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**PLUTONIUM ISOTOPIC ANALYSIS SYSTEM FOR
PLUTONIUM SAMPLES ENRICHED IN ^{238}Pu
IN EP 60/61 AND FUEL-CLAD CONTAINERS
VOLUME 1
USERS MANUAL**

Wayne D. Ruhter

**DO NOT MICROFILM
COVER**

July 1, 1991

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

Volume 1 Users Manual

Wayne D. Ruhter

July 1, 1991

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PREFACE

This user's manual is addressed to the Hanford 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 supervisory 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 reference articles on measuring relative plutonium isotopics in solid samples.

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-107467, 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-107467, 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, and Am-241 isotopic abundances 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 calibrating the Pu-238 isotopic analysis system and for monitoring its 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 VT320 video terminal. 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 sample enclosure while the detector shield lid is closed. The computer senses the sample container type, i.e. whether the sample is in an EP60/61 container or a fuel-clad container, by its height. The computer also senses 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, 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 1991 at the Hanford Site. Contact the instrument 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-107467 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, DEC VT320 video terminal, and DEC LA75 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 position
	TIME BASE SEC/DIV rotary switch	5 microseconds
	VOLTS/DIV rotary switches for 1X PROBE	0.2
	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>Canberra 2020</u>		
<u>AMPLIFIER</u> (See UCRL-CR-107467, Vol. 2, paragraph 3.3.1, for further information.)	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.	

	COARSE GAIN rotary switch	100
	FINE GAIN potentiometer	Approx. 450
	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.	

	INPUT POLARITY toggle switch	- (negative)
	SHAPING MULTIPLIER switch	X2 (pushbutton in)
	SHAPING TIME μ SEC rotary switch	2.0 μ s
	(P/Z) (pole zero)	See UCRL-CR-107467 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-107467 Vol. 2, paragraph 3.3.3, for setup.

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position
<u>Canberra 8077</u>		
<u>ANALOG-DIGITAL</u>		
(See UCRL-CR-107467, Vol. 2, paragraph 3.4, for further information.)	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>	Under normal circumstances the stabilizer settings are set by the computer, when the stabilizer is set in REMOTE. If manual settings are required, set switch to MANUAL and proceed as described below.	
<u>STABILIZER</u>		
(See UCRL-CR-107467, Vol. 2, paragraph 3.5, for further information.)		
	ZERO/GAIN toggle switch	ZERO [enter ZERO PEAK value (612)]
	ZERO/GAIN toggle switch	GAIN [enter GAIN PEAK value (3063)]
	ZERO/GAIN toggle switch	ZERO [enter ZERO WINDOW value (11)]
	ZERO/GAIN toggle switch	GAIN [enter GAIN WINDOW value (15)]
	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	REMOTE
<u>ORTEC 729A</u>	There are no required initial control settings for the LN monitor.	
<u>LIQUID NITROGEN</u>		
<u>MONITOR</u>		

-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 659 HIGH-VOLTAGE SUPPLY</u> (See UCRL-CR-107467, Vol. 2, paragraph 3.7.2, for further information.)	<p style="text-align: center;">- C A U T I O N -</p> <p>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.</p>	
	HIGH-VOLTAGE ON/OFF toggle switch and press RESET pushbutton.	ON (Observe power indicator on.)
	OUTPUT VOLTAGE potentiometer	2.00 (-2000 V)

ROUTINE PREOPERATIONAL SETUP (CONTINUED)

Equipment	Control	Position												

<u>CANBERRA SERIES 90</u> <u>MULTICHANNEL</u> <u>ANALYZER (Fig. 2-4)</u> (See UCRL-CR-107467, Vol. 2, paragraph 3.8, for further information.)	NOTE: Data collection parameters are set by the comput- er 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 SUMMRY</u> and observe:													
	<table><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><tr><td>H1*</td><td>EXTENDED</td><td>1</td><td>4K</td><td></td><td>0000</td></tr></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>RETURN</u>
<u>USER</u>	<u>TYPE</u>	<u>GROUP</u>	<u>MEMORY</u>	<u>INPUTS</u>	<u>PASSWD</u>									
H1*	EXTENDED	1	4K		0000									

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 <u>[YES]</u> . If not, touch <u>HOST</u> <u>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>ACO. 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)	----- 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-107467, Vol. 2, paragraph 3.8.2, for further information.) -----	
<u>MICROVAX II COMPUTER</u>	ON/OFF switch	ON (Observe green Run LED and DC OK LED on, and in expansion chassis green LED in Ready pushbutton on; verify green LED in Write Protect <u>not</u> on.)
<u>Digital Equipment Corporation VT320 Video TERMINAL</u>	ON/OFF switch	ON (Terminal has screen saver feature - press SPACEBAR to awaken)
<u>Digital Equipment Corporation LA75 PRINTER</u>	ON/OFF switch	ON (Observe POWER LED on.)
	READY indicator	Observe LED on (Press pushbutton to enable.)
	PROTOCOL indicator	DEC (Press SETUP pushbutton to change)
----- 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.) -----		

