release the detector table brake by raising the brake lever and manually push the detector in the appropriate direction. As the detector moves, its count rate changes. If the detector is already as close to the sample as possible, the analysis will have to be performed with a count rate that is less than ideal. If the detector is backed away from the sample as far as possible and the count rate is still too high, the analysis will have to be performed with a less-than-ideal count rate.

3.7 COUNTING TIME

Counting time is one of the default values read in from the PARMTR file when the program is loaded into memory. The counting time may be changed by the supervisor using the "D" option. It is specified in true clock seconds.

A calculated, recommended count duration is also determined at the beginning of a count by the count rate and a desired measurement precision of 1% for the Pu-238 relative abundance. At the end of a 60-second preliminary count, the operator is given the choice of continuing with the default count time or counting for the time determined by the preliminary count to achieve a 1% measurement precision on the Pu-238 relative abundance.

3.8 LIQUID-NITROGEN-LEVEL MONITOR

While the program is waiting for an option entry, it monitors the status of the liquid-nitrogen-level monitor for low liquid-nitrogen level. If such a condition occurs, the following message is printed on the terminal:

```
!!!WARNING!!!  
!!! Liquid nitrogen level low in detector dewar!!!
```

Press RETURN to continue.

Do not ignore these messages! Check the status of the liquid nitrogen in the detector dewar before pressing RETURN on the terminal.

3.9 Sample Rotation and Elevator Monitors

The sample rotation and motion up and down (elevator) are monitored during the course of a measurement. If for some reason the sample stops rotating or going up and down, a message is printed on the terminal to that effect along with the message

Press RETURN to retry (type A and a <CR> to ABORT).

Press RETURN to retry starting the system. If the message repeats, type A followed by a carriage return to abort the measurement. The next step should be to open the lid and check whether the sample elevator works in unloading the sample. Then reload the sample and check whether the sample rotation mechanism works. If they appear to be working, try restarting the count. If it fails again, consult an electronic technician.

CHAPTER 4

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Chapter 4

OPERATOR INTERACTIONS AND PROCEDURES

Presented in this chapter are the routine measurements and analyses that can be performed by choosing the appropriate option from the menu of the resident instrument-control and data-analysis program. There are basic measurement (routine) options and supervisor options, distinguished in that supervisor options require a password to be entered before they can be performed.

4.1 ROUTINE OPTIONS

The following dialog will be displayed on the operator terminal when the program is loaded and running in the computer system:

```
da-mon-yr hr:mn:sc Enter OPTION (H to menu) -> H
```

If H is typed as the menu option, the following listing is printed on the operator terminal:

```
A - Assay
MB - Measurement control - bias
MP - Measurement control - precision
```

Options during data acquisition

```
Q - Quit assay - no results
S - Suspend assay temporarily
T - Terminate assay with results
```

These basic measurement options are allowed on the Pu-238 isotopic analysis system without a password. Examples of operator-interactive dialogue for each of these options are presented on the following pages. In each example, the response typed by the operator follows the arrow.

In each of these sample assays the spectrum quality is checked in the analysis of the data. The resolution of the 766.4-keV peak is checked in all measurements and, if it exceeds 2.4 keV, a warning message is printed (See Chapter 7 on Instrument Diagnostic Messages) on the operator terminal. The channel positions of the 152.7- and 766.4-keV peaks are also checked in all measurements. If either the gain or zero-channel offset exceed certain values (See Chapter 7 on Instrument Diagnostic Messages), a message is printed on the operator terminal.

ROUTINE OPTIONS

Option	Description
<u>ASSAY (A)</u>	<p>This option is for routine sample assay. Default values for the counting time and analysis parameters are read in from the PARMTR file when the program is loaded. The default values may be changed using the "D" option (supervisory) described below.</p> <p>When the A option is selected, the program checks the measurement control file to determine the status of the last bias and precision measurements. If the time period since the last bias/precision measurements were performed exceeds the specified interval, the following messages are printed on the operator terminal:</p> <p>**** MEASUREMENT CONTROL BIAS RUN SHOULD BE MADE ****</p> <p>and/or</p> <p>**** MEASUREMENT CONTROL PRECISION RUN SHOULD BE MADE ****</p> <p>These messages indicate that the corresponding measurement has not been performed within a specified period of time. The period of time is contained in the PARMTR file and is specified or changed with the PU238_CHNG program described later in this manual. The assay results will be flagged to indicate that measurement control conditions have not been met on the instrument.</p> <p>If the last bias/precision measurements were outside acceptable limits, the following messages are printed on the operator terminal:</p> <p>**** LAST MEASUREMENT CONTROL BIAS RUN WAS OUT OF LIMIT ****</p> <p>and/or</p> <p>**** LAST MEASUREMENT CONTROL PRECISION RUN WAS OUT OF LIMIT ****</p> <p>In this case, the user is queried as to whether to proceed with the assay. The user may choose to proceed, but the assay results will be flagged to indicate that measurement-control conditions have not been met on the instrument.</p>

ROUTINE OPTIONS (CONTINUED)

Option	Description						
<u>ASSAY (A)</u> (CONTINUED)	<p>The following illustrates the operator dialog for the Assay (A) option:</p> <p>Enter operator ID (8 chars) or RETURN to escape -> WDR</p> <p>Enter sample barcode or enter sample ID (RETURN to escape) -> TEST</p> <p>When the sample is ready for assay, press RETURN PLEASE WAIT 60 SECONDS WHILE ASSAY CHECK IN PROGRESS...</p> <p>Before pressing the RETURN key to begin an assay, make sure that the sample has been loaded properly and the sample lid is closed. Pressing RETURN starts the ADC for a 60-second preliminary measurement to examine the detector count rate and the intensity of the Pu-238 152.7-keV gamma ray. Using this information, the program determines the approximate amount of time required to achieve 1% precision on the Pu-238 abundance.</p> <table><tr><td>To count for recommended</td><td>10000.0</td><td>secs type <Y> or</td></tr><tr><td>To count for default time</td><td>4000.0</td><td>secs type <N></td></tr></table> <p>and press RETURN -> Y</p> <p>The operator has the choice of counting for the recommended time by typing a Y or using the default time by typing an N.</p> <p>Starting a run of 10000. s at 10:46:04 (26-APR-90) Ends Today at 12:32</p> <p>The operator should ensure that the completion time message has been printed on the terminal before leaving the instrument.</p> <p>Once the measurement has started successfully, the IN USE light in the center of the control box will be lighted, indicating that the system is counting. At this point the sample cannot be removed from the cave unless the measurement is aborted with the "Q" option.</p> <p>If the sample cave lid is not closed before RETURN is pressed to begin an assay, the following message will appear on the terminal:</p> <p>ERROR -- Problem with LID closing or Position switches Press RETURN to retry (type A<CR> to ABORT)</p>	To count for recommended	10000.0	secs type <Y> or	To count for default time	4000.0	secs type <N>
To count for recommended	10000.0	secs type <Y> or					
To count for default time	4000.0	secs type <N>					

ROUTINE OPTIONS (CONTINUED)

Option	Description
	Verify that the sample cave lid is closed and press RETURN to retry. If the message persists when the sample cave lid is closed, this may indicate a failure in the lid-closed detection switch. It may also indicate that the sensor cable between the equipment rack and the control panel is disconnected. Consult a supervisor in this situation.
	The following message will appear on the terminal if the sample stops rotating during the measurement:
	<p>SAMPLE NOT ROTATING. MEASUREMENT SUSPENDED AT HR:MN:SC To resume, press RETURN (press A to ABORT)</p>
	The measurement will not continue until the RETURN key is pressed. When RETURN is pressed, the following message will appear.
	Acquisition resumed at HR:MN:SC
	Once the RETURN key is pressed, the measurement resumes and stops when the specified number of clock seconds have elapsed on the analyzer. Note that the estimated completion time for the measurement is no longer correct. The only reason for the sample to stop rotating during an assay is failure in the rotation mechanism. Possible failures are the fuse in the rotation motor circuit, rotation motor power, and the rotation sensor (see UCRL-CR-103923, Vol. 2, para. 4.5). Similar messages will appear, if the sample elevator stops moving the sample up and down during the measurement. The same comments apply to the causes and possible fixes.
	The spectrum is acquired in the Group #1 region of the Canberra Series 90 analyzer at 0.25 keV/channel. When the ADC times out, the spectral data in the analyzer will be automatically dumped to disk, and the following messages will appear on the terminal:
	4096 channels starting at channel # 0
	Spectrum retrieval completed -- 34 blocks written to CURDTA.IS8
	These messages indicate the successful transfer of the data from the analyzer to the disk. The data filename is CURDTA if the "write data to disk" flag is set to FALSE. The "write data to disk" flag is set to FALSE when the program is loaded. It may be changed under the supervisory "D" option. Although the data have

ROUTINE OPTIONS (CONTINUED)

Option	Description
	been written to disk, they will be stored on disk only until the next assay is performed. If the "write data to disk" option is set to TRUE, the data filename would be the same as the sample ID (e.g., TEST in this case).
<u>MEASUREMENT CONTROL -</u> <u>BIAS (MB)</u>	This option is used to measure the specific power output of a standard sample and to check the results (decay-corrected to 1/1/1990) against the reference value (specific power) stored in the PARMTR file. [The reference value for the specific power of the standard should be determined with the measurement-precision (MP) option.] This measurement must be performed at regular intervals. The permissible time period between bias measurements is also stored in the PARMTR file and can be changed by the supervisor using the PU238_CHNG program. The following illustrates the operator dialog for the "MB" option:

Enter operator ID (8 chars) or RETURN to escape -> WDR

Enter sample bar code or enter sample ID
(RETURN to escape) -> TEST

When the sample is ready for assay,
press RETURN ->

PLEASE WAIT 60 SECONDS WHILE ASSAY CHECK IN PROGRESS...

