Uranium Concentration Monitor Manual 2300 System

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CONTENTS

ABSTRACT	1
INTRODUCTION	2
Overview	2
Routine Use	4
EQUIPMENT SUMMARY	5
Detectors and Electronics	5
Adjustment of Analog Electronics	11
Gain	11
Stabilization	13
Fabricated Hardware	14
Working Standards and Radioisotopic Sources	16
MICROCOMPUTER HARDWARE	17
Front Panel	17
PDAC LED Display	17
Restart Button	17
Keypad	17
Remote AGD Displays	18
Printer	18
RS-422 Communication	18
Cathode-Ray Tube	19
SOFTWARE OPERATION	20
Use of the Keypad	20
Use of the Menu	20
Use of the CRT	33
CRT Features	33
CRT Operations from the Keypad	35
Error Messages	37
Error Messages on the PDAC LED Display	37
Error Messages on the Printout	38

CONTENTS (cont)

CALIBRATION AND MEASUREMENT CONTROL	39
The Calibration Curve	39
Normalizing the Calibration	39
Direct Normalization Measurement with Reference	
Solution in Standard Cell	41
Normalization Measurement by Uranium Foil Assay . . .	46
Background Measurement and Adjustment	49
Recommended Measurement Control Procedures	51
Weekly Procedure	51
Monthly Procedure	52
Yearly Procedure	52
Logging Measurement Control Data	53
SOFTWARE SUMMARY	54
Overview	54
EVALUATION RESULTS	59
Summary	59
REFERENCES	62
APPENDIX A: CALCULATED 186-keV COUNT RATES VS ELEMENTAL URANIUM CONCENTRATION	A.1
APPENDIX B: SOURCE LISTINGS OF DATA ANALYSIS AND OUTPUT SUBROUTINES	B.1

URANIUM CONCENTRATION MONITOR MANUAL 2300 SYSTEM

by

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ABSTRACT

This manual describes the design, operation, and procedures for measurement control for the automated uranium concentration monitor on the 2300 solvent extraction system at the Oak Ridge Y-12 Plant. The nonintrusive monitor provides a near-real time readout of uranium concentration at two locations simultaneously in the solvent extraction system for process monitoring and control. Detectors installed at the top of the extraction column and at the bottom of the backwash column acquire spectra of gamma rays from the solvent extraction solutions in the columns. Pulse-height analysis of these spectra gives the concentration of uranium in the organic product of the extraction column and in the aqueous product of the solvent extraction system. The visual readouts of concentrations for process monitoring are updated every 2 min for both detection systems. Simultaneously, the concentration results are shipped to a remote computer that has been installed by Y-12 to demonstrate automatic control of the solvent extraction system based on input of near-real time process operation information.

OVERVIEW

The uranium concentration monitors for the 2300 solvent extraction system consist of two NaI(Tl)-based detection systems and electronics for automated, continuous assay of uranium concentration monitored nondestructively and nonintrusively at two locations on the Y-12 secondary solvent extraction columns. Two enlarged alphanumeric gas-discharge (AGD) displays give a digital readout of each result of the concentration assay in near-real time for manual process control. The assay results are simultaneously shipped to a remote computer that accepts and interprets real-time operation data and automatically controls the solvent extraction system. Monitor operation and readout are independent of the status of the remote computer, installed initially as part of a demonstration effort by the Y-12 Division of Development.

The 186-keV gamma ray of ^{235}U is the signature for the concentration assay. The assay assumes a known ^{235}U enrichment. The two independent pulse-height spectra are acquired and stored simultaneously by multiplexing the two analog signals into one analog-to-digital converter (ADC) and then by routing the digitized spectra into separate halves of the multichannel analyzer (MCA) memory. The microprocessor-based MCA automates the data acquisition and readout of results, and provides options for real-time spectral display, generation of a hard copy of the results, and input of data reduction and analysis parameters.

OVERVIEW
(cont)

An ^{241}Am radioisotopic source is attached to each NaI(Tl) detector in fixed geometry. The net area of the ^{241}Am 60-keV photopeak normalizes the 186-keV photopeak area in each spectrum so that count rate losses do not bias the assay results. The 60-keV photopeak, dominating the count rate in each spectrum, is also used for analog spectrum gain stabilization.

The detection system (through the analog electronics) and the assay method are identical to those of the EUREKA instrument.¹⁻⁴ Refer to the EUREKA Operation Manual⁵ in the appropriate sections below for details of redundant designs.

The computer-based MCA, the PDAC-100, is a Los Alamos prototype instrument. This manual describes PDAC software specific to the 2300 monitor functions and the MCA operation features that are part of the 2300 monitor software package. A separate manual⁶ describes the PDAC-100 hardware and operating system.

The monitor operates unattended in the continuous assay mode (120 s/cycle) on the organic product of the extraction column (detector A) and on the aqueous product of the solvent extraction system (detector B). Relocation of the monitor detectors to other points on the solvent extraction system is possible with appropriate changes in the concentration assay parameters.

ROUTINE USE

The process operator uses the monitors by visual observation of the uranium concentration on the two AGD displays. These displays, labeled "2310 ORGANIC" and "2314 AQUEOUS," are on the third floor adjacent to the operations logging area between the 1300 and 2300 solvent extraction systems. The readout of the corresponding uranium concentration (left side of each AGD display), in grams per liter to the nearest tenth, is updated once every 2 min for the normal assay cycle. The right side of each AGD display gives the time remaining, to the nearest second, for the present cycle.

Use of monitors for automatic control of the solvent extraction system requires reading specific information from an alphanumeric data file. At the end of each assay cycle, the monitor ships the file by RS-422 communications to a remote computer responsible for automation of the control.

DETECTORS AND ELECTRONICS

The NaI(Tl) detectors are 3.2-cm-diam by 1.3-cm-thick crystals integrally mounted to 12-pin, 3.8-cm-diam photomultiplier tubes. The tube bases contain preamplifiers, whose power is tapped from the high-voltage input to the base. The pre-amplifier signals are amplified and shaped by linear amplifiers that use an internal single-channel analyzer for analog gain stabilization. The amplifier outputs are multiplexed into a single ADC, and the digitized spectra are stored in separate halves of the 1024-channel MCA memory. A hard-copy unit prints both assay results, reduced data, and the assay parameters. Two remote digital readouts display the concentration result from each assay in near-real time. RS-422 communications lines ship the assay results (the complete print file) to a remote computer.

Table I lists the electronics components. Figure 1 is a block diagram of the electronics and detectors. Table II gives the initial electronics settings. Figure 2 is a photograph of the electronics inside the environmentally controlled cabinet adjacent to the solvent extraction system. Instrument air continuously feeds the environmental cabinet.

Figure 3 shows the hardware modifications to the PDAC-100 required to route two spectra into separate halves of the analyzer memory. Figure 4 shows the wiring diagrams for the remote displays, printer, and RS-422 communications.

Fig. 1. Block diagram of the electronics and detectors.

TABLE I
ELECTRONICS COMPONENTS

Model No.	Component	Manufacturer	No. of Units
1.25M.5Q/1.5	NaI(Tl) detector	Bicron	2
PA-12-X	Preamplifier base	Bicron	2
NA-25	High voltage supply	Harshaw	1
4001C/402D	NIM power bin	EG&G-Ortec	1
NA-23	Stabilized amplifier	Harshaw	2
8222	Multiplexer-router	Canberra	1
3075	ADC	Canberra	1
PDAC-100	MCA	Prototype (Los Alamos National Laboratory)	1
APP-48	Printer	Datel-Intersil	1
W-416	LED display	Cherry	2

TABLE II
INITIAL ELECTRONICS SETTINGS

NA-23 Stabilized Amplifier				
Polarity	Normal			
Output	Bipolar			
Modes	Track, Differential			
Detector	CG	FG	E	ΔE
A	40	0.90	72	70
B	160	0.55	67	70

High Voltage Supply	ADC	Multiplexer-Router
650 V	Range 1 k	Module 1
	Gain 512	Memory 1 k
	OFF 0	Expander OFF
	LLD 11	Inputs 2
	Modes PHA	
	ANTI

Fig. 2. Photograph of the electronics inside the environmental enclosure (with front Plexiglas cover removed).

Fig. 3. Illustration of the interconnections between the PDAC-100 MCA, the 8075 ADC, and the 8222 mixer-router.

Fig. 4. Wiring schematics for operator displays, printer, and RS-422 communications.

ADJUSTMENT OF ANALOG
ELECTRONICS

Replacement of a detector or amplifier or the nonroutine occurrence of a large change in the electronic gain of an existing detection system requires readjustment of the analog electronics.

Gain

Under normal circumstances, the NA-23 stabilized amplifier should adequately compensate for changes in gain in the detectors or in the amplifier itself. However, if drifts become large enough to exceed the tracking range of the NA-23, some adjustment of amplifier gain might be necessary. Adjust the gain if one of the two red lights (indicating that the NA-23 tracking range is exceeded) flickers on and off or stays on, or if a new detector or a new NA-23 amplifier is installed. Minimize the airflow into the environmental cabinet by closing the Plexiglas cover immediately after each adjustment because a change of temperature in the electronics will also shift the gain.

Use the following procedure to adjust the gain:

- (1) Switch the NA-23 TRACK/DISABLE switch to DISABLE.
- (2) Insert the uranium foil into the detector holder and, with the detector high voltage on, examine the linear output of the NA-23 with an oscilloscope. The 60-keV photopeak pulse height should be approximately 1.75 V.

ADJUSTMENT OF ANALOG
ELECTRONICS

Gain
(cont)

- (3) Record the original amplifier fine gain setting. Then, if necessary, carefully adjust the amplifier fine gain to achieve the desired 1.75-V pulse height.
- (4) Switch the NA-23 TRACK/DISABLE switch to TRACK.
- (5) Carefully fine tune the amplifier fine gain to achieve an alternate flickering of the two green lights indicating that tracking operation is mid-range. Push the RESET button on the NA-23 after each adjustment of the fine gain.
- (6) Verify the proper gain setting by performing a foil assay. The 60-keV peak centroid should be in the prescribed channel (100.0 ± 0.5 for detector A and 612 ± 0.5 for detector B). Check the foil P2' value to verify a constant normalization. (Refer to NORMALIZATION MEASUREMENT BY URANIUM FOIL ASSAY, pp. 46-49 under CALIBRATION AND MEASUREMENT CONTROL.)
- (7) Record the new amplifier fine gain setting in the monitor log book. (Refer to Logging Measurement Control Data, p. 53 under CALIBRATION AND MEASUREMENT CONTROL.)