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: <table><tr><th>Soft No.</th><th>Assignment</th><th>Soft No.</th><th>Assignment</th></tr><tr><td>1</td><td>X-AXIS CALIB.</td><td>5</td><td>NORMALIZE</td></tr><tr><td>2</td><td>XFER</td><td>6</td><td>SMOOTH (3-pt)</td></tr><tr><td>3</td><td>PEAK SEARCH</td><td>7</td><td>STRIP</td></tr><tr><td>4</td><td>SORT ROI</td><td>8</td><td>DIFFER</td></tr></table> -----		Soft No.	Assignment	Soft No.	Assignment	1	X-AXIS CALIB.	5	NORMALIZE	2	XFER	6	SMOOTH (3-pt)	3	PEAK SEARCH	7	STRIP	4	SORT ROI	8	DIFFER							
Soft No.	Assignment	Soft No.	Assignment																										
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: <table><tr><th>Field No.</th><th>Option</th><th>Fixed places format</th></tr><tr><td>1</td><td>AREA</td><td>1</td></tr><tr><td>2</td><td>% ERROR</td><td>3</td></tr><tr><td>3</td><td>PEAK CENTER</td><td>3</td></tr><tr><td>4</td><td>FWHM</td><td>3</td></tr><tr><td>5</td><td>PRESET TIME</td><td>1</td></tr><tr><td>6</td><td>TRUE TIME</td><td>1</td></tr><tr><td>7</td><td>% DEADTIME</td><td>2</td></tr><tr><td>8</td><td>CPS INTEG</td><td>3</td></tr></table> -----		Field No.	Option	Fixed places format	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
	Field No.	Option	Fixed places format																										
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>	

CHAPTER 3

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ILLUSTRATIONS

- Fig. 3-1. Pu-238 isotopic analysis system sample enclosure. The control box at the left is used to load/unload the sample by opening/closing the sample enclosure lid and raising/lowering the sample turntable. The count-rate meter indicates the detector count rate to advise the operator in the operation of the instrument. 3-4

Chapter 3

SYSTEM OPERATION

3.1 STARTING INSTRUMENT CONTROL PROGRAM

The instrument control program, WHC_ASY238, starts automatically from a startup command file when the system is turned on. The startup command file will load and start the WHC_ASY238 program on the remote terminal.

If the WHC_ASY238 program has been aborted, restart it by logging onto the operator terminal under the WHC_ASY238 account to cause the startup command file to be executed and the WHC_ASY238 program to be started. When the program starts, you are automatically logged off of the WHC_ASY238 account.

When the WHC_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.WH8
PARMTR.WH8   was written 22-MAR-91  14:50:42 by WDR
Reading BACKGR.WH8
BACKGR.WH8   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 enclosure lid cannot be operated unless the WHC_ASY238 program is running or the computer is turned off.

3.2 HALTING INSTRUMENT CONTROL PROGRAM

The WHC_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 enclosure (top). The control box shown at the bottom is used to load/unload the sample by opening/closing the sample enclosure lid and raising/lowering the sample turntable. The count-rate meter indicates the detector count rate to advise the operator in the operation of the instrument.

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 VT320 video terminal is a slave terminal which allows the operator to interact with the instrument through dialog generated by the WHC_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 provides control for loading and unloading samples and for monitoring the detector count rate (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 enclosure is a Lucite guide which usually remains inside the enclosure, its conical opening serving to position the EP60/61 containing the sample on the circular sample turntable. When measuring a sample in a fuel-clad canister (FCC), remove the Lucite guide for access to the turntable and remove the polyethylene ring from the turntable and replace it with the polyethylene disk that has a 2-inch diameter indentation in it for the FCC to be placed into.

With the sample enclosure 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 enclosure, using the Lucite guide to help position the EP60/61 container in the center of the turntable.
3. Depress and hold either pushbutton labeled LOAD. This causes the turntable to descend. As soon as it clears the top of the enclosure, the sample enclosure lid shuts. When the lid is fully closed, the LOAD pushbuttons are lit, denoting that the sample is loaded.

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 enclosure 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, depress and hold either pushbutton labeled UNLOAD. The sample enclosure 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.

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.

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
ASSAY (A) (CONTINUED)	The following illustrates the operator dialog for the Assay (A) option:

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

Enter sample barcode 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...

Before pressing the RETURN key to begin an assay, make sure that the sample has been loaded properly and the sample cave 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 and displays the message below.

To count for recommended	10000.0	secs type <Y> or
To count for default time	4000.0	secs type <N>

and press RETURN -> Y

The operator has the choice of counting for the recommended time by typing a Y or using the default time by typing an N.

Starting a run of 10000. s at 10:46:04 (26-APR-91) Ends
Today at 12:32

The operator should ensure that the completion time message has been printed on the terminal before leaving the instrument.

During the 60-second assay check the system also senses the size of the sample container, i.e. an EP60/61 or fuel-clad container. This information is needed to use the appropriate attenuation corrections for the container walls.

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.