Starting a run of 2000. s at 10:46:04 (26-APR-90) Ends Today
at 11:19

The same comments about loading the sample and positioning the detector for the assay option apply here. Before pressing RETURN to start the assay, make sure that the sample is loaded and the detector is positioned properly. Wait 60 seconds for the preliminary assay to finish, and verify that the actual assay starts. Sample rotation and scanning are monitored during data acquisition; acquisition is suspended if either stop. After acquisition is completed, the spectral data are dumped to disk and analyzed. Results of the analysis are printed out (see printout formats). At the end of the printout, the following information is printed:

Current value = 478.86
Reference value = 479.30
Difference = 0.44

***** STATUS OF HARDWARE OKAY *****

ROUTINE OPTIONS (CONTINUED)

Option	Description
<u>MEASUREMENT CONTROL -</u> <u>BIAS (MB)</u> (CONTINUED)	<p>If the difference is greater than 1.96 times the standard deviation on the reference value (the standard deviation is stored along with the reference value in the PARMTR file), the following message appears on the terminal:</p> <p>BIAS CHECK WARNING LIMITS EXCEEDED</p> <p>If the difference is greater than 3.00 times the standard deviation on the reference value, the following messages are printed on the terminal:</p> <p>BIAS CHECK ACTION LIMITS EXCEEDED</p> <p>Do you want to repeat bias check? (Y/N) -></p> <p>If this condition occurs, the user is given the option of repeating the measurement. If the measurement is not repeated or is repeated but does not satisfy conditions, the bias results are stored in the measurement-control results file MCLOGF and are flagged indicating that they exceeded the bias check limits. All further assay results are flagged, to indicate a problem with the system, until the bias measurement is repeated and measurement conditions are satisfied. In addition, at the beginning of each assay, a warning message appears on the terminal, as described earlier.</p> <p>If all measurement control conditions are met, the bias results are stored in the measurement-control results file MCLOGF, and the flags are set to indicate that the instrument has passed the bias check.</p> <p>If a bias measurement fails, then the system and results must be examined to determine the cause of failure. This should be done even if a second bias measurement passes the statistical tests. One possible cause for failure is using the wrong standard for the measurement. Another is that the bias measurement was not long enough. The difference between the measured value and reference value is compared against a "standard deviation" on the reference value that is dependent on the length of the count used to determine the reference value. Finally, failure to meet the bias-check requirements may be due to a hardware failure in the detector or the electronics.</p>

ROUTINE OPTIONS (CONTINUED)

Option	Description
<u>MEASUREMENT CONTROL -</u> <u>PRECISION (MP)</u>	This option automatically makes a series of 5 or 15 measurements (as determined by the value of MCRUNS set in the PARMTR file). A precision check on the specific power results of these measurements is then made to determine whether they are in statistical agreement. The operator dialog is the same as for the bias measurement option described above.

At the end of the 5 or 15 runs, the following information appears on the terminal:

```

Average result =          2.6058
Mean Sq sigma  =          0.0438
Standard deviation =       0.2366
Chi-square =          1.2774
*** STATUS OF HARDWARE OKAY ***
  
```

"Average result" is the average of the specific power results for the sample from the 5 or 15 measurements. "Mean Sq sigma" is the mean of the sigmas quoted on the specific power results squared. "Standard deviation" is derived from the specific power results of the 5 or 15 runs. "Chi-square" is determined by dividing the square of the standard deviation by the Mean Sq sigma.

If Chi-square is below or above the specific limits shown below, a warning message will appear on the terminal as follows:

PRECISION CHECK WARNING LIMITS EXCEEDED

or

PRECISION CHECK ACTION LIMITS EXCEEDED

These chi-square limits have the following values:

	CHI-SQUARE LIMITS			
	<u>Warning</u>		<u>Action</u>	
	<u>5 runs</u>	<u>15 runs</u>	<u>5 runs</u>	<u>15 runs</u>
LOWER	0.12	0.40	0.05	0.29
HIGHER	2.79	1.87	3.72	2.24

If "Chi-square" is less than the appropriate lower warning limits or greater than the appropriate high warning limits, a corresponding message will appear on the terminal. If Chi-square does not fall within the

ROUTINE OPTIONS (CONTINUED)

Option	Description
<u>MEASUREMENT CONTROL -</u> <u>PRECISION (MP)</u> (CONTINUED)	appropriate action limits, the following query will appear on the terminal: Do you want to repeat the precision check? (Y/N) -> If the precision check is not repeated or fails the second time, the results will be flagged in the measurement-control results file and will continue to be flagged until the system successfully passes the precision check. If the system fails the precision check, a message warning the user of that condition will appear on the terminal, as described earlier, at the beginning of each assay. Even if the system passes the precision check on its second test, the user should determine the cause of the initial failure to meet test conditions. There is always a chance that the test failed due to a statistical fluctuation. However, the failure might also be due to an intermittent failure in the detector or the electronics. For example, an intermittent ground loop will cause the detector resolution to vary, producing variations in the results that are outside the allowable statistical limits.

4.2 OPTIONS AVAILABLE DURING DATA ACQUISITION

The following options are available to the operator during data acquisition:

Option	Description
<u>QUIT (Q)</u>	The quit option is available during data acquisition. If Q is pressed on the operator terminal during data acquisition, the acquisition is aborted, and the system is ready for a new option. The data accumulated in the analyzer are not analyzed.
<u>TERMINATE (T)</u>	The terminate option is available during data acquisition. Pressing T on the operator terminal during data acquisition also stops the acquisition (same effect as the Q option), but data accumulated in the analyzer are analyzed. Once analysis is completed, the system is ready for a new option. The T option is ignored during the measurement bias (MB) and precision (MP) control options. Under these options, only the Q option may be used to terminate a measurement.
<u>SUSPEND (S)</u>	<p>The suspend option is also available during data acquisition. It causes suspension of the data acquisition and then causes the following message to appear on the terminal:</p> <p>Acquisition suspended by S key at HR:MN:SC</p> <p>When ready to resume, press RETURN -></p> <p>Pressing RETURN on the operator terminal causes the data acquisition to be resumed and the following message to appear on the terminal:</p> <p>Acquisition resumed at HR:MN:SC</p> <p>Each of these three options may be used only during data acquisition. They will be ignored at any other time.</p>

4.3 SUPERVISOR OPTIONS

Supervisor options require a password before they can be performed. The passwords are created and changed with the PU238_CHNG program. For a listing of options requiring a password, type HS as the menu option. The HS option requires a password to get the following listing on the operator terminal:

- A - Assay
- MB - Measurement control - bias
- MP - Measurement control - precision

Options during data acquisition

- Q - Quit assay - no results
- S - Suspend assay temporarily
- T - Terminate assay with results

SUPERVISOR OPTIONS

- AC - Assay current data in MCA
- AD - Assay data from disk
- AU - Autocycle
- AUD - Autocycle from disk
- D - Default
- LA - List assay
- LM - List measurement control log
- OU - Change output listing device
- ST - Status
- R - Read data from disk
- W - Write data to disk
- X - Exit from program

Examples of operator-interactive dialog for the supervisor options are presented on the following pages. In each example, the response typed by the operator follows the arrow.

SUPERVISOR OPTIONS

Option	Description
--------	-------------

ASSAY CURRENT
DATA IN MCA (AC)

This option analyzes the data currently stored in the analyzer. The data may have been accumulated automatically by a previous assay or accumulated manually. The operator dialog is as follows:

You have selected a supervisory option which requires a password.

Enter password ->

Enter operator ID (8 chars) or RETURN to escape -> WDR

Note that, to prevent unauthorized use of passwords, the password is not echoed on the terminal. When RETURN is pressed, the following messages appear on the terminal:

4096 channels starting at channel # 0

Spectrum retrieval completed -- 34 blocks written to CURDTA.IS8

Also note that the spectral filename is CURDTA and that this is only a temporary file. If the "write data to disk" flag had been set to TRUE, the dialog with the operator would have queried for the filename with the statement:

Enter the full filename [FILENM.EXT] TEST.IS8

In this case, the spectral data file would have the filename TEST.IS8. The spectral data file would be permanent.

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>ASSAY DATA FROM DISK (AD)</u>	This option allows the operator to repeat an analysis by recalling a previously stored spectrum from disk. The operator dialog is as follows:

You have selected a supervisory option which requires a password.

Enter password ->

Assay from disk

Enter operator ID (8 chars) or RETURN to escape -> WDR

Enter the full filename [FILENM.EXT] -> TEST.IS8

The program reads the spectral data file, and the analysis proceeds.

<u>AUTOCYCLE (AU)</u>	This option allows the operator to make a series of replicate measurements. The dialog is as follows:
-----------------------	---

You have selected a supervisory option which requires a password.

Enter password ->

Enter operator ID (8 chars) or RETURN to escape -> WDR

Enter sample bar code or enter sample ID
(RETURN to escape) -> TEST

Enter number of cycles -> 5

When sample is ready, press RETURN ->

The program automatically performs the number of measurements indicated by the number of cycles entered. The counting time for each measurement will be the counting time set under the Default (D) option. The spectral filenames will be CURDTA if the "write to disk" flag is FALSE. The filename extensions will be I01, I02, etc. If the "write to disk" flag is TRUE, the filenames will be the sample ID with the extensions described above. At the end of the requested number of measurements, an average of the specific power results will appear together with its standard deviation.

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>AUTOCYCLE FROM DISK (AUD)</u>	This option is similar to the AU option except that the spectra analyzed have been stored previously on disk. The dialog is similar except that the spectrum filename must be given. The option expects a sequence of files on the disk with the appropriate extensions.
<u>DEFAULT (D)</u>	This option allows the operator to change memory resident default flags or values used in controlling the instrument or analyzing the data. If these values are changed, they are used for all subsequent runs until the program is reloaded. The default values are stored in the PARMTR file and are read into memory when the Pu-238 isotopic assay program is loaded. To change the default values stored in the PARMTR file, use the PU238_CHNG program. The operator dialog to change memory resident values is as follows:

You have selected a supervisory option which requires a password.