ADJUSTMENT OF ANALOG
ELECTRONICS

(cont)

Stabilization

Drifts may occur with time in the stabilizer threshold (adjustable with the "E" control potentiometer of the NA-23 amplifier). The result is a gradual shift in the measured centroid of the 60-keV photopeak. The centroid channel should be 100 ± 2 for detector A and 612 ± 2 for detector B. The monitor code flags shifts outside these limits. Under no circumstances should frequent (that is, monthly) adjustments for these effects be required.

When an adjustment is required [that is, when $CENT(DEV)$, the deviation in the 60-keV centroid channel, reaches or exceeds ± 2 for either detector], the following procedures are recommended:

- (1) Connect and power up the printer.
- (2) Note the measured $CENT(DEV)$ in number of channels for the 60-keV photopeak of the detector that requires adjustment. Compute the approximate magnitude of the adjustment using the formula

$$\text{Adjustment (turns)} = [CENT(DEV)/100] \cdot E(\text{turns})$$

where E is the "E" control potentiometer setting. The required adjustment is a very small fraction of a full turn.

ADJUSTMENT OF ANALOG
ELECTRONICS

Stabilization

(cont)

- (3) Open the front panel of the electronics enclosure. Adjust "E." Close the Plexiglas panel immediately after making the adjustment.
- (4) With the detector mounted on the column and the uranium foil inserted in the slot of the detector shield, do a foil measurement and observe the 60-keV centroid listed in the printout.
- (5) Continue checking the 60-keV centroid to determine if (or how much) additional "E" adjustment is required and repeat steps (3) and (4) if necessary.
- (6) After the adjustment of "E" has established the required centroid for the 60-keV peak, repeat the foil assay. In the final printout, verify that the 60-keV centroid is within a few tenths of the desired channel. Then check the foil P2' value to verify a constant normalization.

FABRICATED HARDWARE

The fabricated hardware consists of stainless-steel-encased lead shields for the gamma-ray detectors, and stainless steel holders and brackets for mounting the detectors onto or adjacent to the columns.

The holder and bracket for detector A are affixed to external support structure so that the detector

FABRICATED HARDWARE
(cont)

views (through glass) the pure organic solution on the phase separator of the extraction column of the secondary solvent extraction system.

The holder and bracket for detector B mount directly on the backwash column of the secondary solvent extraction system so that the detector views (through stainless steel) the pure aqueous product solution in the inactive region at the bottom of the column.

Mechanical design drawings 68Y-155450, D-1 through D-4, specify the detector shields and holder-bracket hardware. Copies of these drawings appear in Appendix B, pages B1 through B4 of the EUREKA Operation Manual.⁵ Figure 5 shows detector B inside the lead shield mounted at the bottom of the 2300 backwash column for assay of the aqueous product solution.

Fig. 5. Detector B mounted at the bottom of the 2300 system backwash column.

**WORKING STANDARDS AND
RADIOISOTOPIC SOURCES**

Each NaI(Tl) detector is mounted in its shield with a 50-nCi ^{241}Am radioisotopic source (obtained from Isotope Products Laboratories, Type M, grade C) attached to the front of the detector in fixed geometry with respect to the crystal. The 60-keV gamma ray emitted by ^{241}Am is used to correct for count rate losses. The 60-keV gamma ray is also used for analog gain stabilization.

Each NaI(Tl) detector is equipped with an enriched uranium metal foil (working standard) mounted in a tungsten holder. The foils are 1.3 cm in diameter and 0.13 cm thick, and each contains 3 g of 97%-enriched uranium metal. The working standards are used to check the normalization of each detector calibration. Each tungsten holder mounts in a slot in the collimator portion of the detector shield, the uranium foil positioned approximately 5 cm in front of the crystal. The two foils are not identical; consequently, they cannot be interchanged.

FRONT PANEL

The front panel of the PDAC consists of the light-emitting diode (LED) display, the restart button (second of three buttons in a row above the keypad), and the keypad. Refer to Fig. 2.

PDAC LED Display

The 16-character LED display normally shows the uranium concentration computed from spectrum A at the end of the most recently completed cycle and the elapsed time for the current cycle. When the LOOK key is pushed, the display sequentially shows the date and time. If the user terminates the normal (assay) operation, then the LED displays menu options and prompts user input.

Restart Button

At power up, the program initializes all variables and starts the first assay cycle automatically. The restart button performs the same functions as a power up except that it does not clear the random-access memory (RAM). It can be used as a fast method of starting fresh with cycle 1. In this manual, the word "restart" refers to either a power up or the use of the restart button.

The two unlabeled buttons on either side of the restart button and the five buttons to the left of the keypad have no function.

Keypad

The 20-key keypad is the only input device on the monitor. Each key is labeled. Some keys have a dual purpose, one for numeric input in the menu mode and one for cathode-ray tube (CRT) operations during data acquisition. For example, the same

FRONT PANEL

Keypad (cont)

key is used for the decimal point and for changing the vertical scale (YSCL). To use the PDAC keypad, remove the Plexiglas panel on the front of the environmental cabinet. This is not intended during routine monitoring operations. Restrict the keypad use to needs associated with instrument setup and diagnostics.

REMOTE AGD DISPLAYS

The two remote 16-character enlarged AGD displays show the uranium concentration computed from spectrum A or B and the elapsed time for the current cycle. Each display is dedicated to one of the two monitor detectors.

PRINTER

The optional 48-character printer logs information about each assay cycle: date and time, regions-of-interest (ROIs) and associated uncertainties, reduced data, and concentration results. It also prints the values of system parameters whenever they are changed. Keep the printer covered and unplugged from the electronics bin and the ac power when not in use.

RS-422 COMMUNICATION

As another option, a 9600-baud RS-422 interface can communicate the monitor assay results to the PDP 11-23 computer. The output file is identical to that which is printed.

CATHODE-RAY TUBE

The optional CRT displays the gamma-ray spectra. It contains a 1024-channel display with intensified ROIs and alphanumerics showing display parameters. Use of the CRT requires connecting the X, Y, and Z connectors on the side of the environmental cabinet to the CRT display and powering up the display unit.

USE OF THE KEYPAD

Figure 6 shows an enlarged view of the keypad. During data acquisition, only the STOP and LOOK keys function. If the CRT is in use, the keys controlling the CRT also function. The only key recognized during the last 15 s of a cycle is STOP. The remaining keys are used in dialogues initiated by the menu.

STOP

Use the STOP key to stop data acquisition. Confirm by answering YES to the question STOP ACQ?. The menu then appears. In CRT wait mode, use the STOP key to end the pause after acquisition. Confirm by answering YES to the question STOP WAITING?. To activate the STOP while computation or printing are in progress (LED display reads "BUSY"), press STOP during the compute-print sequence after printout of ROIs.

LOOK

During data acquisition, use the LOOK key to view the current date and time, which appear on the LED display for 3 s. Other information displayed following the date and time display is not applicable to the 2300 monitor.

USE OF THE MENU

The menu is a set of questions (requiring a YES or NO response) providing choices on tasks. The answer NO causes the next menu question to appear. The answer YES causes the task to begin. When a task is finished, the menu appears from the top again.

Fig. 6. The PDAC keypad.

USE OF THE MENU

(cont)

Most of the keys on the PDAC keypad function in dialogues initiated by the menu. The following input conventions apply to use of the menu:

- When the LED display flashes, the program is waiting for a keypad response.
- When a question mark (?) appears (as in the menu choices), answer the question YES or NO; no other response is accepted.
- When a right bracket (>) appears, a numerical value is expected. To enter a numerical value, use the 0-9, decimal point (optional with integers), and minus keys. The digits appear on the LED display as you push the keys. To complete the entry, push ENT; the LED display is then cleared. After a mistake, push CLR and start over.

Questions appear in the menu in the following order:

START ASSAY?

Answer YES for continuous assay cycles, the normal mode of operation enabled automatically at restart. Cycling continues until the STOP key is pushed. The most recent concentration result and the elapsed time for the current cycle appear on the LED display during acquisition. At the end of each cycle, the data are analyzed, and a new data acquisition cycle commences simultaneously. Output (to LEDs, printer, and PDP 11-23, depending on device selection) follows the data analysis. Figure 7 illustrates the output file.

G/L(SIG) 121.73(0.67) 119.00(0.68)
COUNTS/SEC 2940.16 2517.93

RESLTN 7.2061 % 6.9189 %
P1 MEAN 100.50(0.00) 612.71(0.00)

P2'(SIG) 0.2332(0.0005) 0.1906(0.0005)
P1'(SIG) 945404.(1129.) 862995.(1115.)

1 BACKGROUND REGION(S) FOR 186 KEY PEAK (HB)

P2(SIG) 221358.96(487.56) 165036.96(412.40)
P1(SIG) 939166.25(1121.84) 857300.75(1108.23)

	DETECTOR A	DETECTOR B
H186	8179.	2520.
P186	229538.	167557.
L186	8179.	2520.
HB60	7999.	4703.
PK60	994227.	930023.
LB60	3472.	13034.

600 SECOND RUN ENDING 12/15/83 11:06

G/L(SIG) 124.12(0.69) 118.76(0.67)
COUNTS/SEC 2985.50 2558.56

RESLTN 7.2159 % 6.9418 %
P1 MEAN 100.50(0.00) 612.77(0.00)

P2'(SIG) 0.2352(0.0005) 0.1904(0.0005)
P1'(SIG) 957721.(1140.) 876951.(1123.)

1 BACKGROUND REGION(S) FOR 186 KEY PEAK (HB)

P2(SIG) 226204.96(492.66) 167540.93(415.74)
P1(SIG) 951401.71(1132.67) 871164.70(1116.20)

	DETECTOR A	DETECTOR B
H186	8256.	2650.
P186	234461.	170191.
L186	8256.	2650.
HB60	8324.	4691.
PK60	1008564.	944641.
LB60	3585.	13230.

600 SECOND RUN ENDING 12/15/83 10:56

Fig. 7. Sample printout of the results from two 600-s assay cycles.