ROUTINE OPTIONS (CONTINUED)

Option	Description
	<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> <p>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.</p> <p>The following message will appear on the terminal if the sample stops rotating during the measurement:</p> <p>SAMPLE NOT ROTATING. MEASUREMENT SUSPENDED AT HR:MN:SC To resume, press RETURN (press A to ABORT)</p> <p>The measurement will not continue until the RETURN key is pressed. When RETURN is pressed, the following message will appear.</p> <p>Acquisition resumed at HR:MN:SC</p> <p>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-xxxxxx, 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.</p> <p>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:</p>

ROUTINE OPTIONS (CONTINUED)

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

4096 channels starting at channel # 0

Spectrum retrieval completed -- 34 blocks written to CURDTA.WH8

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 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).

MEASUREMENT CONTROL - BIAS (MB)

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

ROUTINE OPTIONS (CONTINUED)

Option	Description
<u>MEASUREMENT CONTROL</u> -	monitored during data acquisition; acquisition is
<u>BIAS (MB)</u>	completed, the spectral data are dumped to disk and
(CONTINUED)	analyzed. Results of the analysis are printed out (see printout formats). At the end of the printout, the following information is printed:

Current value = 2.5960
Reference value = 2.6000
Difference = 0.0040

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

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:

BIAS CHECK WARNING LIMITS EXCEEDED

If the difference is greater than 3.00 times the standard deviation on the reference value, the following messages are printed on the terminal:

BIAS CHECK ACTION LIMITS EXCEEDED

Do you want to repeat bias check? (Y/N) ->

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 results are flagged in the measurement-control results file. 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.

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.

ROUTINE OPTIONS (CONTINUED)

Option	Description
	<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>

MEASUREMENT CONTROL - PRECISION (MP)

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

ROUTINE OPTIONS (CONTINUED)

Option	Description
<u>MEASUREMENT CONTROL -</u> <u>PRECISION (MP)</u> (CONTINUED)	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 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, acquisition stops, 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.WH8

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.WH8

In this case, the spectral data file would have the filename TEST.WH8. The spectral data file would be permanent.

SUPERVISOR OPTIONS (CONTINUED)

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

ASSAY DATA FROM DISK (AD)

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.WH8

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

AUTOCYCLE (AU)

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 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. 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 = T
3. Preset assay time = 1000.
4. Pu-240 abundance (Wt.%) = 2.00
5. Pu-242 abundance (Wt.%) = 0.10
6. Constants file = PARMTR.WH8

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=2.0, -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 to calculate the plutonium-240 abundance. An entry of 0. causes the program to use a default value of 2.0.

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>DEFAULT (D)</u> (CONTINUED)	Plutonium-242 also cannot be measured or calculated, so a declared value must be entered. 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:

OK? (Y/N) -> Y

Respond with a Y if everything is correct. Otherwise, respond with an N and make the necessary changes.

<u>LIST ASSAY LOG (LA)</u>	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:
----------------------------	--

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-91

Enter stop date (oldest) [02-AUG-84] -> 1-MAR-91

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:

Assay log as of 6-MAY-91 10:55:15

Entry	Date	Time	Sample ID	Operator	File	Cycles	Results	240 Flg	Err Flg
1.	2-MAY-91	10:30	TEST	WDR	TEST.WH8	1/1	4.715E+02	F	F
%238=83.0222 %239=14.7136 %240= 1.9670 %241= 0.2971 %242= 0.100 %Am= 0.1977									
Specific power = 4.715E+02									
2.	3-MAY-91	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= 0.100 %Am= 0.2122									
Specific power = 4.726E+02									

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>LIST ASSAY LOG (LA)</u> (CONTINUED)	<p>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.</p> <p>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.</p> <p>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.</p>
<u>LIST MEASUREMENT CONTROL LOG (LM)</u>	<p>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:</p>

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	2.60580E+00	3.000E-03	2.600000E+00	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 fractional error value is the measured variance, and the standard value is the calculated variance.

The third (list all) option lists all 99 entries if the file is full. Note that this takes considerable time with the DEC LA75 printer.

<u>CHANGE OUTPUT 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 requires a password.

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<u>CHANGE OUTPUT</u> <u>LISTING DEVICE (OU)</u> (CONTINUED)	Enter password -> Enter 6 for line printer, 5 for terminal -> The default device setting is the line printer
<u>STATUS (ST)</u>	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.
<u>READ DATA FROM</u> <u>DISK (R)</u>	This option is used to read a spectrum from disk and send it to the Canberra Series 90 analyzer for dis- play. The operator dialog is as follows: You have entered a supervisory option which requires a password. Enter password -> Enter full filename [FILENM.EXT] -> TEST.WH8

SUPERVISOR OPTIONS (CONTINUED)

Option	Description
<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 WHC_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, which is in addition to the summary printout that occurs in each assay:

PU-238 gamma-ray
Assay results for sample: TEST

QFIT = 1.44

ISOTOPIC ANALYSIS AT COUNT TIME

	RATIO	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	0.49725	7.00	0.017
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 Measurement Date: 22-MAY-91 15:10:12
Operator ID: WDR Current Date: 22-MAY-91 16:10:12
Constants File: PARMTR.WH8 Constants Date: 2-MAY-91 09:11:15
Live time (sec): 19871. Clock time (sec): 20000.

Result = 476.024 +/- 0.9 % milliwatts/gm total Pu

This portion of the printout shows the type of analysis performed and information about the measurement. The measurement date is the time at which the measurement was started. The current date is the time at which the analysis of the data was performed. The constants file is read in when the instrument control program is started. Live time is the amount of time the ADC was alive to collect data and the clock time is the actual clock time that elapsed during the measurement.