Enter password ->

1. Long printout = F
2. Write data to disk = F
3. Preset assay time = 1000.
4. Pu-240 abundance (Wt.%) = 2.0000
5. Pu-242 abundance (Wt.%) = 0.1000
6. Constants file = PARMTR.IS8

Enter number (1-6) to change (RETURN for no change) -> 1

Enter a number that corresponds to the value to be changed. A flag value can be changed automatically by typing its corresponding number. If the remaining default values are to be changed, a new value must be entered. For example, the dialogue to change the plutonium-240 abundance value is as follows:

Enter number (1-6) to change (RETURN for no change) -> 4

Enter Pu-240 abundance (Wt.%) (0=1.97, -1=Calc.) -> .3

Enter number (1-6) to change (RETURN for no change) ->

The plutonium-240 abundance cannot be determined by gamma-ray spectrometry for samples enriched in plutonium-238. Either a default value must be used, or it may be calculated using an algorithm that is based on the plutonium-239 and -241 abundances. As the query states, a negative entry causes the program

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>DEFAULT (D)</u> (CONTINUED)	<p>to calculate the plutonium-240 abundance. An entry of 0. causes the program to use a default value of 1.97. The default value for Pu-242 is 0.1, if 0 is entered for the Pu-242 abundance. The Pu-242 abundance cannot be calculated.</p> <p>When all the changes have been made, press RETURN in response to the "Enter number" query. This causes the program to reprint all the default values, allowing the user to verify their correctness. At the end of the new listing of default values, the following query will appear on the terminal:</p> <p>OK? (Y/N) -> Y</p> <p>Respond with a Y if everything is correct. Otherwise, respond with an N and make the necessary changes.</p>
<u>LIST ASSAY LOG (LA)</u>	<p>This option causes information stored in the assay log file to be printed on the operator terminal. The four options for listing the contents of the assay log file are given in the operator dialog that follows:</p>

You have selected a supervisory option that requires a password.

Enter password ->

Menu of options for Listing Assay Log

0. Return to main menu
1. List entries with specified sample ID
2. List entries between two dates
3. List all entries
4. List n entries

Enter option number -> 2

Enter start date (most recent) [09-AUG-84] -> 5-MAY-90

Enter stop date (oldest) [02-AUG-84] -> 1-MAR-90

Option 2 selected here causes a printout of the entries in the assay log file that fall between the dates entered. The listing has the following format:

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>LIST ASSAY LOG (LA)</u>	
(CONTINUED)	

Assay log as of 6-MAY-90 10:55:15

Entry Date	Time	Sample ID	Operator	File	Cycles	Results	240 Flg	Err Flg
1.2-MAY-90	10:30	TEST	WDR	TEST.IS8	1/1	4.715E+02	F	F
%238= 83.0222 %239=14.7136 %240= 1.9670 %241=0.2971 %242=0.1000 %Am= 0.1977								
Specific power = 4.715E+02								
2.3-MAY-90	9:20	MOX	WDR	MOX.I01	2/2	4.726E+02	F	F
%238= 83.1232 %239=14.6349 %240= 1.9670 %241=0.2749 %242=0.1000 %Am= 0.2122								
Specific power = 4.726E+02								

The assay log file contains 99 entries, the most recent being first. If the option to list a selected number of entries is chosen, the listing starts with the most recent entry and gets consecutively older.

The first option lists entries with the specified ID. If this option is selected, then the operator is queried for the sample ID. The third (list all) option lists all 99 entries if the file is full. Note that this takes considerable time with the DEC Letterwriter 100 terminal.

The 240 Flg column indicates whether the Pu-240 abundance was entered or calculated. If the flag is set to TRUE, it was calculated. The Err Flg indicates that the system had failed the last measurement control check.

LIST MEASUREMENT
CONTROL LOG (LM)

This option prints the contents of the measurement control log file. The options and the dialog are the same as in the List Assay log (LA) option. The format of the listing is as follows:

Measurement control log as 05-MAY-90 12:40:13

Ent Date	Time	Operator	Ty	Result	Fractional Error	Standard Value	No Run	VX Fg	Er Fg
1 14-APR	12:07	WDR	MP	1.30840E+00	7.947E-05	6.074071E-05	5	F	F
2 15-APR	14:10	WDR	MB	4.78000E+02	1.000E-02	4.788600E+02	1	F	F

The values for the result, fractional error, and standard value take on a different meaning when precision measurement results are listed. In that case, the result value is the reduced chi-square, the frac-

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>LIST MEASUREMENT</u> <u>CONTROL LOG (LM)</u> (CONTINUED)	<p>tional error value is the measured variance, and the standard value is the calculated variance.</p> <p>The VX Fg indicates in perviously implemented systems that the value has been sent to the ICC VAX (this feature is <u>not</u> implemented on the Pu-238 system). The Er Fg indicates whether the precision or bias check met its limits. An F indicates that it passed and a T indicates that it failed.</p> <p>The third (list all) option lists all 99 entries if the file is full. Note that this takes considerable time with the DEC Letterwriter 100 terminal.</p>
<u>CHANGE OUTPUT</u> <u>LISTING DEVICE (OU)</u>	<p>This option allows the operator to direct the output to a line printer rather than the operator terminal. The dialogue is as follows:</p>

You have entered a supervisory option which require a password.

Enter password ->

Enter 6 for line printer, 5 for terminal ->

This option is not normally used unless a line printer has been connected to the computer system.

STATUS (ST) This option checks the status of the system hardware. If the system is not busy, these messages will appear on the terminal:

**** HARDWARE BUSY CHECKED ****

**** STATUS OF HARDWARE OKAY ****

If the Series 90 is busy, the following messages will appear on the terminal:

**** !! SERIES 90 BUSY !! MANUAL USE?? ****

Press RETURN to retry (type A<CR> to ABORT) ->

The Series 90 can be busy only if set to acquire manually. If so, it must be stopped manually before the instrument can proceed with an assay.

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>READ DATA FROM DISK (R)</u>	<p>This option is used to read a spectrum from disk and send it to the Canberra Series 90 analyzer for display. The operator dialog is as follows:</p> <p>You have entered a supervisory option which requires a password.</p> <p>Enter password -></p> <p>Enter full filename [FILENM.EXT] -> TEST.IS8</p>
<u>WRITE DATA TO DISK (W)</u>	<p>This option is used to store a spectrum on disk that has been acquired by analyzer. The dialog is as follows:</p> <p>You have entered a supervisory option which requires a password.</p> <p>Enter password -></p> <p>Enter full filename [FILENM.EXT] -> TEST.DAT</p>
<u>EXIT FROM PROGRAM (X)</u>	<p>This option is used to exit from the SRS_ASY238 program. However, the system monitor is not available on the remote operator terminal.</p>

CHAPTER 5

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Chapter 5

OUTPUT FORMAT

Short and long printouts of the analysis results are available and can be selected with the default options described earlier.

5.1 SHORT PRINTOUT

The short printout does not show the analysis results for the individual peaks or the channel-by-channel results of the fit to the data in the 375- and 414-keV regions of the spectra. The following is an example of the short printout for a precision measurement, which is in addition to the summary printout that occurs in each assay:

QFIT = 1.44

ISOTOPIC ANALYSIS AT ZERO TIME (1/1/90)

RATIOS	WT.PCT.	PCTERR	Milliwatts/(gm total Pu)
Pu238 = 6.1259866	83.84494	0.75	475.535
Pu239 = 1.0000000	13.69081	4.05	0.264
Pu240 Operator input value	1.96700		0.140
Pu241 = 0.0363306	0.39725	7.00	0.016
Pu242 Operator input value	0.10000		0.000
Am241 = 0.0043316	0.05929	71.69	0.068
			TOTAL = 476.024 +/-0.94%

The reduced chi-square or "QFIT" is shown on the first line of the printout. It is calculated for each analysis as an indication of the quality of the least-squares fit. An ideal value of 1.0 is rarely obtainable, but values below 8.0 are reasonable. The value of QFIT depends on the total counts accumulated.

The isotopic weight percent values are given for the count time except for the bias and precision measurements, where results are decayed to a zero time of 1/1/1990, and the specific power is calculated for that date. This is done to remove any decay effects from the bias measurement when the results are compared to a standard value.

Following this portion of the printout is a general summary of the measurement, as shown by the following example:

Pu-238 isotopic gamma assay - Run Type: MC PRECN

Sample ID:	TEST	Current Date:	22-MAY-90	16:10:12
Operator ID:	WDR			
Constants File:	PARMTR.IS8	Constants Date:	2-MAY-90	09:11:15
Live time (sec):	19871.	Clock time (sec):	20000.	

Result = 476.024 +/- 0.9%

5.2 LONG PRINTOUT

Following this listing is a listing of the peak energies, areas, and their relative weights used in the fitting process. This information is used only for diagnostic purposes and is not required for normal analyses.

The long printout (shown in Fig. 5-1) also includes a channel-by-channel listing of the results of the fit to the 375- and 414-keV regions.

Analysis on 25-FEB-91 at 08:24:53 of

Spectral data file: SN1206.IS8

Parameter control file: PU238.CTL

Group 1 includes 199.7 to 201.9 keV

Recalibrate Gain using energy standards at 152.680 and 766.410 keV

CALIB searching 58 chans from 581 for 152.7 keV peak

CALIB searching 82 chans from 3025 for 766.4 keV peak

St-Ch	Energy	End energy	start	Refen	Zero	Gain
801	199.7000	201.9000	800.9792	200.8320	-0.8628	0.2504

By simple integration of region: 801 to 810

Peak chan = 806.71; Net counts = 4000. +- 11.04%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	806.706	201.134	4000.	5.5462E+03	11.118

Group 2 includes 205.7 to 210.3 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
825	205.7000	210.3000	824.9412	207.9683	-0.8628	0.2504

Results from group 2 (4 iterations)

QFIT 0.791; FWHM 1.29414+/- 0.0056; KEV/CHANNEL 0.25040, ZERO -0.863

EXP1 0.48285+/- 0.0000 EXP2 1.50000+/- 0.0000

NQFIT 0.983 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/- 0.0000

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	834.164	208.009	0.015	18280.	2.1866E+04	2.510	0.000
2	839.356	209.309		20.	2.3330E+01	1881.658	1.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
825	205.715	1	46.65	79.08	29.55	0.35
826	205.965	2	-79.28	-46.70	-105.36	-1.28
827	206.216	3	-2.49	30.09	-69.90	-0.84
828	206.466	4	231.13	263.28	75.62	0.90
829	206.716	5	343.78	375.31	25.25	0.30
830	206.967	6	661.97	692.28	2.47	0.03
831	207.217	7	1136.82	1165.04	-99.05	-1.10
832	207.468	8	2120.23	2144.56	92.24	0.97

Fig. 5-1 Example of long printout showing the individual gamma-ray analyses and the final analysis for the plutonium relative isotopic abundances.