USE OF THE MENU

(cont)

- CALIBRATE? Answer YES for continuous assay cycles. (The operation is identical to that following a YES response to "START ASSAY?")
- DATE/TIME? Answer YES to verify or change the date and time. If either is incorrect, answer NO to the question OK?, and enter the current month, day, year, hour, and minute (24-h clock) as prompted.
- CHANGE DEVICES? Answer YES to select which devices will be used with the system.
- CRT? Answer YES for a display of the spectrum on the optional CRT. Answer NO for normal operation. Answer NO if the CRT is not in use.
- WAIT MODE? Wait mode causes a pause after every cycle for viewing the spectrum. End the pause with the STOP key. This question appears only if the CRT is selected. Answer NO for normal operation.
- LP232? Answer YES to select the local printer to print results. Answer NO otherwise. Answer YES for normal operation.

USE OF THE MENU

CHANGE DEVICES?

(cont)

LP422?

Answer YES to transmit results to the PDP 11-23.
Answer NO otherwise. Answer YES for normal operation.

DUMP SPECTRUM?

Answer YES to print the 1024-channel spectrum on the line printer after each assay. Answer NO otherwise. Answer NO for normal operation.

REMOTE PANEL?

Answer NO (not applicable).

STRIP CHART?

Answer NO (not applicable).

REMOTE LEDS?

Answer YES to display the most recent concentration results on the remote AGDs. Answer NO otherwise. Answer YES for normal operation.

The device selections are then written to electrically alterable read-only memory (EAROM), where they are stored for the next restart.

CHANGE PARAMS?

Answer YES to view or change system parameters. Parameters appear in three groups. The first contains the miscellaneous constants. The other groups are parameters for measurement control and calibration constants; any group can be bypassed. Refer to Fig. 8 for a line printer listing of the typical parameters.

```

-----
P 9 = 0.751063E-01 0.555221E-01
P 8 = -0.155333E+01 -0.111083E+01
P 7 = 0.136631E+02 0.945527E+01
P 6 = -0.664702E+02 -0.444919E+02
P 5 = 0.195091E+03 0.126186E+03
P 4 = -0.353544E+03 -0.220558E+03
P 3 = 0.389666E+03 0.234045E+03
P 2 = -0.244013E+03 -0.139301E+03
P 1 = 0.967810E+02 0.627836E+02
P 0 = -0.938272E+01 -0.484948E+01
      A B
ORDER POLY B = 9 NORM = 0.176600E+02
ORDER POLY A = 9 NORM = 0.152799E+02

DLTA = 2.0000 2.0000
MEAN = 100.0000 611.9999
RESL = 7.5000 7.5000
DP-2 = 0.0009 0.0006

CP-2 = 1.0000 HLFY = 431.9999

SECONDS PER CYCLE = 600

1 BACKGROUND REGION(S) FOR 186 KEY PEAK (HB)

R86' 912 - 1002
P86' 762 - 852
L86' 912 - 1002
R60' 630 - 634
P60' 588 - 628
L60' 582 - 586
H186 400 - 490
P186 250 - 340
L186 400 - 490
HB60 121 - 125
PK60 72 - 119
LB60 66 - 70

```

CONSTANTS AS OF 12/15/83 10:45

Fig. 8. Sample printout of the parameter file.

USE OF THE MENU

CHANGE PARAMS?

(cont)

DEV/SG LIMITS?

Answer NO (not applicable).

MISC CONSTANTS?

Answer YES to change or view.

SEC/CY =

Seconds per cycle (clock time).

SG =

Not applicable; enter displayed value.

CP-2 =

Constant multiplying 186-keV background ROI total before subtraction from peak total.

DP-2 =

Background 186/60 subtracted from measured ratio for detector A (typically less than 0.001).

NOW B

DP-2 =

Background 186/60 subtracted from measured ratio for detector B (typically less than 0.001).

HLFY =

Half-life, in years, of normalization source (432.0 for ²⁴¹Am).

USE OF THE MENU

CHANGE PARAMS?
(cont)

MEAS CONTROL?
Answer YES to change or view.

RESL =
Allowed 60-keV photopeak resolution for
detector A (per cent). Typical value is 7%.

MEAN =
Expected centroid of the 60-keV photopeak for
detector A (channel). Typical value is 100.

DELTA =
Allowed delta around the centroid of the
60-keV photopeak for detector A (channels).
Typical value is 2.

NOW B

RESL =
Allowed 60-keV photopeak resolution for
detector B (per cent). Typical value is 7%.

MEAN =
Expected centroid of the 60-keV photopeak for
detector B (channel). Typical value is 612.

DELTA =
Allowed delta around the centroid of the
60-keV photopeak for detector B (channels).
Typical value is 2.

USE OF THE MENU

CHANGE PARAMS?
(cont)

CALIBRATION?
Answer YES to change or view.

POLY A FIRST

ORDR P =

Order of polynomial fit to calibration curve
for detector A. Typical value is 9.

NORM =

Normalization factor for detector A counting
efficiency. Typical values range from 15 to
20.

P0 =

Zero-order coefficient of polynomial fit to
calibration curve for detector A.

P1 =

First-order coefficient of polynomial fit to
calibration curve for detector A.

.
.
.
.
.
.

P(ORDR P) =

(ORDR P)-order coefficient of polynomial fit
to calibration curve for detector A.

NOW B

ORDR P =

(Analogous to ORDR P for POLY A).

USE OF THE MENU

CHANGE PARAMS?

CALIBRATION? (cont)

NORM =

(Analogous to NORM FOR POLY A).

P0 =

(Analogous to P0 FOR POLY A).

P1 =

(Analogous to P1 for POLY A).

.
. .
. .
. .
. .
. .

P(ORDR P) =

[Analogous to P(ORDR P) for POLY A].

To change a parameter, enter its new value on the keypad and push ENT. To retain the displayed value, push ENT. The new parameter file is printed out and written to EAROM. At this point, the menu will again display "START ASSAY?"

CHANGE ROIS?

Answer YES to view or change ROI channels. Input the left and then right channel for each ROI as follows:

LB60 L = Low background, 60 keV, detector A,
left channel.

USE OF THE MENU

CHANGE ROIS?
(cont)

LB60 R = Low background, 60 keV, detector A,
right channel.

PK60 L = Peak, 60 keV, detector A, left
channel.

PK60 R = Peak, 60 keV, detector A, right
channel.

HB60 L = High background, 60 keV, detector A,
left channel.

HB60 R = High background, 60 keV, detector A,
right channel.

L186 L = Low background, 186 keV, detector A,
left channel.

L186 R = Low background, 186 keV, detector A,
right channel.

P186 L = Peak, 186 keV, detector A, left
channel.

P186 R = Peak, 186 keV, detector A, right
channel.

H186 L = High background, 186 keV, detector
A, left channel.

H186 R = High background, 186 keV, detector
A, right channel.

USE OF THE MENU

CHANGE ROIS?
(cont)

L60' L = Low background, 60 keV, detector B,
left channel.

L60' R = Low background, 60 keV, detector B,
right channel.

P60' L = Peak, 60 keV, detector B, left
channel.

P60' R = Peak, 60 keV, detector B, right
channel.

R60' L = High background, 60 keV, detector B,
left channel.

R60' R = High background, 60 keV, detector B,
right channel.

L86' L = Low background, 186 keV, detector B,
left channel.

L86' R = Low background, 186 keV, detector B,
right channel.

P86' L = Peak, 186 keV, detector B, left
channel.

P86' R = Peak, 186 keV, detector B, right
channel.

R86' L = High background, 186 keV, detector
B, left channel.

USE OF THE MENU

CHANGE ROIS?

(cont)

R86' R = High background, 186 keV, detector B,
right channel.

ONE BK REGION?

This question chooses between using one or two background regions to determine the Compton continuum under the 186-keV peak. Better results are obtained with one region on the high-energy side of the peak for low-resolution detectors. Answer YES.

ON HIGH SIDE?

Answer YES.

To change the ROI channel, enter its new value on the keypad and push ENT. To retain the present value, push ENT. After all ROI channels have been displayed, they are printed out (Fig. 8) and then written to EAROM.

USE OF THE CRT

CRT Features

The CRT displays the counts in each channel of the gamma-ray spectrum (Fig. 9). Channel numbers range from 0 to 1023. Channel zero is an exception and contains the elapsed time of the data acquisition. Along the baseline a dot indicates every tenth channel, and a bright dot indicates every hundredth channel. The spectrum from detector A appears in channels 0 to 511 and the spectrum from detector B appears in channels 512 to 1023.

USE OF THE CRT
CRT Features
(cont)

Fig. 9. Sample CRT display of the gamma-ray spectra. The 1024 channels are displayed with a vertical full scale of 32768.

The numbers in the upper-left and -right corners indicate the left- and right-most channels that are displayed. An x-scale feature expands the x-axis by cycling in powers of 2, from 1024 to 64 channels. An offset feature allows the expansion to start at an arbitrary channel.

The number at the upper center, the maximum y-coordinate, indicates the vertical scale. (The maximum channel count is approximately three-fourths of this value to avoid overlap with the alphanumeric.) In the default autoscale mode, the scale value is set at 8192 at the start of acquisition and increases automatically in powers of 2 as necessary. The y-axis can be expanded manually in powers of 2 by the y-scale feature.

USE OF THE CRT

CRT Features (cont)

ROIs used in the calculations of uranium concentration are intensified on the display. For example, in Fig. 9 the intensified ROIs are the ^{241}Am photopeak ROI at 60 keV, its left and right background ROIs, the ^{235}U photopeak ROI at 186-keV, and its right background ROI for each spectrum (A and B).

The cursor appears on the CRT display as a bright vertical bar. It can be moved left or right one channel at a time or to an arbitrary channel. At the upper center of the CRT display, the cursor channel is shown with the counts in that channel. In Fig. 9 the cursor is at channel 280, which contains the value 3012. If the cursor falls within a ROI, the boundary channels of that ROI are shown, along with the integral counts within the entire ROI. In Fig. 9 the ROI containing channel 280 covers channels 250 through 340, and the integral within the ROI is 25001.

During acquisition, the CRT display is refreshed approximately every 10 s, or whenever a keypad entry changes the display.

CRT Operations from the Keypad

The following keys (Fig. 6) control the CRT display and are operational during data acquisition, except for the last 15 s of a cycle.

Moves the cursor one channel to the right.