5.2 LONG PRINTOUT

If a long printout is selected under the default settings (Item 1 under the D option is set to True), a listing of the peak energies, areas, and their relative weights used in the fitting process are printed. 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 2-MAY-91 at 13:42:19 of

Spectral data file: MAR3B8.WH8 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 41 chans from 590 for 152.7 keV peak

CALIB searching 58 chans from 3036 for 766.4 keV peak

St-Ch	Energy	End energy	start	Refen	Zero	Gain
801	199.7000	201.9000	800.6948	200.7777	-0.7373	0.2503

By simple integration of region: 801 to 809

Peak chan = 806.00; Net counts = 60023. +- 1.90%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	806.000	201.028	60023.	1.2043E+04	6.027

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

Group 2 includes 206.7 to 209.7 keV

St-Ch Energy End energy start Refen Zero Gain

829 206.7000 209.7000 828.6580 208.2876 -0.7373 0.2503 Fig. 5-1

By simple integration of region: 829 to 841

Peak chan = 833.83; Net counts = 224313. +- 0.81%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	833.833	207.995	224313.	3.8849E+04	5.485

Group 3 includes 236.3 to 242.3 keV

Recalibrate Gain using energy standards at 152.680 and 766.400 keV

CALIB searching 41 chans from 592 for 152.7 keV peak

CALIB searching 58 chans from 3035 for 766.4 keV peak

St-Ch Energy End energy start Refen Zero Gain

947 236.3000 239.9000 950.1051 238.4505 -0.7354 0.2503

Results from group 3 (3 iterations)

QFIT 0.977; FWHM 1.34933+/- 0.0015; KEV/CHANNEL 0.25033, ZERO -0.735

EXP1 0.03953+/- 0.0000 EXP2 1.50000+/- 0.9935

NQFIT 0.999 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/-

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	956.297	238.611	0.009	39932.	3.4782E+04	2.938	0.000
2	965.440	240.900	0.056	5744.	4.5392E+03	7.760	0.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
947	236.283	1	-34.83	-31.43	-33.84	-0.29
948	236.533	2	66.25	69.77	47.89	0.41
949	236.784	3	67.58	70.01	15.76	0.13
950	237.034	4	164.39	167.54	-6.88	-0.06
951	237.284	5	813.17	816.07	278.52	2.34
952	237.535	6	1213.63	1215.48	-11.72	-0.09
953	237.785	7	2519.30	2522.94	25.79	0.20
954	238.036	8	3977.26	3979.28	-202.87	-1.54
955	238.286	9	5888.28	5890.35	-0.68	-0.01
956	238.536	10	6990.28	6991.33	133.73	0.94
957	238.787	11	6537.37	6538.55	-38.83	-0.27
958	239.037	12	5451.38	5451.03	173.11	0.43
959	239.288	13	3240.36	3240.93	-220.48	-1.34
960	239.538	14	1981.13	1981.98	17.58	0.34
961	239.788	15	968.84	968.26	-45.24	-0.21
962	240.039	16	824.49	824.66	153.63	0.85
963	240.289	17	625.10	626.16	-40.07	-0.25
964	240.540	18	923.97	923.00	69.26	0.87
965	240.790	19	1007.97	1007.97	22.16	0.32
966	241.040	20	788.36	788.93	-159.48	-1.34
967	241.291	21	813.13	813.98	19.58	0.34
968	241.541	22	527.84	527.26	-9.24	-0.21
969	241.791	23	414.49	414.51	100.63	0.85
970	242.042	24	267.10	267.10	112.07	0.25
971	242.292	25	104.97	104.97	44.26	0.38

Fig. 5-1 (continued).

Group 4 includes 372.8 to 377.3 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
1492	372.8000	377.3000	1492.1995	375.0030	-0.7354	0.2503

Results from group 4 (3 iterations)

QFIT 0.482; FWHM 1.67533+/- 0.0015; KEV/CHANNEL 0.25033, ZERO -0.735

EXP1 0.03953+/- 0.0000 EXP2 1.50000+/- 0.9935

NQFIT 0.984 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/-

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	1500.847	374.965	0.009	117856.	5.4682E+03	2.938	0.000
2	1507.071	376.523		1358.	6.2723E+01	78.760	1.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
1492	372.750	1	164.83	179.43	19.84	0.10
1493	373.000	2	655.25	669.77	222.89	1.17
1494	373.251	3	753.58	768.01	-163.76	-0.86
1495	373.501	4	2265.39	2279.54	180.88	0.93
1496	373.751	5	3970.17	3983.83	36.52	0.18
1497	374.002	6	6592.63	6605.48	-61.72	-0.30
1498	374.252	7	9948.30	9959.94	-63.79	-0.30
1499	374.502	8	13255.26	13265.28	-74.87	-0.34
1500	374.753	9	15813.28	15821.35	68.68	0.30
1501	375.003	10	16493.28	16499.33	60.73	0.27
1502	375.253	11	15217.37	15221.55	28.83	0.13
1503	375.504	12	12557.38	12560.03	95.11	0.43
1504	375.754	13	8711.36	8712.93	-282.48	-1.34
1505	376.004	14	5950.13	5950.98	62.58	0.31
1506	376.255	15	3478.84	3479.26	42.24	0.21
1507	376.505	16	2025.49	2025.66	164.63	0.85
1508	376.755	17	860.10	860.16	-48.07	-0.25
1509	377.006	18	251.97	252.00	-166.26	-0.87
1510	377.256	19	295.97	295.97	61.16	0.32