833	207.718	9	2705.85	2725.21	-30.72	-0.31
834	207.968	10	3147.50	3161.08	54.50	0.54
835	208.219	11	2772.54	2781.03	-103.49	-1.05
836	208.469	12	2283.49	2287.79	75.45	0.79
837	208.719	13	1368.19	1369.98	-0.69	-0.01
838	208.970	14	642.25	642.86	-48.97	-0.56
839	209.220	15	299.02	299.08	8.63	0.10
840	209.471	16	202.20	201.89	94.18	1.12
841	209.721	17	17.73	17.39	-10.84	-0.13
842	209.971	18	-54.25	-54.49	-56.91	-0.69
843	210.222	19	-132.10	-132.10	-121.37	-1.47

Group 3 includes 236.0 to 243.5 keV

Recalibrate Gain using energy standards at 152.680 and 766.400 keV

CALIB searching 49 chans from 589 for 152.7 keV peak

CALIB searching 75 chans from 3027 for 766.4 keV peak

St-Ch	Energy	End energy	start	Refen	Zero	Gain
946	236.0000	243.5000	945.9893	239.7586	-0.8705	0.2504

Results from group 3 (3 iterations)

QFIT 1.359; FWHM 1.41153+/- 0.0029; KEV/CHANNEL 0.25039, ZERO -0.870

EXP1 0.50643+/- 0.0000 EXP2 1.50000+/- 0.0000

NQFIT 1.037 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/- 0.0000

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	956.325	238.588	0.010	24474.	1.7724E+04	2.100	0.000
2	965.734	240.944		1703.	1.1958E+03	16.108	1.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
946	236.003	1	106.45	133.78	87.03	1.09
947	236.253	2	96.00	123.23	60.34	0.76
948	236.503	3	149.27	176.34	82.08	1.03
949	236.754	4	138.25	165.17	20.50	0.26
950	237.004	5	443.95	470.39	195.65	2.39
951	237.255	6	533.36	559.23	54.79	0.66
952	237.505	7	952.48	977.34	23.31	0.27
953	237.755	8	1693.32	1716.37	48.10	0.54
954	238.006	9	2381.87	2402.37	-141.32	-1.52
955	238.256	10	3296.13	3313.12	-62.21	-0.64
956	238.507	11	3902.11	3914.93	82.24	0.82
957	238.757	12	3734.80	3743.63	33.90	0.34
958	239.007	13	3104.20	3109.73	71.83	0.74
959	239.258	14	2013.32	2016.69	-69.20	-0.76
960	239.508	15	1213.15	1215.23	-12.88	-0.15
961	239.759	16	559.70	561.18	-70.22	-0.85
962	240.009	17	426.96	427.98	87.16	1.07
963	240.259	18	221.93	222.72	-11.00	-0.14
964	240.510	19	240.62	241.15	3.41	0.04

Fig. 5-1 (continued).

965	240.760	20	322.02	322.21	54.84	0.68
966	241.011	21	160.14	160.15	-98.73	-1.23
967	241.261	22	328.97	328.63	88.37	1.09
968	241.511	23	98.51	98.07	-68.48	-0.86
969	241.762	24	130.76	130.18	21.47	0.27
970	242.012	25	136.73	136.01	74.01	0.93
971	242.263	26	-110.58	-111.19	-123.68	-1.58
972	242.513	27	-136.19	-136.65	-132.14	-1.69
973	242.763	28	-172.07	-172.35	-157.82	-2.02
974	243.014	29	-113.25	-113.41	-103.83	-1.32
975	243.264	30	37.29	37.09	34.20	0.43
976	243.515	31	-185.46	-185.46	-166.69	-2.14

Group 4 includes 365.5 to 384.7 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
1463	365.5000	384.7000	1463.1733	375.0968	-0.8705	0.2504

Results from group 4 (4 iterations)

QFIT 1.321; FWHM 1.56543+/- 0.0049; KEV/CHANNEL 0.25039, ZERO -0.870

EXP1 0.62042+/- 0.0000 EXP2 1.50000+/- 0.0000

NQFIT 1.117 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/- 0.0000

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	1469.393	367.057		714.	2.0037E+02	43.163	1.632
2	1475.368	368.553		918.	2.5610E+02	26.453	1.000
3	1484.905	370.941		563.	1.5532E+02	41.165	1.000
4	1501.311	375.049	0.024	10871.	2.9513E+03	3.596	1.000
5	1507.513	376.602		213.	5.7334E+01	150.576	1.000
6	1521.774	380.173		3053.	8.1216E+02	10.641	1.710
7	1532.094	382.757		2557.	6.7335E+02	13.313	1.945

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
1463	365.457	1	-34.49	-30.83	-38.35	-0.58
1464	365.707	2	126.33	129.98	104.09	1.55
1465	365.957	3	92.20	95.83	58.98	0.88
1466	366.208	4	-123.97	-120.32	-157.65	-2.41
1467	366.458	5	73.73	77.36	1.16	0.02
1468	366.709	6	45.82	49.45	-45.66	-0.69
1469	366.959	7	264.48	268.05	144.06	2.11
1470	367.209	8	67.32	70.88	-48.88	-0.73
1471	367.460	9	93.76	97.30	-26.96	-0.40
1472	367.710	10	175.09	178.60	46.79	0.69
1473	367.961	11	88.38	91.87	-39.72	-0.59
1474	368.211	12	218.03	221.48	75.56	1.11
1475	368.461	13	35.24	38.69	-97.09	-1.46
1476	368.712	14	113.61	117.03	-15.76	-0.23
1477	368.962	15	113.63	117.03	3.46	0.05

Fig. 5-1 (continued).

1478	369.213	16	100.54	103.92	16.40	0.24
1479	369.463	17	186.06	189.40	119.22	1.76
1480	369.713	18	37.06	40.40	-6.78	-0.10
1481	369.964	19	41.89	45.22	-0.45	-0.01
1482	370.214	20	160.75	164.05	102.88	1.53
1483	370.465	21	47.66	50.95	-15.49	-0.23
1484	370.715	22	48.66	51.94	-24.88	-0.37
1485	370.965	23	136.40	139.66	53.75	0.80
1486	371.216	24	70.33	73.57	-2.89	-0.04
1487	371.466	25	80.81	84.04	19.55	0.29
1488	371.716	26	-81.93	-78.69	-115.79	-1.76
1489	371.967	27	-71.91	-68.66	-94.54	-1.44
1490	372.217	28	1.81	5.06	-19.98	-0.30
1491	372.468	29	21.31	24.56	-1.05	-0.02
1492	372.718	30	12.91	16.16	-15.18	-0.23
1493	372.968	31	18.52	21.76	-25.71	-0.39
1494	373.219	32	13.14	16.38	-63.88	-0.96
1495	373.469	33	147.83	151.05	-3.75	-0.06
1496	373.720	34	294.85	298.01	12.01	0.18
1497	373.970	35	434.22	437.30	-55.73	-0.80
1498	374.220	36	798.73	801.65	11.46	0.16
1499	374.471	37	985.75	988.49	-120.87	-1.65
1500	374.721	38	1422.88	1425.35	26.11	0.34
1501	374.972	39	1749.25	1751.37	197.90	2.53
1502	375.222	40	1465.94	1467.79	-27.89	-0.36
1503	375.472	41	1232.38	1234.00	-35.75	-0.48
1504	375.723	42	882.03	883.47	-56.45	-0.78
1505	375.973	43	598.46	599.79	-14.60	-0.21
1506	376.224	44	379.76	381.02	22.07	0.32
1507	376.474	45	77.79	79.04	-104.33	-1.56
1508	376.724	46	149.93	151.14	49.60	0.74
1509	376.975	47	124.43	125.62	68.50	1.02
1510	377.225	48	14.82	16.01	-13.63	-0.21
1511	377.476	49	32.45	33.63	13.03	0.20
1512	377.726	50	33.22	34.39	18.27	0.27
1513	377.976	51	109.61	110.77	89.98	1.34
1514	378.227	52	19.89	21.04	0.92	0.01
1515	378.477	53	-96.51	-95.35	-118.45	-1.81
1516	378.728	54	48.32	49.48	-11.42	-0.17
1517	378.978	55	114.89	116.03	5.48	0.08
1518	379.228	56	132.14	133.25	-46.30	-0.69
1519	379.479	57	295.86	296.92	22.65	0.33
1520	379.729	58	512.70	513.65	142.69	2.04
1521	379.979	59	400.38	401.26	-18.63	-0.27
1522	380.230	60	276.11	276.94	-148.53	-2.17
1523	380.480	61	396.81	397.56	0.55	0.01
1524	380.731	62	285.58	286.28	-30.52	-0.45
1525	380.981	63	294.50	295.14	58.94	0.86
1526	381.231	64	324.73	325.31	148.35	2.16

Fig. 5-1 (continued).

1527	381.482	65	182.04	182.58	38.67	0.57
1528	381.732	66	317.28	317.76	147.58	2.15
1529	381.983	67	219.82	220.26	5.97	0.09
1530	382.233	68	336.50	336.88	51.02	0.74
1531	382.483	69	364.37	364.67	24.19	0.35
1532	382.734	70	271.69	271.95	-84.05	-1.23
1533	382.984	71	272.25	272.46	-64.79	-0.95
1534	383.235	72	146.78	146.96	-125.64	-1.87
1535	383.485	73	372.13	372.23	159.89	2.32
1536	383.735	74	150.49	150.57	23.51	0.35
1537	383.986	75	192.38	192.42	116.44	1.72
1538	384.236	76	-1.99	-1.95	-31.97	-0.48
1539	384.487	77	116.02	116.04	96.34	1.44
1540	384.737	78	86.75	86.75	76.87	1.15

Group 5 includes 411.0 to 417.3 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
1645	411.0000	417.3000	1644.8866	414.1583	-0.8705	0.2504

Results from group 5 (2 iterations)

QFIT 1.199; FWHM 1.57839+/- 0.0042; KEV/CHANNEL 0.25039, ZERO -0.870

EXP1 0.65786+/- 0.0000 EXP2 1.50000+/- 0.0000

NQFIT 1.036 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/- 0.0000

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	1655.623	413.688	0.020	11418.	2.6933E+03	3.050	0.000
2	1664.002	415.786		673.	1.5762E+02	44.474	1.567

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
1645	411.028	1	118.74	131.75	105.63	1.66
1646	411.279	2	78.56	91.49	58.75	0.93
1647	411.529	3	103.33	116.15	66.23	1.04
1648	411.780	4	116.23	128.93	48.39	0.76
1649	412.030	5	137.27	149.82	9.51	0.15
1650	412.280	6	324.07	336.28	75.41	1.16
1651	412.531	7	354.69	366.52	-79.16	-1.21
1652	412.781	8	687.65	698.75	-31.27	-0.46
1653	413.032	9	1085.33	1095.28	25.40	0.36
1654	413.282	10	1365.53	1374.03	-6.15	-0.08
1655	413.532	11	1568.52	1575.35	0.80	0.01
1656	413.783	12	1634.52	1639.61	42.63	0.57
1657	414.033	13	1423.98	1427.55	11.34	0.16
1658	414.284	14	1051.27	1053.73	-42.63	-0.60
1659	414.534	15	732.99	734.67	-16.90	-0.25
1660	414.784	16	426.39	427.62	-34.72	-0.53
1661	415.035	17	323.27	324.15	47.08	0.72

Fig. 5-1 (continued).