USE OF THE CRT

CRT Operations
from the Keypad
(cont)

←

Moves the cursor one channel to the left.

XSCL

Expands the x-scale and displays the left half of the current channels on the full horizontal scale. The x-range cycles in powers of 2 from 1024 down to 64 channels, then back to 1024.

YSCL

Expands the y-scale by dividing the maximum channel count by 2. If the YSCL key is pushed repeatedly, the maximum channel count cycles in powers of 2 down to 256 and then back to a maximum value of 2^{20} .

AUTO

Resumes autoscaling after the YSCL key has been used to change the y-scale.

CSR

Allows moving the cursor to an arbitrary channel. Enter the channel number when the LED display prompts CURSOR CHAN?.

OFFSET

Allows input of the left-most channel of the displayed expanded region. Enter the channel number when the LED display prompts OFFSET CHAN?.

ERROR MESSAGES

Error Messages on the PDAC LED Display

*

The asterisk next to the uranium concentration indicates that a measurement control error occurred in the analysis of the most recent cycle. See the printout for details.

CYCLE TOO SHORT

This message is displayed at the completion of data acquisition if the analysis and/or output of results from the previous assay cycle are still in progress.

NO RUN COMPLETED

This message is displayed when the LOOK key is pressed if the first assay cycle has not yet been completed. Cycle counting begins at restart or if a YES answer is given to START ASSAY?. After cycle 1, this message indicates that mathematical errors prevented the completion of the assay cycle.

(No concentration display)

Normally, concentration is not displayed during cycle 1. If the concentration is not displayed after the completion of one or more cycles, mathematical errors have occurred. See the printout for details.

ERROR MESSAGES

(cont)

Error Messages on the Printout

EAROM DESTROYED

Some or all of the EAROM constants have been destroyed. Enter the devices, parameters, and ROIs as prompted before proceeding.

**** MATH ERROR ** DET A ****

Some mathematical error has occurred in the computation of the detector A concentration result: division by zero, square root of a negative value, or logarithm of a nonpositive value. Any results not computed because of the problem appear as -8.888 on the printout.

**** MATH ERROR ** DET B ****

The meaning is the same as the previous description for detector A.

**** PEAK POSITION IS BAD ****

The mean channel for the 60-keV photopeak of the A and/or B spectrum is not within the window $\text{MEAN} \pm \text{DLTA}$.

**** PEAK RESOLUTION IS BAD ****

The resolution $(100 \cdot \text{SIGMA}/\text{MEAN})$ of the 60-keV photopeak of the A or B spectrum is greater than RESL.

**** POSITION PRECISION IS BAD ****

SIGMA of the mean channel for the 60-keV photopeak of the A and/or B spectrum is greater than $\text{DLTA}/3$.

THE CALIBRATION CURVE

The monitor determines the concentration of uranium by using the net area of the 186-keV photopeak (normalized by the net area of the 60-keV photopeak). The shape of the calibration curve (uranium concentration vs count rate) is represented by a polynomial of the ninth order, determined by fitting calculated results obtained by numerical integration. The shape of the calibration curve depends on the location of the detector because effects of solution self-attenuation vary significantly in the wide range of solvent densities in the solvent extraction system, and because column diameters differ for glass and stainless steel sections. The monitor code stores up to 10 polynomial coefficients for each detector in the parameter file. Relocation of a detector almost always requires changing these parameters.

NORMALIZING THE CALIBRATION

The normalization factor, NORM, is applied to the measured (normalized) 186-keV net photopeak area. The division by the 60-keV net area compensates for count-rate losses only. Determining normalization are the intrinsic NaI(Tl) efficiency, the strength of the ^{241}Am source, the source geometry, the NaI(Tl) geometry within the collimator, composition and thickness of the solvent extraction column wall, and widths and positions of the ROIs used to define the photopeaks and backgrounds in the gamma-ray spectra.

To first order, all the factors comprising NORM are constant. However, in practice, a gradual

NORMALIZING THE
CALIBRATION
(cont)

upward drift in the normalization (of the order 0.5 to 1% per year) is observed. The drift is probably electronic in origin. Because the calibration curve is nonlinear, a 1% change in count rate corresponds to a 2 to 3% change in concentration in a concentration range of 100 to 200 g uranium per liter. Therefore, the normalization must be monitored regularly (monthly) and adjusted when necessary.

The normalization is monitored by one of two methods. One method requires assay of a well-characterized uranium reference solution in the standard cell. The standard solution cell reproduces the geometry of the solvent extraction column. The other method uses a working standard uranium foil.

Normalization measurements for a new detector or for a detector that has been disassembled from the collimator shield and remounted in the same shield or in a new shield are made using a reference solution in the standard cell. Thereafter, the uranium foil is used routinely to correct the normalization. However, reference solution measurements are recommended on a yearly basis to verify that the foil corrections are valid. The procedures for both the reference solution and the foil normalizations are described separately below.

DIRECT NORMALIZATION
MEASUREMENT WITH
REFERENCE SOLUTION IN
STANDARD CELL

The following steps are performed for one detector at a time:

- (1) Rinse the standard cell once with the aqueous reference solution. (Typically, the uranium concentration is 100 ± 50 g/l, and the acidity is very low. The 1300 or 2300 product solution is ideal.)
- (2) Fill the standard cell with the aqueous reference solution. The detector must be mounted above the plates and rods that occupy the lower part of the standard cell. The solution height must be above the detector center by at least 4 in.
- (3) Move the standard cell to the detector location at the solvent extraction column.
- (4) Mount the detector onto the standard cell.
- (5) Power up the printer and connect the RS-232 printer cable.
- (6) Insert the tungsten shield into the detector collimator slot and run at least five background assay cycles.
- (7) Verify that the average background $P2'$ (that is, $\overline{P2B}$) is 0.0000 ± 0.0002 . If necessary, adjust DP-2(OLD), the background stored in

DIRECT NORMALIZATION
MEASUREMENT WITH
REFERENCE SOLUTION IN
STANDARD CELL

(cont)

the parameter file, as instructed in this Section under BACKGROUND MEASUREMENT AND ADJUSTMENT.

- (8) Log all background results and the average, $\overline{P2B}$, on the detector measurement control log sheet. Refer to the sample form, Fig. 10.
- (9) Remove the shield and run 10 or more solution assay cycles. Run at least 20 cycles for a new detector.
- (10) At the end of the solution assay, withdraw three solution samples from the top of the cell for external assay, and obtain the average reference concentration, $\overline{\rho_u}$, the standard deviation, $\sigma(\rho_u)$, in these three results (in grams of elemental uranium per milliliter) and the %RSD:

$$\%RSD(\overline{\rho_u}) = 100 \cdot \frac{\sigma(\rho_u)}{\overline{\rho_u}} \div \sqrt{3} \ .$$

The %RSD should be <0.5%.

MEASUREMENT CONTROL LOG

$\%RSD(NORMO) = \frac{P2FO}{P2FO} \times 100$

[illegible]

B = Background, F = Foil, SN = Solution Normalization, FN = Foil Normalization

a) SN measurements only.
b) SN or FN measurements only.

Fig. 10. A Sample measurement control log sheet.

DIRECT NORMALIZATION
MEASUREMENT WITH
REFERENCE SOLUTION IN
STANDARD CELL

(cont)

- (11) At the end of the solution assay, compute the average $P2'$ from the N (10 or more) assay cycles ($P2$) and the %RSD:

$$\%RSD(\overline{P2}) = 100 \cdot \frac{\sigma(P2)}{\overline{P2}} \div \sqrt{N} .$$

The %RSD should be $<0.5\%$.

- (12) Using an interpolation of the appropriate table from Appendix A (choose $M = 0.2$ if the 1300 or 2300 product solution was used as the reference solution), obtain the expected count rate C (s^{-1}) for the reference solution concentration, $\overline{\rho}_u$ (that is, RHOU, g/cm^3).

- (13) Compute the new normalization value, NORM*:
(a) Detector A (Organic, Extraction Column):

$$NORM = \frac{C}{P2} \cdot 0.008573 .$$

The constant, 0.008573, incorporates the attenuation effects of the glass column as well as the relative geometries for counting the 186- and 60-keV gamma rays.

*If normalization is for a new or remounted detector, then $NORM \equiv NORMG$.

DIRECT NORMALIZATION
MEASUREMENT WITH
REFERENCE SOLUTION IN
STANDARD CELL
(cont)

(b) Detector B (Aqueous Product, Backwash Column):

$$\text{NORM} = \frac{C}{P2} \cdot 0.009920 \quad .$$

The constant, 0.009920, incorporates the attenuation effects of the stainless steel column as well as the relative geometries for counting the 186- and 60-keV gamma rays.

(14) Compute the %RSD in NORM:

$$\%RSD(\text{NORM}) = [\%RSD(\overline{\rho_U})^2 + \%RSD(\overline{P2})^2]^{1/2} \quad .$$

The %RSD should be <1%.

(15) The new value of NORM should be within 1% of the previously stored value (unless the detector is new or remounted).

(16) Log the values for:

- DP2(OLD), N, $\overline{P2}$, $\%RSD(\overline{P2})$,
- $\overline{\rho_U}$, $\%RSD(\overline{\rho_U})$, and
- NORM, $\%RSD(\text{NORM})$

on the detector log sheet. Refer to the sample form, Fig. 10.

DIRECT NORMALIZATION
MEASUREMENT WITH
REFERENCE SOLUTION IN
STANDARD CELL
(cont)

- (17) Enter the new value of NORM in the PDAC parameter file.
- (18) Mount the detector in its normal position on solvent extraction column.
- (19) Carry out steps 2-7 under NORMALIZATION MEASUREMENT BY URANIUM FOIL ASSAY in this Section.
- (20) Remove the foil from the detector slot.
- (21) Power down the printer.

NORMALIZATION MEASUREMENT
BY URANIUM FOIL ASSAY

- With the detector or detectors (both can be measured simultaneously) mounted in the normal position(s) on the solvent extraction column(s):
- (1) Power up the printer.
 - (2) Insert the tungsten shield(s) into the detector collimator(s) and run at least five background assay cycles.
 - (3) Verify the average background(s) $\overline{P2}$ (that is, $\overline{P2B}$) to be 0.0000 ± 0.0002 . If necessary, adjust the background(s) as instructed. (Refer to BACKGROUND MEASUREMENT AND ADJUSTMENT in this Section).
 - (4) Log the background results on the detector(s) measurement control log sheet(s). Refer to the sample form, Fig. 10.