Group 5 includes 410.0 to 418.0 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
1641	410.0000	418.0000	1640.7705	375.0021	-0.8421	0.2504

Results from group 5 (2 iterations)

QFIT 1.473; FWHM 1.73778+/- 0.0012; KEV/CHANNEL 0.25033, ZERO -0.735

EXP1 0.04971+/- 0.0000 EXP2 1.50000+/- 1.0093

NQFIT 1.654 EXP3 0.00000+/- 0.0000 EXP4 0.00000+/-

Peak	Channel	Energy	Error	Counts	Gammas/min	Pcterr	Qfit
1	1645.021	411.055		0.	0.0000E+00	200.000	1.000
2	1655.265	413.619	0.008	118821.	4.9756E+03	2.735	0.000
3	1663.661	415.721	0.043	22818.	9.5086E+02	5.050	0.000

CHANNEL	ENERGY	INDEX	YNET	RECONSTRUCT	RESIDUALS	STD DEV
1641	410.049	1	52.10	54.68	43.11	0.24
1642	410.299	2	7.60	10.18	3.47	0.02
1643	410.549	3	15.96	18.53	6.60	0.04

Fig. 5-1 (continued).

1644	410.800	4	-351.26	-348.67	-311.35	-1.76
1645	411.050	5	-436.43	-433.84	-408.64	-2.31
1646	411.300	6	-186.85	-184.26	-274.30	-1.54
1647	411.551	7	5.69	8.28	-293.11	-1.65
1648	411.801	8	548.47	551.06	-232.00	-1.29
1649	412.051	9	1617.35	1619.91	-109.19	-0.60
1650	412.301	10	3243.08	3245.58	-78.93	-0.42
1651	412.552	11	5994.04	5996.43	236.84	1.22
1652	412.802	12	8683.91	8686.14	-47.29	-0.24
1653	413.052	13	12069.46	12071.47	97.88	0.47
1654	413.303	14	14500.56	14502.31	-78.61	-0.37
1655	413.553	15	15926.60	15928.05	-6.80	-0.03
1656	413.803	16	15679.82	15680.99	81.53	0.37
1657	414.054	17	13667.12	13668.04	-16.77	-0.08
1658	414.304	18	10744.75	10745.47	-142.24	-0.69
1659	414.554	19	8129.06	8129.63	23.57	0.12
1660	414.805	20	5775.54	5776.01	-89.08	-0.46
1661	415.055	21	4768.25	4768.63	223.85	1.17
1662	415.305	22	3986.09	3986.39	135.98	0.72
1663	415.556	23	3539.51	3539.75	20.35	0.11
1664	415.806	24	2836.86	2837.05	-347.13	-1.87
1665	416.056	25	3017.91	3018.04	152.35	0.82
1666	416.307	26	2170.00	2170.10	-80.41	-0.44
1667	416.557	27	1413.04	1413.11	-183.19	-1.01
1668	416.807	28	1337.40	1337.45	243.10	1.34
1669	417.058	29	701.63	701.67	82.11	0.46
1670	417.308	30	473.05	473.08	137.43	0.77
1671	417.558	31	616.09	616.10	401.21	2.23
1672	417.809	32	253.15	253.16	165.16	0.92
1673	418.059	33	584.07	584.07	476.95	2.65

Group 6 includes 580.4 to 586.1 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
2321	580.4000	586.1000	2321.5176	583.2737	-0.7354	0.2503

By simple integration of region: 2324 to 2342

Peak chan = 2332.15; Net counts = 819552. +- 0.17%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	2332.149	583.061	819552.	2.6249E+04	2.057

Group 7 includes 724.6 to 730.5 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
2898	724.6000	730.5000	2897.5701	727.5864	-0.7354	0.2503

By simple integration of region: 2898 to 2921

Peak chan = 2908.28; Net counts = 161715. +- 0.84%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	2908.279	727.281	161715.	4.5532E+03	1.978

Fig. 5-1 (continued).