1662	415.285	18	295.66	296.23	116.33	1.79
1663	415.535	19	73.12	73.61	-50.70	-0.80
1664	415.786	20	131.97	132.33	23.05	0.36
1665	416.036	21	-34.57	-34.19	-118.19	-1.90
1666	416.287	22	51.58	51.91	-20.05	-0.32
1667	416.537	23	46.03	46.32	-4.84	-0.08
1668	416.787	24	227.14	227.18	183.62	2.85
1669	417.038	25	58.29	58.27	38.76	0.61
1670	417.288	26	-18.48	-18.48	-24.79	-0.40

Group 6 includes 580.1 to 586.6 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
2320	580.1000	586.6000	2320.2212	583.2998	-0.8705	0.2504

Results from group 6 (2 iterations)

QFIT 0.803; FWHM 1.71901+/- 0.0009; KEV/CHANNEL 0.25039, ZERO -0.870

EXP1 0.84785+/- 0.0000 EXP2 1.50000+/- 0.0000

NQFIT 0.995 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/- 0.0000

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	2332.263	583.115	0.006	86972.	1.3705E+04	1.422	0.000
2	2337.299	584.376		659.	1.0354E+02	84.334	1.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
2320	580.045	1	51.10	115.24	20.31	0.40
2321	580.295	2	37.27	101.39	-34.84	-0.68
2322	580.545	3	79.50	143.55	-61.55	-1.20
2323	580.796	4	247.06	310.9	-17.19	-0.32
2324	581.046	5	506.32	569.8	19.08	0.34
2325	581.297	6	868.60	931.4	-25.11	-0.43
2326	581.547	7	1612.68	1674.34	-7.16	0.11
2327	581.797	8	2827.95	2887.52	27.99	0.38
2328	582.048	9	4541.01	4597.21	44.99	0.53
2329	582.298	10	6468.00	6519.42	-109.34	-1.15
2330	582.549	11	8799.93	8844.84	64.70	0.61
2331	582.799	12	10312.14	10349.41	-74.49	-0.66
2332	583.049	13	11295.42	11324.33	121.99	1.04
2333	583.300	14	10802.49	10823.41	-53.41	-0.46
2334	583.550	15	9431.53	9445.47	2.59	0.02
2335	583.801	16	7290.84	7299.38	-3.97	-0.04
2336	584.051	17	5024.96	5029.78	-11.69	-0.13
2337	584.301	18	3042.16	3044.72	-64.90	-0.87
2338	584.552	19	1861.19	1862.38	125.50	1.89
2339	584.802	20	853.65	854.21	-12.65	-0.22
2340	585.053	21	307.58	307.91	-85.50	-1.60
2341	585.303	22	181.41	181.61	11.58	0.22
2342	585.553	23	105.91	106.03	35.99	0.70
2343	585.804	24	26.16	26.26	-0.11	0.00
2344	586.054	25	105.40	105.42	90.83	1.76
2345	586.305	26	-29.44	-29.40	-31.02	-0.62
2346	586.555	27	59.64	59.64	55.56	1.09

Fig. 5-1 (continued).

Group 7 includes 719.3 to 730.3 keV
 St-Ch Energy End energy start Refen Zero Gain
 2876 719.3000 730.3000 2876.1440 724.7726 -0.8705 0.2504

Results from group 7 (2 iterations)
 QFIT 1.076; FWHM 1.85558+/- 0.0013; KEV/CHANNEL 0.25039, ZERO -0.870
 EXP1 1.04829+/- 0.0000 EXP2 1.50000+/- 0.0000
 NQFIT 1.017 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/- 0.0000

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	2886.569	721.910	0.692	202.	2.5929E+01	77.987	0.000
2	2908.076	727.296	0.011	17930.	2.2869E+03	1.927	0.000
3	2916.838	729.490		0.	0.0000E+00	200.000	1.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
2876	719.264	1	-80.71	-80.39	-73.32	-2.10
2877	719.514	2	-61.07	-60.75	-56.67	-1.61
2878	719.765	3	-7.23	-6.91	-7.96	-0.22
2879	720.015	4	-49.36	-49.04	-47.74	-1.35
2880	720.266	5	-8.49	-8.17	-11.67	-0.32
2881	720.516	6	6.53	6.85	0.31	0.01
2882	720.766	7	-85.65	-85.33	-86.17	-2.47
2883	721.017	8	-9.88	-9.56	-22.94	-0.64
2884	721.267	9	36.22	36.54	17.15	0.47
2885	721.518	10	66.53	66.85	42.89	1.16
2886	721.768	11	17.80	18.11	-6.06	-0.17
2887	722.018	12	56.03	56.35	30.53	0.83
2888	722.269	13	75.42	75.74	50.90	1.37
2889	722.519	14	-55.49	-55.17	-69.14	-1.96
2890	722.769	15	34.49	34.81	18.28	0.50
2891	723.020	16	-29.46	-29.14	-39.41	-1.10
2892	723.270	17	-20.56	-20.24	-29.47	-0.82
2893	723.521	18	21.48	21.80	10.68	0.29
2894	723.771	19	-27.49	-27.18	-37.67	-1.05
2895	724.021	20	1.48	1.79	-14.69	-0.41
2896	724.272	21	-5.49	-5.18	-28.43	-0.79
2897	724.522	22	12.57	12.89	-22.91	-0.63
2898	724.773	23	68.83	69.15	11.19	0.30
2899	725.023	24	166.52	166.83	69.58	1.81
2900	725.273	25	131.38	131.69	-27.76	-0.73
2901	725.524	26	257.49	257.80	-15.65	-0.40
2902	725.774	27	446.46	446.76	-9.34	-0.22
2903	726.025	28	724.70	724.99	2.29	0.05
2904	726.275	29	1115.78	1116.04	46.98	0.95
2905	726.525	30	1413.73	1413.97	-34.88	-0.67
2906	726.776	31	1846.67	1846.88	40.56	0.72
2907	727.026	32	2013.25	2013.42	-31.48	-0.55
2908	727.277	33	2090.49	2090.63	-39.14	-0.67

Fig. 5-1 (continued).

2909	727.527	34	2045.82	2045.92	2.33	0.04
2910	727.777	35	1807.37	1807.44	32.99	0.59
2911	728.028	36	1416.20	1416.24	23.50	0.45
2912	728.278	37	962.72	962.74	-24.61	-0.52
2913	728.529	38	638.12	638.13	2.51	0.06
2914	728.779	39	382.93	382.93	12.68	0.31
2915	729.029	40	212.57	212.57	17.24	0.44
2916	729.280	41	55.32	55.32	-36.08	-0.98
2917	729.530	42	-36.60	-36.60	-71.84	-2.02
2918	729.781	43	33.41	33.41	17.17	0.47
2919	730.031	44	33.61	33.61	27.10	0.74
2920	730.281	45	-43.39	-43.39	-42.13	-1.19

Group 8 includes 739.8 to 745.5 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
2958	739.8000	745.5000	2958.0149	742.6758	-0.8705	0.2504

By simple integration of region: 2958 to 2981

Peak chan = 2969.99; Net counts = 82553. +- 0.55%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	2969.992	742.799	82553.	1.0336E+04	1.412

Group 9 includes 760.7 to 772.9 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
3041	760.7000	772.9000	3041.4834	766.7137	-0.8705	0.2504

By simple integration of region: 3041 to 3090

Peak chan = 3064.25; Net counts = 362903. +- 0.24%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	3064.248	766.400	362903.	4.4234E+04	1.323

Group 10 includes 782.0 to 790.0 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
3127	782.0000	790.0000	3126.5491	785.9941	-0.8705	0.2504

By simple integration of region: 3127 to 3158

Peak chan = 3143.58; Net counts = 55297. +- 0.73%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	3143.580	786.264	55297.	6.5969E+03	1.493

Fig. 5-1 (continued).

Group 11 includes 857.5 to 864.0 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
3428	857.5000	864.0000	3428.0732	860.7368	-0.8705	0.2504

By simple integration of region: 3428 to 3454

Peak chan = 3440.49; Net counts = 13258. +- 2.07%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	3440.485	860.608	13258.	1.4719E+03	2.444

Group 12 includes 660.4 to 664.7 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
2641	660.4000	664.7000	2640.9153	662.5496	-0.8705	0.2504

By simple integration of region: 2641 to 2658

Peak chan = 2644.00; Net counts = 1960. +- 12.97%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	2644.000	661.172	1960.	2.7280E+02	13.039

Group 13 includes 310.3 to 314.3 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
1243	310.2500	314.2500	1242.5215	312.2478	-0.8705	0.2504

By simple integration of region: 1243 to 1258

Peak chan = 1249.15; Net counts = 5044. +- 10.04%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	1249.152	311.910	5044.	1.8785E+03	10.124

Group 14 includes 150.5 to 154.7 keV

Recalibrate Gain using energy standards at 152.680 and 766.410 keV

CALIB searching 31 chans from 598 for 152.7 keV peak

CALIB searching 54 chans from 3037 for 766.4 keV peak

St-Ch	Energy	End energy	start	Refen	Zero	Gain
604	150.5000	154.7000	604.4523	152.5152	-0.8596	0.2504

By simple integration of region: 604 to 621

Peak chan = 613.13; Net counts = 144697. +- 0.45%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	613.130	152.673	144697.	1.1808E+06	1.376

SUMMARY OF PEAK RESULTS ON 14 GROUPS

Fig. 5-1 (continued).