NORMALIZATION MEASUREMENT
BY URANIUM FOIL ASSAY
(cont)

(5) Insert the uranium foil(s) into the detector collimator(s) and run at least 10* foil assay cycles.

(6) Average the foil P2' results to get $\overline{P2F}$. Obtain the %RSD(s)** for the N-cycle average(s):

$$\%RSD(\overline{P2F}) = 100 \cdot \frac{\sigma(\overline{P2F})}{\overline{P2F}} \div \sqrt{N} .$$

The %RSD should be <0.5%.

(7) Log the foil results [DP-2(OLD), N, $\overline{P2F}$, %RSD($\overline{P2F}$)] on the measurement control log sheet(s) of the detector(s). Refer to the sample form, Fig. 10. Plot the foil results. Refer to the sample form, Fig. 11.

(8) Compute the new normalization value(s), NORM:

$$NORM = \frac{P2F0}{\overline{P2F}} \cdot NORM0 .$$

*If the detector is new (or newly mounted), at least two sets (5 cycles per set) of foil measurements, with foil repositioning between sets, are recommended.

**If the detector is new (or newly mounted), then $\overline{P2F} \equiv P2F0$, and %RSD($\overline{P2F}$) $\equiv$ %RSD(P2F0) for the foil(s).

Fig. 11. A Sample blank graph of foil results ($\overline{P2F}$) for 1 yr vs date.

NORMALIZATION MEASUREMENT
BY URANIUM FOIL ASSAY
(cont)

During the October 1983 calibration and installation, the following values were established:

Detector A	NORMO = 15.28	P2FO = 0.2388
Detector B	NORMO = 17.66	P2FO = 0.2499

(9) Compute the %RSD(s) in NORM:

$$\%RSD(NORM) = [\%RSD(\overline{P2F})^2 + \%RSD(P2FO)^2 + \%RSD(NORMC)^2]^{1/2}$$

The %RSD should be <1%.

(10) The new value(s) of NORM should be within 1% of the previously stored value(s).

(11) Install the new value(s) of NORM in the parameter file.

(12) Remove the foil(s) from the detector slot(s).

(13) Power down the printer.

BACKGROUND MEASUREMENT
AND ADJUSTMENT

The detector parameter file stores the background subtracted from all measured values of the 186- to 60-keV net photopeak area ratio (P2) to give the background-subtracted ratio (P2'). This ratio, P2', has also been corrected for ²⁴¹Am

BACKGROUND MEASUREMENT
AND ADJUSTMENT

(cont)

decay. The background value is labeled DP-2 in the parameter file listing. The value of DP-2 must be evaluated and stored for a new (or re-mounted) detector. Each time measurement control is performed, DP-2 is verified (and updated, if necessary). Under no circumstances should DP-2 exceed 0.002, and in most cases it will be less than 0.001.

If the measured DP-2 ever exceeds 0.001, suspect that there is contamination on the collimator or the tungsten shield. Wipe these surfaces clean with alcohol, and repeat the measurements. In this discussion, DP-2(OLD) refers to the value of DP-2 stored in the parameter file, and DP-2(NEW) refers to the most recently measured value of DP-2.

- (1) Measure the background with the tungsten shield inserted in the detector collimator slot in five complete background assay cycles. The average value of P2ⁱ for the five cycles (that is, $\overline{P2B}$) is typically 0.0000 ± 0.0002 if DP-2(OLD) is still valid.

- (2) If

$$|\overline{P2B}| > 0.0002 \quad ,$$

compute the new value of DP-2:

$$DP-2(NEW) = DP-2(OLD) + \overline{P2B} \quad .$$

BACKGROUND MEASUREMENT
AND ADJUSTMENT

(cont)

Store DP-2(NEW) as DP-2, henceforth considered DP-2(OLD), in the detector parameter file.

- (3) Record the new result for DP-2, DP-2(OLD) that is, the value stored in the parameter file at the time of the measurement), $\bar{N}$, and $\overline{P2B}$, in the detector measurement control log.

RECOMMENDED MEASUREMENT
CONTROL PROCEDURES

Weekly Procedure

Once a week:

- (1) Verify that no red lights are lit (solid or flashing) on the NA-23 amplifiers. If red lights are lit, follow the procedures described under ADJUSTMENT OF ANALOG ELECTRONICS in the EQUIPMENT SUMMARY Section.
- (2) Check the AGD and LED displays to verify proper operation of the display hardware.
- (3) Check the results on the operator's LED displays during pulsed operation. Detector 1 (extraction column organic) assay should read 120 ± 20 g/l. Detector 2 (backwash column aqueous product) assay should read 105 ± 20 g/l.
- (4) Ensure that plastic tents are in place on detectors and that detectors are free of visible HEU contamination.

**RECOMMENDED MEASUREMENT
CONTROL PROCEDURES**

(cont)

Monthly Procedure

Once a month or at least once every 4 months:

- (1) Remove HEU contamination by wiping the column surfaces in front of the detectors, the Teflon end caps on the detectors, and the tungsten foil holders/shields.
- (2) Verify (update, if necessary) the normalization factor for the calibration by uranium foil assay, described in NORMALIZATION MEASUREMENT BY URANIUM FOIL ASSAY in this Section.
- (3) For all printed results, check that the 60-keV photopeak centroid (MEAN) and resolution (RESL) are within the acceptable limits, verified by the absence of an error message in the printout of results for each cycle. If MEAN is unacceptable, follow procedures described under ADJUSTMENT OF ANALOG ELECTRONICS in EQUIPMENT SUMMARY Section to correct the problem. If RESL is unacceptable, replacement of the detector (described under ADJUSTMENT OF ANALOG ELECTRONICS in EQUIPMENT SUMMARY Section) might be necessary.

Yearly Procedure

Verify (update, if necessary) the normalization factor for the calibration by direct measurement with the reference solution in the standard cell, as described under NORMALIZATION MEASUREMENT WITH REFERENCE SOLUTION IN STANDARD CELL in this Section.

RECOMMENDED MEASUREMENT

CONTROL PROCEDURES

(cont)

Logging Measurement
Control Data

- (1) Log all measurement control results on the measurement control log sheets. Figure 10 shows a sample log sheet.
- (2) Plot all foil $\overline{P2F}$ results vs date on a separate plot for each detector. Investigate any departures from a smooth monotonic dependence on time. Figure 11 is a sample blank graph.
- (3) Log all procedures, including measurement control operations, maintenance, repairs, equipment replacements or adjustments of electronics settings, in chronological order in a logbook dedicated to this instrument. The logbook will contain the original measurement control log sheets.

OVERVIEW

The software automating the 2300 monitors consists of 53 FORTRAN and 33 assembly language subroutines. Table III lists the FORTRAN subroutines, organized by file, and briefly describes the function of each. Table IV is a similar list of the assembly language subroutines.

Figure 12 shows a simplified layout of structure levels within the code. The ASSAY subroutine executes data analysis and output of results. The FORTRAN subroutines most relevant to the data analysis and output functions are included in the ANALYZ and ASSAY files. Source listings of these eight subroutines are given in Appendix B.

TABLE III
FORTRAN SUBROUTINES

Filename:	Subroutine:	Function
ACQUIR:	ACQUIR:	Start data acquisition
	ACWAIT:	Wait for acquisition to finish, monitor keypad, ADC, CRT
	SPDATA:	Insert elapsed time (ET) into channel 0
	SHOW :	Show assay results and ET on LEDs
	SHOWIT:	Display line for 3 s
	SHOWRE:	Show results on remote LEDs
ALPHA :	ALPHAX:	Convert a real number to ASCII
	ALPHAI:	Convert an integer number to ASCII
	NUMBER:	Convert ASCII number to real
ANALYZ:	ANALYZ:	Uranium concentration analysis
	POLYNM:	Compute a polynomial
	PEAKS :	Compute peak areas, sigmas; initialize mean and resolution flags
	TESTS :	Measurement control (MC) tests
	AREA :	Determine net area from three ROIs
ASSAY :	ASSAY :	Do repeated assays
	OUTPT1:	Print ROI sums, net areas
	OUTPT2:	Print corrected areas, MC results, uranium concentration, error messages
CHANGE:	MODCON:	Modify constants
	CHGPLY:	Change polynomial coefficients
	MODROI:	Modify ROI
	CHANGX:	Change a real number
	CHANGI:	Change an integer number
	MCDDEV:	Modify device status
	PRTCON:	Print constants

TABLE III (cont)

Filename:	Subroutine:	Function
	PRTPLY:	Print polynomial coefficient
	PRTBK :	Print number background ROIs for each peak
	ENTRSG:	Enter specific gravity
CRTSUB:	CRTINP:	Interpret keypad input for CRT
	KEFRSH:	Refresh CRT
	CURSOR:	Display cursor and cursor information
	INICRT:	Initialize parameters for CRT
	STRCRT:	Initialize CRT for a new run
DATTIM:	DATTIM:	Retrieve or change date and time
	JULDAY:	Compute Julian day from 10/30/79
MAIN :	MAIN :	Execute menu and calls to high-level routines
	INITL :	Initialize constants on power up/restart
READ :	READX :	Prompt user and read a real number
	READI :	Prompt user and read an integer
	ACCEPT:	Accept numeric input from keypad
	QUESTN:	Ask Y/N question and wait for response
	FLASH :	Flash a message on LED panel and wait for input
ROI :	GETROI:	Get ROI sum
	INTROI:	Intensify ROIs
UTIL :	ROUND :	Round real number to fit a format
	DUMPSP:	Dump spectrum to printer
	OPENLP:	Open LP RS232
	CLOSLP:	Close LP RS232
	REPROM:	Read EEPROM
	WEPROM:	Write EEPROM
	OPN422:	Open LP RS422
	CLS422:	Close LP RS422
	PALARM:	Turn on precipitation alarm light
	USTRIP:	Put out uranium grams/liter to strip chart