Group 8 includes 738.9 to 746.6 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
2955	738.9000	746.5600	2954.6960	742.2304	-0.7354	0.2503

By simple integration of region: 2955 to 2981
 Peak chan = 2970.15; Net counts = 787600. +- 0.17%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	2970.147	742.768	787600.	2.1933E+04	1.779

Group 9 includes 760.7 to 772.9 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
3042	760.7000	772.9000	3041.7827	766.8875	-0.7354	0.2503

By simple integration of region: 3042 to 3091
 Peak chan = 3064.55; Net counts = 3427010. +- 0.08%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	3064.555	766.401	3427010.	9.3931E+04	1.740

Group 10 includes 783.0 to 788.8 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
3131	783.0000	788.8000	3130.8667	785.9122	-0.7354	0.2503

By simple integration of region: 3131 to 3154
 Peak chan = 3143.95; Net counts = 511309. +- 0.18%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	3143.952	786.276	511309.	1.3839E+04	1.723

Group 11 includes 858.0 to 863.5 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
3430	858.0000	863.5000	3430.4766	860.6343	-0.7354	0.2503

By simple integration of region: 3430 to 3452
 Peak chan = 3441.35; Net counts = 110915. +- 0.54%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	3441.345	860.721	110915.	2.8791E+03	1.716

Group 12 includes 310.3 to 314.3 keV

St-Ch	Energy	End energy	start	Refen	Zero	Gain
1242	310.2500	314.2500	1242.3247	312.1713	-0.7354	0.2503

By simple integration of region: 1242 to 1258
 Peak chan = 1248.58; Net counts = 270616. +- 0.59%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	1248.578	311.815	270616.	1.6104E+04	3.341

Fig. 5-1 (continued).

Group 13 includes 149.8 to 155.1 keV
 Recalibrate Gain using energy standards at 152.680 and 766.410 keV
 CALIB searching 41 chans from 592 for 152.7 keV peak
 CALIB searching 58 chans from 3035 for 766.4 keV peak
 St-Ch Energy End energy start Refen Zero Gain
 601 149.8000 155.1000 601.3593 152.4637 -0.7379 0.2503
 By simple integration of region: 601 to 623
 Peak chan = 612.90; Net counts = 2067769. +- 0.13%

Peak	Channel	Energy	Counts	Gammas/min	Pcterr
1	612.896	152.688	2067769.	2.5301E+06	9.337

SUMMARY OF PEAK RESULTS ON 13 GROUPS

Peak	Channel	Energy	Counts	Gammas/min	Pcterr	Qfit
1	612.896	152.688	2067769.	2.5301E+06	9.337	0.000
2	806.000	201.028	60023.	1.2043E+04	6.027	0.000
3	833.833	207.995	224313.	3.8849E+04	5.485	0.000
4	955.884	238.547	236024.	2.5289E+04	4.521	0.000
5	965.440	240.900	5744.	4.5392E+03	6.916	1.000
6	1248.578	311.815	270616.	1.6104E+04	3.341	0.000
7	1500.847	374.965	117856.	5.4682E+03	2.938	1.000
8	1507.071	376.523	1358.	6.2723E+01	78.760	1.000
9	1645.021	411.055	0.	0.0000E+00	200.000	1.000
10	1655.265	413.619	118821.	4.9756E+03	2.735	1.000
11	1663.661	415.721	22818.	9.5086E+02	5.050	1.121
12	2332.149	583.061	819552.	2.6249E+04	2.057	0.000
13	2908.279	727.281	161715.	4.5532E+03	1.978	0.000
14	2970.147	742.768	787600.	2.1933E+04	1.779	0.000
15	3064.555	766.401	3427010.	9.3931E+04	1.740	0.000
16	3143.952	786.276	511309.	1.3839E+04	1.723	0.000
17	3441.345	860.721	110915.	2.8791E+03	1.716	0.000

Results for MAR3B8.WH8 were inserted in file PU238.RST

PU	DELP	ESLP	DELSLP	ECURV	DELCURV
3.000	0.000	0.000000	0.000000	0.000000	0.000000

QFIT =108.64

2.936	-0.065	0.000000	0.000000	0.000000	0.000000
-------	--------	----------	----------	----------	----------

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	-1.1	1.804E-01	1.353E+00
208.000	38850.	0.000467	20.5	2.718E-01	1.000E+00
238.600	25290.	0.000869	-9.9	3.119E-01	8.754E-01
375.000	5191.	0.006136	-0.5	3.627E-01	5.678E-01
376.600	64.	0.019925	0.0	3.635E-01	5.655E-01
413.700	4977.	0.007227	0.5	3.555E-01	5.174E-01
582.900	26250.	0.001799	3.2	3.013E-01	3.752E-01
727.400	4554.	0.010763	0.3	2.589E-01	3.057E-01

Fig. 5-1 (continued).

742.800	21934.	0.002467	-0.2	2.547E-01	2.998E-01
766.400	93932.	0.000588	1.4	2.489E-01	2.913E-01
786.300	13840.	0.004027	-1.0	2.441E-01	2.846E-01
860.500	2880.	0.019430	3.1	2.283E-01	2.620E-01

QFIT = 6.78

4.135 1.724 -0.000120 -0.000137 0.000000 0.000000

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	3.6	1.843E-01	1.353E+00
208.000	38850.	0.000467	0.0	2.771E-01	1.000E+00
238.600	25290.	0.000869	-1.9	3.172E-01	8.754E-01
375.000	5192.	0.006136	0.0	3.659E-01	5.678E-01
376.600	64.	0.019925	0.0	3.667E-01	5.655E-01
413.700	4977.	0.007227	0.0	3.582E-01	5.174E-01
582.900	26250.	0.001799	1.8	3.027E-01	3.752E-01
727.400	4554.	0.010763	-1.6	2.598E-01	3.057E-01
742.800	21934.	0.002467	-0.5	2.555E-01	2.998E-01
766.400	93932.	0.000588	1.1	2.497E-01	2.913E-01
786.300	13840.	0.004027	-1.4	2.449E-01	2.846E-01
860.500	2880.	0.019430	1.2	2.290E-01	2.620E-01