Peak	Channel	Energy	Counts	Gammas/min	Pcterr	Qfit
1	613.130	152.673	144697.	1.1808E+06	1.376	0.000
2	806.706	201.134	4000.	5.5462E+03	11.118	0.000
3	834.164	208.009	18280.	2.1866E+04	2.510	1.000
4	839.356	209.309	20	2.3330E+01	1881.658	1.000
5	956.325	238.588	24474.	1.7724E+04	2.100	1.000
6	965.734	240.944	1703.	1.1958E+03	16.108	1.000
7	1249.152	311.910	5044.	1.8785E+03	1.124	1.000
8	1469.393	367.057	714.	2.0037E+02	43.163	1.632
9	1475.368	368.553	918.	2.5610E+02	2.453	1.000
10	1484.905	370.941	563.	1.5532E+02	4.165	1.000
11	1501.311	375.049	10871.	2.9513E+03	3.596	1.330
12	1507.513	376.602	213.	5.7334E+01	150.576	1.000
13	1521.774	380.173	3053.	8.1216E+02	10.641	1.710
14	1532.094	382.757	2557.	6.7335E+02	13.313	1.945
15	1655.623	413.688	11418.	2.6933E+03	3.050	1.000
16	1664.002	415.786	673.	1.5762E+02	44.474	1.567
17	2332.263	583.115	86972.	1.3705E+04	1.422	1.000
18	2337.299	584.376	659.	1.0354E+02	84.334	1.000
19	2644.000	661.172	1960.	2.7280E+02	13.039	1.000
20	2886.569	721.910	202.	2.5929E+01	77.987	1.356
21	2908.076	727.296	17930.	2.2869E+03	1.927	1.000
22	2916.838	729.490	0.	0.0000E+00	200.000	1.000
23	2969.992	742.799	82553.	1.0336E+04	1.412	1.000
24	3064.248	766.400	362903.	4.4234E+04	1.323	1.000
25	3143.580	786.264	55297.	6.9569E+03	1.493	1.000
26	3440.485	860.608	13258.	1.4719E+03	2.444	1.000

PU	DELP	ESLP	DELSLP	ECURV	DELCURV
3.000	0.000	0.000000	0.000000	0.000000	0.000000
QFIT = 5.41					
3.332	0.362	0.000000	0.000000	0.000000	0.000000

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.1	1.804E-01	1.353E+00
208.000	21867.	0.001787	0.0	2.718E-01	1.000E+00
238.600	17725.	0.002614	-0.2	3.119E-01	8.754E-01
375.000	2920.	0.009329	0.2	3.627E-01	5.678E-01
376.600	58.	0.011385	0.0	3.635E-01	5.655E-01
413.700	2694.	0.012007	-0.2	3.555E-01	5.174E-01
582.900	13706.	0.004841	3.3	3.013E-01	3.752E-01
727.400	2288.	0.021957	-3.6	2.589E-01	3.057E-01
742.800	10337.	0.006459	-0.4	2.547E-01	2.998E-01
766.400	44235.	0.001599	1.5	2.489E-01	2.913E-01
786.300	6598.	0.009627	-1.1	2.441E-01	2.846E-01
860.500	1473.	0.027212	-0.1	2.283E-01	2.620E-01
QFIT = 5.46					
3.416	0.086	0.000000	0.000000	0.000000	0.000000

Fig. 5-1 (continued).

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.1	1.625E-01	1.353E+00
208.000	21867.	0.001787	0.0	2.470E-01	1.000E+00
238.600	17725.	0.002614	-0.1	2.864E-01	8.754E-01
375.000	2919.	0.009329	0.2	3.468E-01	5.678E-01
376.600	58.	0.011385	0.0	3.478E-01	5.655E-01
413.700	2694.	0.012007	-0.2	3.422E-01	5.174E-01
582.900	13706.	0.004841	3.3	2.944E-01	3.752E-01
727.400	2288.	0.021957	-3.6	2.543E-01	3.057E-01
742.800	10337.	0.006459	-0.4	2.503E-01	2.998E-01
766.400	44235.	0.001599	1.5	2.447E-01	2.913E-01
786.300	6598.	0.009627	-1.1	2.401E-01	2.846E-01
860.500	1473.	0.027212	-0.1	2.249E-01	2.620E-01

QFIT = 4.70

4.201	0.955	-0.000273	-0.000375	0.000000	0.000000
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Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.2	1.585E-01	1.353E+00
208.000	21867.	0.001787	0.0	2.414E-01	1.000E+00
238.600	17725.	0.002614	0.2	2.805E-01	8.754E-01
375.000	2919.	0.009329	0.3	3.429E-01	5.678E-01
376.600	58.	0.011385	0.0	3.439E-01	5.655E-01
413.700	2694.	0.012007	-0.3	3.389E-01	5.174E-01
582.900	13706.	0.004841	1.3	2.927E-01	3.752E-01
727.400	2288.	0.021957	-3.1	2.532E-01	3.057E-01
742.800	10337.	0.006459	-0.8	2.492E-01	2.998E-01
766.400	44235.	0.001599	1.5	2.436E-01	2.913E-01
786.300	6598.	0.009627	-0.6	2.391E-01	2.846E-01
860.500	1473.	0.027212	1.9	2.241E-01	2.620E-01

QFIT = 4.81

4.367	0.172	-0.000303	-0.000030	0.000000	0.000000
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Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.3	1.309E-01	1.374E+00
208.000	21867.	0.001787	0.0	1.983E-01	1.000E+00
238.600	17725.	0.002614	0.4	2.323E-01	8.681E-01
375.000	2918.	0.009329	0.3	2.956E-01	5.419E-01
376.600	58.	0.011385	0.0	2.967E-01	5.395E-01
413.700	2694.	0.012007	-0.3	2.931E-01	4.884E-01
582.900	13706.	0.004841	1.4	2.489E-01	3.368E-01
727.400	2288.	0.021957	-3.2	2.085E-01	2.624E-01
742.800	10337.	0.006459	-0.8	2.043E-01	2.561E-01
766.400	44235.	0.001599	1.6	1.985E-01	2.469E-01
786.300	6598.	0.009627	-0.6	1.938E-01	2.397E-01
860.500	1473.	0.027212	1.7	1.779E-01	2.153E-01

QFIT = 4.81

4.372	0.004	-0.000301	0.000001	0.000000	0.000000
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Fig. 5-1 (continued).

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.3	1.261E-01	1.376E+00
208.000	21867.	0.001787	0.0	1.910E-01	1.000E+00
238.600	17725.	0.002614	0.4	2.241E-01	8.673E-01
375.000	2918.	0.009329	0.3	2.880E-01	5.391E-01
376.600	58.	0.011385	0.0	2.891E-01	5.367E-01
413.700	2694.	0.012007	-0.3	2.859E-01	4.852E-01
582.900	13706.	0.004841	1.4	2.431E-01	3.327E-01
727.400	2288.	0.021957	-3.2	2.030E-01	2.577E-01
742.800	10337.	0.006459	-0.8	1.988E-01	2.513E-01
766.400	44235.	0.001599	1.6	1.930E-01	2.421E-01
786.300	6598.	0.009627	-0.6	1.883E-01	2.348E-01
860.500	1473.	0.027212	1.7	1.725E-01	2.103E-01

QFIT = 4.80

4.372 0.000 -0.000324 -0.000023 0.000000 0.000000

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.4	1.259E-01	1.376E+00
208.000	21867.	0.001787	0.0	1.908E-01	1.000E+00
238.600	17725.	0.002614	0.4	2.239E-01	8.673E-01
375.000	2918.	0.009329	0.3	2.879E-01	5.392E-01
376.600	58.	0.011385	0.0	2.890E-01	5.368E-01
413.700	2694.	0.012007	-0.3	2.859E-01	4.853E-01
582.900	13706.	0.004841	1.6	2.432E-01	3.328E-01
727.400	2288.	0.021957	-3.3	2.031E-01	2.579E-01
742.800	10337.	0.006459	-0.7	1.989E-01	2.515E-01
766.400	44235.	0.001599	1.6	1.932E-01	2.423E-01
786.300	6598.	0.009627	-0.6	1.884E-01	2.350E-01
860.500	1473.	0.027212	1.5	1.726E-01	2.105E-01

QFIT = 3.84

4.372 0.000 -0.000325 0.000000 0.000000 0.000000

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.4	1.261E-01	1.378E+00
208.000	21867.	0.001787	0.0	1.908E-01	1.000E+00
238.600	17725.	0.002614	0.4	2.237E-01	8.667E-01
375.000	2918.	0.009329	0.3	2.871E-01	5.377E-01
376.600	58.	0.011385	0.0	2.882E-01	5.353E-01
413.700	2694.	0.012007	-0.3	2.850E-01	4.838E-01
582.900	13706.	0.004841	1.6	2.424E-01	3.319E-01
727.400	2288.	0.021957	-3.3	2.030E-01	2.577E-01
742.800	10337.	0.006459	-0.7	1.989E-01	2.515E-01
766.400	44235.	0.001599	1.6	1.933E-01	2.425E-01
786.300	6598.	0.009627	-0.6	1.887E-01	2.353E-01
860.500	1473.	0.027212	1.5	1.733E-01	2.113E-01

QFIT = 3.84

4.372 0.000 -0.000325 0.000000 0.000000 0.000000

Fig. 5-1 (continued).