TABLE IV
ASSEMBLY LANGUAGE SUBROUTINES

Filename:	Subroutine:	Function
ADC :	CLRADC:	Zero ADC counts
	CLRSEC:	Zero seconds counter
	STRADC:	Start ADC
	STPADC:	Stop ADC
	GETSEC:	Return elapsed seconds
	GETDAT:	Return spectrum counts
ANALOG:	ANALOG:	Output a value to D to A converter (AD 7522 DAC)
CLOCK :	INITIM:	Start 1-s pulses to ADC
	GETTIM:	Get date and time
	SETTIM:	Set date and time
CRT :	DOTS :	Display N dots
	CLRCRT:	Clear CRT
	MRKCRT:	Mark buifer where cursor starts
	ERACRT:	Erase buffer from cursor down
	EXTEND:	Extend last dot in display buffer upward for a cursor
	SETCRT:	Set CRT parameters
	CHARS :	Display a character string
	INTENS:	Intensify point
DELAY :	DELAY :	Delay a given number of tenths of seconds
DISPLA:	CLRDIS:	Clear LED display
	DISPLA:	Display a message on LEDs
EEPROM:	ERASE :	Erase all pages
	SAVES :	Write one page to EPROM
	UNSAVE:	Read one page from EPROM
KEYPAD:	CLRKEY:	Write to keypad to clear it; initialization
	RDKEY :	Wait for key, read, and clear
	CHKKEY:	Check keypad for input (Y/N)

TABLE IV (cont)

Filename: Subroutine: Function

LIGHTS: LGTOFF: Driver precipitation alarm lights
 LIGHT : Driver precipitation alarm lights
 BAROFF: Driver concentration bar chart lights
 BAR : Driver concentration bar chart lights
 PRINTR: PRINTR: FORTRAN-callable device driver for serial APP-48
 printer
 REMDIS: REMDIS: Driver for remote displays

Fig. 12. The layout and calling sequences in the program for the 2300 monitors.

SUMMARY

The concentration monitor for the aqueous product of the backwash column was evaluated over a 2-month period. The monitor results were compared with the assays of samples removed from the product stream and analyzed using a high-resolution gamma-ray transmission method.^{7,8}

Figure 13 shows the evaluation results for the monitor and external sample assays. The 1σ error bars ($\pm 1.3\%$) on the monitor results give the predicted uncertainty of the 100-s monitor assay based on counting statistics. The 1σ error bars ($\pm 0.7\%$) on the external assay results give the estimated net random uncertainty in the results of the external assay. The monitor results agree with the external assays within the measurement uncertainties.

Similar evaluation data for the concentration monitor of the organic product of the extraction column have not been obtained yet. The monitor was initially installed above but near the phase interface to include a significant (visible) fraction of aqueous phase. Therefore, it is not possible to withdraw a representative sample for comparison. Although this detector location is satisfactory for the needs of process monitoring (the monitor assays the average uranium concentration in the two-phase mixture), evaluation of this monitor must be performed on static, single-phase solutions to circumvent the sampling difficulties.

Fig. 13. Uranium concentration is plotted vs time on specific dates during the evaluation of the backwash column aqueous product monitor. The solid points are the monitor assay results for successive 100-s assay cycles. The open circles are the results of external assay of samples withdrawn from the aqueous product stream. The open circles are plotted at the time of sample withdrawal. Error bars on the open circles correspond to the estimated uncertainty (1σ) in the external assay. Error bars on the solid points are the 1σ values computed from the counting statistics of the 100-s monitor assay.

SUMMARY

(cont)

Shutdown of the 2300 solvent extraction system to install automatic control capabilities in 1984 has caused a postponement of the evaluation of the concentration monitor on the organic product of the extraction column until the system is again operational.

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CALCULATED 186-keV COUNT RATES* VS ELEMENTAL URANIUM CONCENTRATION

AQUEOUS

M = 0.0
H(CM) = 7.62
B = 0.00000

RHOU (G/CM3)	C(RHOU, 0.0) (SEC-1)
.02100	9.5092062E+01
.02200	9.9086026E+01
.02300	1.0303594E+02
.02400	1.0694183E+02
.02500	1.1080445E+02
.02600	1.1462456E+02
.02700	1.1840215E+02
.02800	1.2213798E+02
.02900	1.2583275E+02
.03000	1.2948648E+02
.03100	1.3310011E+02
.03200	1.3667363E+02
.03300	1.4020774E+02
.03400	1.4370315E+02
.03500	1.4715983E+02
.03600	1.5057845E+02
.03700	1.5395969E+02
.03800	1.5730352E+02
.03900	1.6061308E+02
.04000	1.6388219E+02
.04100	1.6711773E+02
.04200	1.7031773E+02
.04300	1.7348143E+02
.04400	1.7661219E+02
.04500	1.7970900E+02
.04600	1.8277005E+02
.04700	1.8579894E+02
.04800	1.8879435E+02
.04900	1.9175667E+02
.05000	1.9468727E+02

*Applies to Y-12 3.75-in.-i.d. stainless steel cell with no plates. Column attenuation of gamma rays is not included in the calculation. Assumes uranium enrichment of the 9212 facilities.

RHOU (G/CM3)	C(RHOU, 0.0) (SEC-1)
.05100	1.9758579E+02
.05200	2.0045316E+02
.05300	2.0328876E+02
.05400	2.0609416E+02
.05500	2.0886944E+02
.05600	2.1161299E+02
.05700	2.1432796E+02
.05800	2.1701300E+02
.05900	2.1966921E+02
.06000	2.2229698E+02
.06100	2.2489617E+02
.06200	2.2746653E+02
.06300	2.3001003E+02
.06400	2.3252539E+02
.06500	2.3501420E+02
.06600	2.3747602E+02
.06700	2.3991141E+02
.06800	2.4232044E+02
.06900	2.4470384E+02
.07000	2.4706121E+02
.07100	2.4939387E+02
.07200	2.5170147E+02
.07300	2.5398396E+02
.07400	2.5624198E+02
.07500	2.5847609E+02
.07600	2.6068627E+02
.07700	2.6287277E+02
.07800	2.6503544E+02
.07900	2.6717619E+02
.08000	2.6929333E+02
.08100	2.7138791E+02
.08200	2.7346095E+02
.08300	2.7551096E+02
.08400	2.7754001E+02
.08500	2.7954737E+02
.08600	2.8153330E+02
.08700	2.8349810E+02
.08800	2.8544202E+02
.08900	2.8736564E+02
.09000	2.8926889E+02
.09100	2.9115239E+02
.09200	2.9301521E+02
.09300	2.9485910E+02
.09400	2.9668330E+02
.09500	2.9848880E+02
.09600	3.0027456E+02
.09700	3.0204185E+02
.09800	3.0379131E+02
.09900	3.0552078E+02
.10000	3.0723367E+02

RHOU (G/CM3)	C(RHOU, 0.0) (SEC-1)
.10100	3.0892816E+02
.10200	3.1060489E+02
.10300	3.1226446E+02
.10400	3.1390634E+02
.10500	3.1553094E+02
.10600	3.1713962E+02
.10700	3.1873060E+02
.10800	3.2030527E+02
.10900	3.2186346E+02
.11000	3.2340582E+02
.11100	3.2493212E+02
.11200	3.2644278E+02
.11300	3.2793756E+02
.11400	3.2941674E+02
.11500	3.3088103E+02
.11600	3.3233037E+02
.11700	3.3376450E+02
.11800	3.3518370E+02
.11900	3.3658885E+02
.12000	3.3797925E+02
.12100	3.3935520E+02
.12200	3.4071763E+02
.12300	3.4206596E+02
.12400	3.4340028E+02
.12500	3.4472077E+02
.12600	3.4602824E+02
.12700	3.4732209E+02
.12800	3.4860331E+02
.12900	3.4987100E+02
.13000	3.5112625E+02
.13100	3.5236796E+02
.13200	3.5359780E+02
.13300	3.5481483E+02
.13400	3.5601986E+02
.13500	3.5721258E+02
.13600	3.5839346E+02
.13700	3.5956215E+02
.13800	3.6071923E+02
.13900	3.6186480E+02
.14000	3.6299880E+02
.14100	3.6412125E+02
.14200	3.6523282E+02
.14300	3.6633291E+02
.14400	3.6742235E+02
.14500	3.6850050E+02
.14600	3.6956823E+02
.14700	3.7062533E+02
.14800	3.7167199E+02
.14900	3.7270788E+02
.15000	3.7373371E+02

RHOU (G/CM3)	C(RHOU, 0.0) (SEC-1)
.15100	3.7474943E+02
.15200	3.7575515E+02
.15300	3.7675108E+02
.15400	3.7773690E+02
.15500	3.7871301E+02
.15600	3.7967946E+02
.15700	3.8063670E+02
.15800	3.8158449E+02
.15900	3.8252284E+02
.16000	3.8345216E+02
.16100	3.8437209E+02
.16200	3.8528330E+02
.16300	3.8618581E+02
.16400	3.8707917E+02
.16500	3.8796409E+02
.16600	3.8884011E+02
.16700	3.8970792E+02
.16800	3.9056703E+02
.16900	3.9141834E+02
.17000	3.9226087E+02
.17100	3.9309574E+02
.17200	3.9392249E+02
.17300	3.9474110E+02
.17400	3.9555183E+02
.17500	3.9635476E+02
.17600	3.9715012E+02
.17700	3.9793788E+02
.17800	3.9871812E+02
.17900	3.9949114E+02
.18000	4.0025629E+02
.18100	4.0101446E+02
.18200	4.0176537E+02
.18300	4.0250922E+02
.18400	4.0324598E+02
.18500	4.0397577E+02
.18600	4.0469867E+02
.18700	4.0541484E+02
.18800	4.0612420E+02
.18900	4.0682675E+02
.19000	4.0752309E+02
.19100	4.0821266E+02
.19200	4.0889578E+02
.19300	4.0957250E+02
.19400	4.1024300E+02
.19500	4.1090728E+02
.19600	4.1156537E+02
.19700	4.1221719E+02
.19800	4.1286295E+02
.19900	4.1350299E+02
.20000	4.1413708E+02