QFIT = 5.36

5.287 1.484 -0.000221 -0.000110 0.000000 0.000000

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	3.0	1.318E-01	1.362E+00
208.000	38850.	0.000467	0.0	2.014E-01	1.000E+00
238.600	25290.	0.000869	-1.3	2.368E-01	8.722E-01
375.000	5177.	0.006136	0.1	3.060E-01	5.564E-01
376.600	64.	0.019925	0.0	3.072E-01	5.540E-01
413.700	4977.	0.007227	-0.1	3.050E-01	5.046E-01
582.900	26250.	0.001799	1.4	2.660E-01	3.583E-01
727.400	4554.	0.010763	-1.9	2.285E-01	2.866E-01
742.800	21934.	0.002467	-0.5	2.245E-01	2.805E-01
766.400	93932.	0.000588	1.2	2.192E-01	2.718E-01
786.300	13840.	0.004027	-1.2	2.148E-01	2.647E-01
860.500	2880.	0.019430	1.4	2.000E-01	2.414E-01

QFIT = 5.19

6.086 0.916 -0.000259 -0.000040 0.000000 0.000000

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	2.9	1.037E-01	1.370E+00
208.000	38850.	0.000467	0.0	1.584E-01	1.000E+00
238.600	25290.	0.000869	-1.2	1.880E-01	8.695E-01
375.000	5166.	0.006136	0.1	2.612E-01	5.469E-01
376.600	64.	0.019925	0.0	2.625E-01	5.445E-01
413.700	4977.	0.007227	-0.1	2.641E-01	4.939E-01
582.900	26250.	0.001799	1.4	2.365E-01	3.442E-01
727.400	4554.	0.010763	-2.0	2.033E-01	2.706E-01
742.800	21934.	0.002467	-0.5	1.996E-01	2.644E-01
766.400	93932.	0.000588	1.2	1.946E-01	2.554E-01

Fig. 5-1 (continued).

786.300	13840.	0.004027	-1.2	1.905E-01	2.482E-01
860.500	2880.	0.019430	1.4	1.767E-01	2.243E-01
QFIT = 5.18					
6.385	0.311	-0.000268	-0.000008	0.000000	0.000000
Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	2.9	9.026E-02	1.373E+00
208.000	38850.	0.000467	0.0	1.377E-01	1.000E+00
238.600	25290.	0.000869	-1.2	1.639E-01	8.684E-01
375.000	5159.	0.006136	0.1	2.366E-01	5.432E-01
376.600	64.	0.019925	0.0	2.381E-01	5.408E-01
413.700	4977.	0.007227	-0.1	2.415E-01	4.898E-01
582.900	26250.	0.001799	1.4	2.210E-01	3.388E-01
727.400	4554.	0.010763	-2.1	1.908E-01	2.645E-01
742.800	21934.	0.002467	-0.4	1.873E-01	2.583E-01
766.400	93932.	0.000588	1.2	1.826E-01	2.492E-01
786.300	13840.	0.004027	-1.2	1.788E-01	2.419E-01
860.500	2880.	0.019430	1.3	1.658E-01	2.177E-01
QFIT = 5.18					
6.410	0.026	-0.000267	0.000000	0.000000	0.000000
Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	2.9	8.609E-02	1.373E+00
208.000	38850.	0.000467	0.0	1.313E-01	1.000E+00
238.600	25290.	0.000869	-1.2	1.564E-01	8.682E-01
375.000	5157.	0.006136	0.1	2.286E-01	5.424E-01
376.600	64.	0.019925	0.0	2.300E-01	5.400E-01
413.700	4977.	0.007227	-0.1	2.341E-01	4.889E-01
582.900	26250.	0.001799	1.4	2.161E-01	3.376E-01
727.400	4554.	0.010763	-2.1	1.870E-01	2.632E-01
742.800	21934.	0.002467	-0.4	1.836E-01	2.569E-01
766.400	93932.	0.000588	1.2	1.790E-01	2.478E-01
786.300	13840.	0.004027	-1.2	1.753E-01	2.405E-01
860.500	2880.	0.019430	1.3	1.626E-01	2.163E-01
QFIT = 4.98					
6.410	0.000	-0.000415	-0.000167	0.000000	0.000000
Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	2.6	8.574E-02	1.373E+00
208.000	38850.	0.000467	0.0	1.308E-01	1.000E+00
238.600	25290.	0.000869	-1.7	1.558E-01	8.682E-01
375.000	5157.	0.006136	0.1	2.280E-01	5.425E-01
376.600	64.	0.019925	0.0	2.294E-01	5.400E-01
413.700	4977.	0.007227	0.0	2.336E-01	4.890E-01
582.900	26250.	0.001799	1.8	2.157E-01	3.376E-01
727.400	4554.	0.010763	-1.8	1.868E-01	2.633E-01
742.800	21934.	0.002467	-0.3	1.834E-01	2.570E-01
766.400	93932.	0.000588	1.2	1.789E-01	2.479E-01
786.300	13840.	0.004027	-1.3	1.751E-01	2.406E-01
860.500	2880.	0.019430	0.9	1.625E-01	2.163E-01
QFIT = 3.98					
6.410	0.000	-0.000430	-0.000016	0.000000	0.000000

Fig. 5-1 (continued).