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	1180834.	0.000058	-0.4	1.261E-01	1.378E+00
208.000	21867.	0.001787	0.0	1.908E-01	1.000E+00
238.600	17725.	0.002614	0.4	2.237E-01	8.667E-01
375.000	2918.	0.009329	0.3	2.870E-01	5.377E-01
376.600	58.	0.011385	0.0	2.882E-01	5.353E-01
413.700	2694.	0.012007	-0.3	2.850E-01	4.838E-01
582.900	13706.	0.004841	1.6	2.424E-01	3.318E-01
727.400	2288.	0.021957	-3.3	2.029E-01	2.577E-01
742.800	10337.	0.006459	-0.7	1.988E-01	2.514E-01
766.400	44235.	0.001599	1.6	1.932E-01	2.424E-01
786.300	6598.	0.009627	-0.6	1.886E-01	2.352E-01
860.500	1473.	0.027212	1.5	1.732E-01	2.113E-01

QFIT = 3.84

ISOTOPIC ANALYSIS AT
COUNT TIME

RATIOS	WT.PCT.	PCTERR	Milliwatts/(gm total Pu)
Pu238 = 5.7494693	83.00409	0.74	470.766
Pu239 = 1.0000000	14.43683	4.24	0.278
Pu240 Operator input value	1.99000		0.141
Pu241 = 0.0200242	0.28909	6.27	0.010
Pu242 Operator input value	0.28000		3.156E-02
Am241 = 0.0039875	0.05757	306.22	0.066
Total			= 471.293 +/-0.42%

PU-238 isotopic gamma assay - Run Type: Fromdisk

Input file:	SN1206.IS8	Current Date:	25-FEB-91 08:24:48
Operator ID:	WDR		
Constants File:	PARMTR.IS8	Constants Date:	10-DEC-90 09:21:00
Live time (sec):	2583.	Clock time (sec):	3000.

Result = 471.3 +/- 0.4 % 1

CHAPTER 6

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Chapter 6

PARAMETER CHANGE

6.1 PU238_CHNG PROGRAM

The PU238_CHNG program allows the user (supervisor) to change the constant values in the PARMTR.IS8 file. The supervisor must log into the SRP account to use this program in the ASSAY directory. The program is menu-driven and operated from the console terminal. A password is required; the allowable passwords are the same as those for the supervisory options in the SRS_ASY238 program. The passwords are stored in the BACKGR.IS8 file. If for some reason this file does not exist or PU238_CHNG is being used for the first time and the file has not been created, a default password may be used. Please note, however, that an error message will be generated if the BACKGR.IS8 file does not exist, and a password will be requested. The password in this case is PASS.

To run the PU238_CHNG program, type the following on the console terminal:

```
R PU238_CHNG
```

When the program starts, the following dialog is printed on the console terminal:

```
Reading BACKGR.IS8
```

```
You have entered a supervisory option which requires a password.
```

```
Enter password ->
```

```
Enter operator ID (8 chars) or RETURN to escape -> WDR
```

```
PARMTR.IS8   was written  2-MAR-90  10:39:43  by WDR
```

```
CODE-OPTION
```

```
HE - HElp
MC - Measurement Control
PT - Preset Time
PW - PassWords
DV - Default Values
RD - Read Constants from Disk
LI - LIst All Constants
OU - OUtput Device
EX - EXit from Changes
```

```
Note:  Enter -9999.  or -9999 to input 0
```

```
14-MAY-90 16:37:52
```

```
Enter the CODE of the OPTION you want ->
```


6.2 PARAMETER CHANGE OPTIONS

After entering the two-letter code that corresponds to the option desired, the user is prompted to enter the new values. Descriptions of each of the options and the corresponding dialog follow.

PARAMETER CHANGE OPTIONS

Option	Description
<u>HElp (HE)</u>	Displays the menu shown on the preceding page.
<u>Measurement Control (MC)</u>	This option allows the user to modify the bias or precision measurement control information. The dialog for the bias measurement control is as follows:

```
Measurement control - Bias or Precision? (B/P) -> B
Biastime    = 1.0000    ->
  Bias ref is the specific power (mW/g) on 1/1/90
Bias ref     = 478.86    ->
Hist std     = 2.2300    ->
```

The Biastime value is the allowed interval in days between bias control measurements. The Bias ref value is the expected specific power value for the standard sample. Note, to get a specific power value decayed back to 1/1/1990, this value should be obtained by a precision measurement. The specific power value obtained in a bias or precision measurement is always decayed back to this date. The Hist std value is the expected standard deviation on the measured value for some specified count time. To change a value, type the new value after the -> sign. All entries in this case should be input in F or floating-point format: that is, a whole number, a decimal fraction, or a combination of the two. If any of the constants are not to be changed, press RETURN after the -> sign.

The dialog for the precision measurement control is as follows:

```
Measurement control - Bias or Precision (B/P) -> P
Prctime = 10.0000    ->
No. runs = 5         ->
```

The Prctime value is the allowed number of days between precision control measurements. The No. runs value is the number of measurements to be performed for the precision control check. This value must be 5 or 15 and in integer format: that is, a whole number without a decimal point.

PARAMETER CHANGE OPTIONS (CONTINUED)

Option	Description
<u>Preset Time (PT)</u>	This option allows the user to change the default clock time for all assays. The new value should be entered in F format.
<u>PassWords (PW)</u>	This option allows the user to change any of the passwords. The program allows three different passwords.
<u>Default Values (DV)</u>	This option allows the user to change the plutonium-240 default value. A typical dialog for this option is as follows:

Enter Pu-240 abundance (Wt.%) (0=1.97,-1=Calc.)

Pu-240 = 0.0000 -> 1.967

Enter Pu-242 abundance (Wt.%) (0=0.1)

Pu-242 = 0.0000 -> 3.55

Because the plutonium-240 abundance cannot be determined by gamma-ray spectrometry for samples enriched in Pu-238, its value must be specified to the system so that the relative abundances of all plutonium isotopes can be determined. The relative abundance of plutonium-240 for plutonium enriched to 80% in Pu-238 is about 2.0, so a 0 entry defaults to 2.0. If a negative value is entered, the plutonium-240 relative abundance is calculated using the plutonium-239 and -241 relative abundances.

Because the plutonium-242 abundance also cannot be determined by gamma-ray spectrometry, its value must be specified to the system so that the relative abundances of all plutonium isotopes can be determined. For highly enriched Pu-238 samples (80% or greater) the Pu-242 abundance is small (about 0.1%, the default value) and could be ignored. However, for lower Pu-238 enrichments (20% to 40%) its value cannot be ignored. The Pu-242 value cannot be calculated, so a negative entry is not appropriate.

<u>Read Constants from Disk (RD)</u>	This option allows the user to select or change the constant's filename in a list of constants files. The dialog for this option is as follows:
--------------------------------------	---

The constants file read was: PARTMR.IS8

Do you want to select another constants file (Y/N) -> Y

Table 6-1. PARMTR.IS8 file obtained with LI option in PU238_CHNG program.

6-JUN-90 16:02:15

SY:PARMTR.IS8 TEST CONSTANTS FILE FOR FIRST

Written 22-MAR-90 16:32:10 by WDR

Measurement Control

	Bias	Precision
Interval =	1.00000	10.0000
Reference =	478.860	
Standard Dev. =	2.23000	
Cycles =		5

Default Analysis Values

Pu-240 abundance (wt. %) = 1.97
Pu-242 abundance (wt. %) = 3.55

PARAMETER CHANGE OPTIONS (CONTINUED)

Option	Description
<u>Read Constants from Disk (RD)</u> (CONTINUED)	

The current constants files are:

- 1 PARMTR.IS8 TEST FILE
- 2 PARMTR.001
- 3 PARMTR.002
- 4 PARMTR.003
- 5 PARMTR.004

Enter constants file selected (1-5) or 6 for new file -> 2

Constants file = PARMTR.001 OK? (Y/N) -> Y

The constants filenames are contained in a file named CONSTA.IS8. This file is an ASCII file and must contain five entries. The RD option allows the user to select any one of these files to change constants or allows the user to change the list of names in the constants filenames file. In this example, the second constants file is read in, and the constants in that file may be changed. When the program is started, the first constants file in the list is read in by default.

List All Constants (LI)

This option prints all constants on the output device. The output device is determined by the OU option. See Table 6-1 for a listing of the PARMTR.IS8 file obtained with the LI option in the PU238_CHNG program.

NOTE: Whenever a change is made to the file, a new listing should be added to this manual.

Change Output Device (OU)

This option changes the output device from the terminal to the printer or vice versa. The default device is the terminal. Under normal operating conditions, a printer will not be attached to the system. This output device setting is relevant only to the PU238_CHNG program and has no effect on the SRS_ASY238 program.

PARAMETER CHANGE OPTIONS (CONTINUED)

Option	Description
<u>EXit from Changes (EX)</u>	This option takes the user out of the menu options portion of the program. The user is given the option of making the changes permanent by writing them to disk.

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Chapter 7

ERROR MESSAGES

Error messages for the Pu-238 isotopic analysis system are of two kinds: action error messages and instrument diagnostic messages.

7.1 ACTION ERROR MESSAGES

A file named ERRMSG.INS contains a set of error messages that are accessed by the ERRMSG subroutine whenever an error or condition occurs that requires action by the operator or supervisor. The following is a list of these errors and a brief description of each.

ACTION ERROR MESSAGES

Message	Description
ERROR IN OPENING FILE	A problem occurs in accessing a file. Usually the file name is listed along with the error message. The most probable cause of this message is that the file is missing. Correct this problem by creating the file or copying it from the backup tape. Consult VAX system operator for copying files from a backup tape.
ERROR IN READING FILE	A problem occurs in reading a file. The most probable cause is an improperly formatted file. Correct this problem by creating a new file or copying a backup.
ERROR IN WRITING FILE	A problem occurs in writing a file. The most probable cause is insufficient writing space on the disk. Consult the supervisor about creating additional space on the disk. Additional space may be obtained by copying files that need to be archived onto a TK50 tape and deleting them from the system disk.
RECORD POINTER INVALID	The MCLOGF and ASYLOG files contain pointers in the first record of the file to indicate the positions of the first and last entries. If the values of these pointers are less than or more than certain specified limits, this error message will occur. To correct the problem, delete the file indicated.
SUPERVISOR NEEDS TO CORRECT PROBLEM	The error or condition that has occurred requires supervisory action to correct.