RHOU (G/CM3)	C(RHOU, 0.0) (SEC-1)
.20100	4.1476529E+02
.20200	4.1538768E+02
.20300	4.1600428E+02
.20400	4.1661529E+02
.20500	4.1722067E+02
.20600	4.1782054E+02
.20700	4.1841499E+02
.20800	4.1900393E+02
.20900	4.1958757E+02
.21000	4.2016577E+02
.21100	4.2073894E+02
.21200	4.2130678E+02
.21300	4.2186956E+02
.21400	4.2242714E+02
.21500	4.2297982E+02
.21600	4.2352737E+02
.21700	4.2407015E+02
.21800	4.2460807E+02
.21900	4.2514117E+02
.22000	4.2566950E+02
.22100	4.2619312E+02
.22200	4.2671201E+02
.22300	4.2722636E+02
.22400	4.2773611E+02
.22500	4.2824135E+02
.22600	4.2874212E+02
.22700	4.2923853E+02
.22800	4.2973059E+02
.22900	4.3021820E+02
.23000	4.3070161E+02
.23100	4.3118072E+02
.23200	4.3165566E+02
.23300	4.3212644E+02
.23400	4.3259329E+02
.23500	4.3305584E+02
.23600	4.3351455E+02
.23700	4.3396928E+02
.23800	4.3441999E+02
.23900	4.3486690E+02
.24000	4.3530994E+02
.24100	4.3574898E+02
.24200	4.3618447E+02
.24300	4.3661623E+02
.24400	4.3704431E+02
.24500	4.3746871E+02
.24600	4.3788946E+02
.24700	4.3830655E+02
.24800	4.3872025E+02
.24900	4.3913034E+02
.25000	4.3953716E+02

RHOU (G/CM3)	C(RHOU, 0.0) (SEC-1)
.25100	4.3994027E+02
.25200	4.4034018E+02
.25300	4.4073664E+02
.25400	4.4112977E+02
.25500	4.4151968E+02
.25600	4.4190638E+02
.25700	4.4228981E+02
.25800	4.4266994E+02
.25900	4.4304707E+02
.26000	4.4342101E+02
.26100	4.4379188E+02
.26200	4.4415964E+02
.26300	4.4452446E+02
.26400	4.4488620E+02
.26500	4.4524506E+02
.26600	4.4560088E+02
.26700	4.4595394E+02
.26800	4.4630401E+02
.26900	4.4665129E+02
.27000	4.4699577E+02
.27100	4.4733740E+02
.27200	4.4767639E+02
.27300	4.4801250E+02
.27400	4.4834605E+02
.27500	4.4867673E+02
.27600	4.4900492E+02
.27700	4.4933052E+02
.27800	4.4965342E+02
.27900	4.4997390E+02
.28000	4.5029167E+02
.28100	4.5060692E+02
.28200	4.5091978E+02
.28300	4.5123009E+02
.28400	4.5153807E+02
.28500	4.5184357E+02
.28600	4.5214662E+02
.28700	4.5244736E+02
.28800	4.5274583E+02
.28900	4.5304184E+02
.29000	4.5333566E+02
.29100	4.5362717E+02
.29200	4.5391641E+02
.29300	4.5420342E+02
.29400	4.5448832E+02
.29500	4.5477096E+02
.29600	4.5505141E+02
.29700	4.5532975E+02
.29800	4.5560599E+02
.29900	4.5588007E+02
.30000	4.5615216E+02

AQUEOUS

M = 0.2
H(CM) = 7.62
B = 0.00000

RHOU (G/CM3)	C(RHOU, 0.2) (SEC-1)
.01100	5.2540794E+01
.01200	5.7003101E+01
.01300	6.1415466E+01
.01400	6.5778886E+01
.01500	7.0093500E+01
.01600	7.4360312E+01
.01700	7.8579457E+01
.01800	8.2751686E+01
.01900	8.6877791E+01
.02000	9.0957856E+01
.02100	9.4992878E+01
.02200	9.8982914E+01
.02300	1.0292871E+02
.02400	1.0683104E+02
.02500	1.1068992E+02
.02600	1.1450635E+02
.02700	1.1828032E+02
.02800	1.2201284E+02
.02900	1.2570387E+02
.03000	1.2935415E+02
.03100	1.3296442E+02
.03200	1.3653462E+02
.03300	1.4006572E+02
.03400	1.4355767E+02
.03500	1.4701119E+02
.03600	1.5042696E+02
.03700	1.5380492E+02
.03800	1.5714760E+02
.03900	1.6045287E+02
.04000	1.6371917E+02
.04100	1.6695208E+02
.04200	1.7014863E+02
.04300	1.7331020E+02
.04400	1.7643794E+02
.04500	1.7953179E+02
.04600	1.8259111E+02
.04700	1.8561630E+02
.04800	1.8860994E+02
.04900	1.9157041E+02
.05000	1.9449805E+02

RHOU (G/CM3)	C(RHOU, 0.2) (SEC-1)
.05100	1.9739440E+02
.05200	2.0025936E+02
.05300	2.0309300E+02
.05400	2.0589569E+02
.05500	2.0866796E+02
.05600	2.1141097E+02
.05700	2.1412287E+02
.05800	2.1680612E+02
.05900	2.1946023E+02
.06000	2.2208667E+02
.06100	2.2468292E+02
.06200	2.2725222E+02
.06300	2.2979379E+02
.06400	2.3230727E+02
.06500	2.3479426E+02
.06600	2.3725469E+02
.06700	2.3968787E+02
.06800	2.4209567E+02
.06900	2.4447762E+02
.07000	2.4683292E+02
.07100	2.4916400E+02
.07200	2.5146970E+02
.07300	2.5375110E+02
.07400	2.5600703E+02
.07500	2.5823984E+02
.07600	2.6044878E+02
.07700	2.6263428E+02
.07800	2.6479567E+02
.07900	2.6693438E+02
.08000	2.6905036E+02
.08100	2.7114387E+02
.08200	2.7321538E+02
.08300	2.7526474E+02
.08400	2.7729227E+02
.08500	2.7929794E+02
.08600	2.8128303E+02
.08700	2.8324754E+02
.08800	2.8518987E+02
.08900	2.8711246E+02
.09000	2.8901467E+02
.09100	2.9089705E+02
.09200	2.9275944E+02
.09300	2.9460211E+02
.09400	2.9642552E+02
.09500	2.9822969E+02
.09600	3.0001473E+02
.09700	3.0178125E+02
.09800	3.0352937E+02
.09900	3.0525911E+02
.10000	3.0697101E+02

RHOU (G/CM3)	C(RHOU, 0.2) (SEC-1)
.10100	3.0866424E+02
.10200	3.1034041E+02
.10300	3.1199918E+02
.10400	3.1364024E+02
.10500	3.1526432E+02
.10600	3.1687198E+02
.10700	3.1846226E+02
.10800	3.2003658E+02
.10900	3.2159439E+02
.11000	3.2313621E+02
.11100	3.2466192E+02
.11200	3.2617169E+02
.11300	3.2766597E+02
.11400	3.2914493E+02
.11500	3.3060873E+02
.11600	3.3205706E+02
.11700	3.3349131E+02
.11800	3.3491027E+02
.11900	3.3631436E+02
.12000	3.3770435E+02
.12100	3.3908028E+02
.12200	3.4044207E+02
.12300	3.4178975E+02
.12400	3.4312372E+02
.12500	3.4444403E+02
.12600	3.4575135E+02
.12700	3.4704492E+02
.12800	3.4832585E+02
.12900	3.4959328E+02
.13000	3.5084808E+02
.13100	3.5208956E+02
.13200	3.5331938E+02
.13300	3.5453587E+02
.13400	3.5574076E+02
.13500	3.5693352E+02
.13600	3.5811412E+02
.13700	3.5928251E+02
.13800	3.6043952E+02
.13900	3.6158491E+02
.14000	3.6271883E+02
.14100	3.6384108E+02
.14200	3.6495230E+02
.14300	3.6605251E+02
.14400	3.6714150E+02
.14500	3.6821987E+02
.14600	3.6928752E+02
.14700	3.7034437E+02
.14800	3.7139094E+02
.14900	3.7242734E+02
.15000	3.7345293E+02

RHOU (G/CM3)	C(RHOU, 0.2) (SEC-1)
.15100	3.7446846E+02
.15200	3.7547411E+02
.15300	3.7646992E+02
.15400	3.7745589E+02
.15500	3.7843223E+02
.15600	3.7939873E+02
.15700	3.8035599E+02
.15800	3.8130353E+02
.15900	3.8224197E+02
.16000	3.8317137E+02
.16100	3.8409142E+02
.16200	3.8500274E+02
.16300	3.8590493E+02
.16400	3.8679872E+02
.16500	3.8768363E+02
.16600	3.8855980E+02
.16700	3.8942777E+02
.16800	3.9028707E+02
.16900	3.9113830E+02
.17000	3.9198129E+02
.17100	3.9281595E+02
.17200	3.9364265E+02
.17300	3.9446162E+02
.17400	3.9527257E+02
.17500	3.9607577E+02
.17600	3.9687123E+02
.17700	3.9765924E+02
.17800	3.9843950E+02
.17900	3.9921240E+02
.18000	3.9997822E+02
.18100	4.0073653E+02
.18200	4.0148749E+02
.18300	4.0223163E+02
.18400	4.0296859E+02
.18500	4.0369858E+02
.18600	4.0442179E+02
.18700	4.0513805E+02
.18800	4.0584785E+02
.18900	4.0655051E+02
.19000	4.0724707E+02
.19100	4.0793688E+02
.19200	4.0862035E+02
.19300	4.0929734E+02
.19400	4.0996806E+02
.19500	4.1063261E+02
.19600	4.1129075E+02
.19700	4.1194317E+02
.19800	4.1258925E+02
.19900	4.1322934E+02
.20000	4.1386377E+02

RHOU
(G/CM3)

C(RHOU, 0.2)
(SEC-1)

.20100	4.1449228E+02
.20200	4.1511499E+02
.20300	4.1573179E+02
.20400	4.1634315E+02
.20500	4.1694869E+02
.20600	4.1754897E+02
.20700	4.1814376E+02
.20800	4.1873293E+02
.20900	4.1931707E+02
.21000	4.1989556E+02
.21100	4.2046902E+02
.21200	4.2103723E+02
.21300	4.2160035E+02
.21400	4.2215825E+02
.21500	4.2271113E+02
.21600	4.2325930E+02
.21700	4.2380238E+02
.21800	4.2434061E+02
.21900	4.2487400E+02
.22000	4.2540256E+02
.22100	4.2592655E+02
.22200	4.2644588E+02
.22300	4.2696057E+02
.22400	4.2747069E+02
.22500	4.2797632E+02
.22600	4.2847744E+02
.22700	4.2897415E+02
.22800	4.2946663E+02
.22900	4.2995463E+02
.23000	4.3043839E+02
.23100	4.3091790E+02
.23200	4.3139333E+02
.23300	4.3186449E+02
.23400	4.3233153E+02
.23500	4.3279465E+02
.23600	4.3325368E+02
.23700	4.3370882E+02
.23800	4.3415989E+02
.23900	4.3460719E+02
.24000	4.3505048E+02
.24100	4.3549012E+02
.24200	4.3592595E+02
.24300	4.3635809E+02
.24400	4.3678660E+02
.24500	4.3721142E+02
.24600	4.3763245E+02
.24700	4.3805004E+02
.24800	4.3846411E+02
.24900	4.3887466E+02
.25000	4.3928176E+02