Energy	Gammas	Wt. Fctr.	Residual	Tot. Eff.	Det. Eff.
152.680	2530082.	0.000004	2.6	8.649E-02	1.385E+00
208.000	38850.	0.000467	0.0	1.308E-01	1.000E+00
238.600	25290.	0.000869	-1.7	1.551E-01	8.644E-01
375.000	5157.	0.006136	0.1	2.235E-01	5.319E-01
376.600	64.	0.019925	0.0	2.249E-01	5.294E-01
413.700	4977.	0.007227	0.0	2.283E-01	4.780E-01
582.900	26250.	0.001799	1.8	2.097E-01	3.283E-01
727.400	4554.	0.010763	-1.8	1.828E-01	2.576E-01
742.800	21934.	0.002467	-0.3	1.797E-01	2.518E-01
766.400	93932.	0.000588	1.2	1.757E-01	2.435E-01
786.300	13840.	0.004027	-1.3	1.724E-01	2.368E-01
860.500	2880.	0.019430	0.9	1.616E-01	2.152E-01

PU-238 gamma-ray
Assay results for sample: TEST

QFIT = 3.98

ISOTOPIC ANALYSIS AT
COUNT TIME

RATIOS	WT.PCT.	PCTERR	Milliwatts/gm
Pu238 = 5.9076457	83.56667	1.05	473.957
Pu239 = 1.0000000	14.14551	5.48	0.273
Pu240 Operator input value	1.96700		0.140
Pu241 = 0.0226791	0.32081	12.62	0.011
Pu242 Operator input value	0.10000		0.000
Am241 = 0.0025335	0.03584	156.42	0.041
			Total = 474.421 +/-1.42%

PU-238 isotopic gamma assay - Run Type: Fromdisk

Input file: MAR3B8.WH8	Measurement Date: 22-MAY-91 11:10:12
Operator ID: WDR	Current Date: 22-MAY-91 13:42:11
Constants File: PARMTR.WH8	Constants Date: 1-MAY-91 12:54:49
Live time (sec): 5222.	Clock time (sec): 8000.

Result = 474.4 +/- 1.4 % milliwatts/gm total Pu

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.WH8 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.WH8 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.WH8 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.WH8
```

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

```
Enter password ->
```

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

```
PARMTR.WH8   was written  2-MAR-91  10:39:43  by WDR
```

CODE-OPTION

```
HE - HElp
MC - Measurement Control
PT - Preset Time
PW - PassWords
DV - Default Values
SZ - Stabilizer settings
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    = 2.6000    ->
Hist std    = 0.3000    ->
```

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>	<p>This option allows the user to change the plutonium-240 default value. A typical dialog for this option is as follows:</p> <pre> 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 </pre> <p>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.</p> <p>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 here.</p>
<u>Read Constants from Disk (RD)</u>	<p>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:</p> <p>The constants file read was: PARTMR.WH8</p> <p>Do you want to select another constants file (Y/N) -> Y</p>

PARAMETER CHANGE OPTIONS (CONTINUED)

Option	Description
<u>Read Constants from</u> <u>Disk (RD)</u> (CONTINUED)	The current constants files are: 1 PARMTR.WH8 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.WH8. 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.

Stabilizer settings (SZ) This option allows the user to set or change the settings of the Canberra 8232 stabilizer. A typical dialog for this options is as follows:

Zero pk	= 0000	-> 612
Zero wnd	= 0000	-> 11
Zero rng	= 0000	->0.125
Gain pk	= 0000	->3063
Gain wnd	= 0000	-> 15
Gain rng	= 0000	->0.125

The zero stabilizer should be set to the 152.7-keV peak at channel 612 with a window width of 11 channels. The analog range for the zero stabilizer should be set to 0.125. The gain stabilizer should be set to the 766.4-keV peak at channel 3063 with a window width of 15 channels. Its analog range should also be set to 0.125.

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.WH8 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.

Table 6-1. PARMTR.WH8 file obtained with LI option in PU238_CHNG program.

6-JUN-91 16:02:15

SY:PARMTR.WH8 TEST CONSTANTS FILE FOR FIRST

WRITTEN 22-MAR-91 16:32:10 by WDR

MEASUREMENT CONTROL

	BIAS	PRECISION
INTERVAL =	1.00000	10.0000
REFERENCE =	2.55000	
STANDARD DEV. =	0.300000	
CYCLES =		5

DEFAULT ANALYSIS VALUES

Pu-240 abundance (wt. %) = 2.00
Pu-242 abundance (wt. %) = 0.10

Stabilizer settings for zero and gain

	Zero settings	Gain settings
Peak positions	612	3063
Peak windows	11	15
Analog ranges	0.125000	0.125000

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 WHC_ASY238 program.

EXit from Changes (EX)

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 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 peak at 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 ARTICLE

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

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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

Fig. 3-1 (page 3-4) shows a photograph of the system 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 left-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.

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