ACTION ERROR MESSAGES (Continued)

Message	Description
PRECISION CHECK WARNING LIMITS EXCEEDED	This message is displayed if the chi-square value calculated from the precision check measurements exceeds certain warning limits. These limits are specified under the description of the MP option in this manual. Consult the supervisor to determine course of action.
PRECISION CHECK ACTION LIMITS EXCEEDED	This message occurs when the results of the precision measurement check exceed certain action limits. These limits are specified under the description of the MP option in this manual. If this condition occurs, the operator is asked if the measurement is to be repeated. Consult the supervisor before proceeding.
BIAS CHECK WARNING LIMITS EXCEEDED	This message occurs when the difference between the measurement result and the reference value is greater than 1.96 times the standard deviation on the reference value. Before proceeding, check that the correct reference standard sample was used and then consult the supervisor.
BIAS CHECK ACTION LIMITS EXCEEDED	This message is displayed when the difference between the measurement result and the reference value is greater than 3.0 times the standard deviation on the reference. If this condition occurs, the operator is asked if the measurement is to be repeated. Before proceeding, check that the correct reference standard sample was used and then consult the supervisor.

7.2 INSTRUMENT DIAGNOSTIC MESSAGES

Diagnostic messages may occur during analysis of the spectral data. These messages indicate that a parameter determined from the spectral data exceeds a specified limit. The messages and limits are given below.

INSTRUMENT DIGNOSTIC MESSAGES

Message	Description
***WARNING: Zero-channel intercept or gain is incorrect. Please center 152.7-keV peak at channel 612 and the 766.4-keV peak at 3063. Check stabilizers. Analysis is aborted. See supervisor.	If the absolute value of the zero-channel energy is greater than 5 or the gain differs from 0.25 keV per channel by 0.002 keV/channel, then this message occurs. The analysis is aborted. DGFLG(2) is set to TRUE. To have a gain of 0.25 keV per channel and a zero-channel energy near 0, the position of the 152.7-keV peak must be at channel 612, and the position of the 766-keV peak must be at channel 3063. Because these peaks are used for zero and gain stabilization of the detector system, the stabilizer should be checked to see that it is performing properly.
WARNING: Did not converge in "P238AB" routine.	This message indicates that the iterative analysis in the subroutine P238AB to determine the plutonium thickness and adjustments to the relative efficiency did not converge. The results of the analysis may be suspect. Check the magnitude of the QFIT value. If it is reasonable, the results are okay even though this message occurred. Verify that there are sufficient data in the spectrum. This message may also indicate that there are absorbing materials in the sample that cannot be corrected for.
!WARNING! Energy resolution exceeds 2.4 keV.	If the FWHM of the 766.4-keV peak in the spectrum exceeds 2.4 keV, this message appears, and the DGFLG(3) is set to TRUE. If this condition occurs, check the count rate. If the count rate produces an analyzer dead time greater than 50%, the 766.4-keV resolution may exceed 2.4 keV. Adjust the detector position, if possible. If it persists, check the amplifier pole zero and amplifier signal baseline for noise and indications of a ground loop.
766-keV peak outside limit. Check stabilizer.	The position of the 766.4-keV peak is expected at channel 3063. If the position of the peak is greater or less than three channels from channel 3063, this message appears on the terminal, and DGFLG(4) is set to TRUE. Because this peak is used for gain stabilization of the detector system, the stabilizer should be checked to ensure that it is performing properly.

INSTRUMENT DIGNOSTIC MESSAGES (Continued)

Message	Description
Matrix is singular in P238AB. Analysis aborted.	Because the matrix of equations set up to determine the relative isotopic abundances is singular, it cannot be inverted for solution of the problem. The analysis is aborted. Check the spectra to ensure that they contain sufficient data.

Chapter 8

REFERENCE ARTICLES

An Isotopic Analysis System for Plutonium Samples Enriched in ^{238}Pu

W. D. Ruhter, R. Gunnink, and D. C. Camp

Abstract

We designed, built and delivered to Westinghouse Savannah River Company a computer-based, gamma-ray spectrometry system for measuring the relative abundances of plutonium in plutonium samples enriched in ^{238}Pu . The system utilizes sophisticated, unique gamma-ray analysis techniques and is capable of achieving 2% accuracy on the ^{238}Pu abundance in samples enriched to 83% in ^{238}Pu .

Introduction

Plutonium enriched in ^{238}Pu is used widely as a source of heat and power (0.57 W/g). Radioactive thermal-electric generators (RTG) using plutonium enriched in ^{238}Pu are found on many satellites. Many plutonium materials enriched in ^{238}Pu now exist throughout the DOE complex and at other government agencies, e.g., at the National Aeronautics and Space Administration (NASA). Much of this material, particularly scrap materials, is being returned to the WSRC H-canyon near Aiken, South Carolina, for recovery. To account properly for the material being received, it is necessary to determine its plutonium isotopic composition. Gamma-ray spectrometry is one means by which the relative abundances of the various isotopes can be determined. Unfortunately, the gamma-ray spectrum is dominated by gamma-rays from ^{238}Pu . However, there are several gamma-ray lines that can be used to determine the two fissile isotopes of plutonium, i.e. ^{239}Pu and ^{241}Pu .

System Design

Figure 3-1 (page 3-4) shows a photograph of the system we have built to measure the relative abundances of plutonium isotopes in samples enriched in ^{238}Pu . The 20% efficient, coaxial, high-purity germanium detector views the sample through a 2.75 inch window in the sample-shielding enclosure. The window contains a graded absorber assembly to reduce the intensity of the strong 99.86- and 152.68-keV gamma rays from ^{238}Pu . The absorber assembly consists of .030 in. of lead, .062 in. of cadmium, .030 in. of copper and 2 in. of borated polyethylene. The borated polyethylene is used to reduce the exposure of the detector to the neutrons emitted by the samples. Two inches of lead immediately surround the sample window inside the enclosure to prevent the detector from "seeing" high-energy gamma-rays from the sample other than those that pass through the window. A 2-in.-thick lead barrel surrounds the detector to also shield the detector from sample gamma rays other than those passing through the sample window and from other samples that may be in the room. The system has a substantial amount of shielding to

protect personnel from the gamma radiation and from neutrons emitted from these enriched samples. The sample-shielding enclosure consists of 2-in.-thick borated polyethylene for neutron shielding plus 0.5 in. each of lead and stainless steel to reduce the external exposure from the sample's gamma-ray emissions. Because the samples will be quite warm (they can generate more than 100 W), convection cooling holes are located at the top and bottom on three sides of the sample-shielding enclosure.

The samples are loaded at the top of the sample enclosure. A control box on the right-hand side of the sample enclosure is used to load or unload a sample. When unloading a sample a lid on top of the sample closure is moved back by a linear actuator and the sample elevator inside the enclosure is raised completely; this raises the handle of the calorimeter container well above the top of the enclosure.

Each sample will contain up to 200 g of plutonium in oxide form; however, the exact location of the material within the stainless steel "flashlight" canister, which is enclosed within a calorimeter container, is unknown. Therefore, for the detector to view the enclosed material from all directions, the calorimeter container is scanned from top to bottom as it rotates.

Data Analysis Methodology

We have selected twelve gamma rays from the isotopes of ^{238}Pu , ^{239}Pu , ^{241}Pu , ^{241}Am and ^{228}Th that can be used in determining the relative plutonium isotopic abundances. Table 1 lists the gamma rays and their isotopic source.

<u>Energy (keV)</u>	<u>Isotope</u>
152.68	^{238}Pu
208.0	^{241}Pu , ^{241}Am
238.6	^{228}Th
375.04	^{239}Pu
376.6	^{241}Am
413.7	^{239}Pu
582.9	^{228}Th
727.4	^{228}Th
742.8	^{238}Pu
766.4	^{238}Pu
786.3	^{238}Pu
860.5	^{238}Pu , ^{238}Pu

Table 1. List of gamma rays used in the isotopic analysis of plutonium samples enriched in ^{238}Pu .

Figure 2-3 shows a 0- to 1-MeV gamma-ray spectrum from a ^{238}Pu sample with an enrichment of 83.4% with some of these gamma rays identified. The 208-keV line from the decay of ^{237}U is used to determine the amount of ^{241}Pu ; the spectral peaks at 375 and 413.7-keV are used to determine

the amount of ^{239}Pu . The 152.7- and the 766.4-keV peaks are two of the principal gamma-ray peaks used to calculate the amount of ^{238}Pu in the sample. The ^{228}Th gamma-ray peaks are used to determine the relative detection efficiency over the range of energies measured.

The intensities of these twelve gamma rays are determined from the measured gamma-ray spectra with the computer program GRPANL.¹ The intensities of the gamma rays are corrected by the GRPANL program for the absorption effects of the sample stainless steel containers, aluminum calorimeter container, and the absorbers in the sample-enclosure window. The gamma-ray intensities are also corrected for the relative differences in detection efficiency of the germanium detector by the GRPANL program, which is given a set of coefficients describing the relative-detection efficiency curve for the detector. These coefficients are stored in the PU238.DET file and are described in Volume 3.

The corrected gamma-ray intensities are then passed to a separate subroutine, P238AB, through a disk file, PU238.RST, to determine the relative isotopic abundances. This requires correction of the gamma-ray intensities for the branching intensities of the emitting isotopes and the self-attenuation by the plutonium material. The peaks identified as ^{228}Th peaks are natural decay-chain products from ^{238}Pu and are used to establish a relative efficiency curve

It is not possible to quantitatively measure the amount of ^{240}Pu present in these samples: it is not very abundant (about 2% of the entire sample), and it emits only a few gamma rays. We have developed an algorithm that predicts with sufficient accuracy the amount of ^{240}Pu present in a sample from the relative amounts of ^{239}Pu and ^{241}Pu have been determined. Also, no significant gamma rays are emitted by ^{242}Pu ; hence, we cannot determine its relative abundance. However, ^{242}Pu is negligible in these samples because its total abundance rarely exceeds 0.1%.

Representative amounts of ^{239}Pu in these samples will be from 12 to 18%, and preliminary data indicate that we will be able to determine its abundance to an accuracy of about 10%. Typical abundance for the ^{241}Pu isotope will be from 0.3 to 0.6%; here again, our initial results indicate that we will be able to determine its content to about 15%. In the event we were to measure a sample with substantially less than 70% ^{238}Pu , the amounts of ^{239}Pu , ^{240}Pu , and ^{241}Pu in the sample would be greater. Thus, the peak intensities of their gamma rays would be more easily observed, and we expect to be able to determine their relative abundances to acceptable accuracies.

Reference

1. R. Gunnink, W. D. Ruhter, and J. B. Niday, GRPANL: A Suite of Computer Programs for Analyzing Complex Ge and Alpha-Particle Detector Spectra, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53861, vol. 1 (1988).