RHOU (G/CM3)	C(RHOU, 0.2) (SEC-1)
.25100	4.3968535E+02
.25200	4.4008570E+02
.25300	4.4048253E+02
.25400	4.4087615E+02
.25500	4.4126641E+02
.25600	4.4165347E+02
.25700	4.4203734E+02
.25800	4.4241798E+02
.25900	4.4279543E+02
.26000	4.4316987E+02
.26100	4.4354108E+02
.26200	4.4390929E+02
.26300	4.4427448E+02
.26400	4.4463667E+02
.26500	4.4499595E+02
.26600	4.4535220E+02
.26700	4.4570568E+02
.26800	4.4605612E+02
.26900	4.4640383E+02
.27000	4.4674880E+02
.27100	4.4709087E+02
.27200	4.4743008E+02
.27300	4.4776672E+02
.27400	4.4810068E+02
.27500	4.4843191E+02
.27600	4.4876043E+02
.27700	4.4908636E+02
.27800	4.4940971E+02
.27900	4.4973056E+02
.28000	4.5004878E+02
.28100	4.5036455E+02
.28200	4.5067777E+02
.28300	4.5098859E+02
.28400	4.5129696E+02
.28500	4.5160289E+02
.28600	4.5190637E+02
.28700	4.5220757E+02
.28800	4.5250645E+02
.28900	4.5280294E+02
.29000	4.5309714E+02
.29100	4.5338902E+02
.29200	4.5367872E+02
.29300	4.5396620E+02
.29400	4.5425139E+02
.29500	4.5453446E+02
.29600	4.5481538E+02
.29700	4.5509414E+02
.29800	4.5537080E+02
.29900	4.5564532E+02
.30000	4.5591782E+02

AQUEOUS

M = 0.4
H(CM) = 7.62
B = 0.00000

RHOU (G/CM3)	C(RHOU, 0.4) (SEC-1)
.01100	5.2485006E+01
.01200	5.6942511E+01
.01300	6.1350532E+01
.01400	6.5709275E+01
.01500	7.0019703E+01
.01600	7.4281978E+01
.01700	7.8497088E+01
.01800	8.2665133E+01
.01900	8.6787131E+01
.02000	9.0863139E+01
.02100	9.4894186E+01
.02200	9.8880306E+01
.02300	1.0282225E+02
.02400	1.0672080E+02
.02500	1.1057596E+02
.02600	1.1438873E+02
.02700	1.1815911E+02
.02800	1.2188808E+02
.02900	1.2557564E+02
.03000	1.2922276E+02
.03100	1.3282941E+02
.03200	1.3639656E+02
.03300	1.3992416E+02
.03400	1.4341317E+02
.03500	1.4686357E+02
.03600	1.5027625E+02
.03700	1.5365119E+02
.03800	1.5699104E+02
.03900	1.6029200E+02
.04000	1.6355657E+02
.04100	1.6678619E+02
.04200	1.6998075E+02
.04300	1.7314024E+02
.04400	1.7626453E+02
.04500	1.7935541E+02
.04600	1.8241258E+02
.04700	1.8543600E+02
.04800	1.8842656E+02
.04900	1.9138437E+02
.05000	1.9431030E+02

RHOU (G/CM3)	C(RHOU, 0.4) (SEC-1)
.05100	1.9720389E+02
.05200	2.0006627E+02
.05300	2.0289740E+02
.05400	2.0569886E+02
.05500	2.0846932E+02
.05600	2.1120842E+02
.05700	2.1391953E+02
.05800	2.1660062E+02
.05900	2.1925304E+02
.06000	2.2187649E+02
.06100	2.2447165E+02
.06200	2.2703889E+02
.06300	2.2957807E+02
.06400	2.3209046E+02
.06500	2.3457530E+02
.06600	2.3703408E+02
.06700	2.3946568E+02
.06800	2.4187124E+02
.06900	2.4425111E+02
.07000	2.4660652E+02
.07100	2.4893526E+02
.07200	2.5123914E+02
.07300	2.5351944E+02
.07400	2.5577423E+02
.07500	2.5800521E+02
.07600	2.6021291E+02
.07700	2.6239660E+02
.07800	2.6455708E+02
.07900	2.6669424E+02
.08000	2.6880923E+02
.08100	2.7090172E+02
.08200	2.7297140E+02
.08300	2.7501983E+02
.08400	2.7704607E+02
.08500	2.7905077E+02
.08600	2.8103489E+02
.08700	2.8299746E+02
.08800	2.8493903E+02
.08900	2.8686084E+02
.09000	2.8876213E+02
.09100	2.9064332E+02
.09200	2.9250474E+02
.09300	2.9434653E+02
.09400	2.9616860E+02
.09500	2.9797233E+02
.09600	2.9975652E+02
.09700	3.0152263E+02
.09800	3.0326937E+02
.09900	3.0499845E+02
.10000	3.0670910E+02

RHOU
(G/CM3)

C(RHOU, 0.4)
(SEC-1)

.10100	3.0840180E+02
.10200	3.1007736E+02
.10300	3.1173527E+02
.10400	3.1337579E+02
.10500	3.1499979E+02
.10600	3.1660636E+02
.10700	3.1819592E+02
.10800	3.1976966E+02
.10900	3.2132657E+02
.11000	3.2286772E+02
.11100	3.2439276E+02
.11200	3.2590266E+02
.11300	3.2739594E+02
.11400	3.2887461E+02
.11500	3.3033740E+02
.11600	3.3178614E+02
.11700	3.3321922E+02
.11800	3.3463747E+02
.11900	3.3604174E+02
.12000	3.3743108E+02
.12100	3.3880663E+02
.12200	3.4016795E+02
.12300	3.4151550E+02
.12400	3.4284900E+02
.12500	3.4416918E+02
.12600	3.4547594E+02
.12700	3.4676918E+02
.12800	3.4804947E+02
.12900	3.4931684E+02
.13000	3.5057141E+02
.13100	3.5181302E+02
.13200	3.5304211E+02
.13300	3.5425899E+02
.13400	3.5546369E+02
.13500	3.5665567E+02
.13600	3.5783613E+02
.13700	3.5900456E+02
.13800	3.6016117E+02
.13900	3.6130644E+02
.14000	3.6244019E+02
.14100	3.6356261E+02
.14200	3.6467336E+02
.14300	3.6577359E+02
.14400	3.6686257E+02
.14500	3.6794097E+02
.14600	3.6900851E+02
.14700	3.7006542E+02
.14800	3.7111175E+02
.14900	3.7214779E+02
.15000	3.7317374E+02

RHOU
(G/CM3)

C(RHOU, 0.4)
(SEC-1)

.15100	3.7418928E+02
.15200	3.7519479E+02
.15300	3.7619057E+02
.15400	3.7717656E+02
.15500	3.7815277E+02
.15600	3.7911932E+02
.15700	3.8007651E+02
.15800	3.8102426E+02
.15900	3.8196260E+02
.16000	3.8289196E+02
.16100	3.8381227E+02
.16200	3.8472369E+02
.16300	3.8562614E+02
.16400	3.8651980E+02
.16500	3.8740455E+02
.16600	3.8828102E+02
.16700	3.8914902E+02
.16800	3.9000864E+02
.16900	3.9085991E+02
.17000	3.9170295E+02
.17100	3.9253784E+02
.17200	3.9336475E+02
.17300	3.9418354E+02
.17400	3.9499487E+02
.17500	3.9579816E+02
.17600	3.9659361E+02
.17700	3.9738187E+02
.17800	3.9816253E+02
.17900	3.9893568E+02
.18000	3.9970152E+02
.18100	4.0045988E+02
.18200	4.0121127E+02
.18300	4.0195559E+02
.18400	4.0269272E+02
.18500	4.0342303E+02
.18600	4.0414641E+02
.18700	4.0486288E+02
.18800	4.0557270E+02
.18900	4.0627593E+02
.19000	4.0697257E+02
.19100	4.0766263E+02
.19200	4.0834632E+02
.19300	4.0902366E+02
.19400	4.0969452E+02
.19500	4.1035932E+02
.19600	4.1101737E+02
.19700	4.1167044E+02
.19800	4.1231670E+02
.19900	4.1295734E+02
.20000	4.1359199E+02

RHOU (G/CM3)	C(RHOU, 0.4) (SEC-1)
.20100	4.1422076E+02
.20200	4.1484376E+02
.20300	4.1546097E+02
.20400	4.1607247E+02
.20500	4.1667850E+02
.20600	4.1727901E+02
.20700	4.1787410E+02
.20800	4.1846367E+02
.20900	4.1904794E+02
.21000	4.1962698E+02
.21100	4.2020050E+02
.21200	4.2076911E+02
.21300	4.2133239E+02
.21400	4.2189068E+02
.21500	4.2244408E+02
.21600	4.2299252E+02
.21700	4.2353597E+02
.21800	4.2407445E+02
.21900	4.2460823E+02
.22000	4.2513728E+02
.22100	4.2566151E+02
.22200	4.2618122E+02
.22300	4.2669618E+02
.22400	4.2720675E+02
.22500	4.2771280E+02
.22600	4.2821424E+02
.22700	4.2871130E+02
.22800	4.2920408E+02
.22900	4.2969249E+02
.23000	4.3017666E+02
.23100	4.3065653E+02
.23200	4.3113223E+02
.23300	4.3160396E+02
.23400	4.3207132E+02
.23500	4.3253467E+02
.23600	4.3299421E+02
.23700	4.3344962E+02
.23800	4.3390124E+02
.23900	4.3434889E+02
.24000	4.3479262E+02
.24100	4.3523259E+02
.24200	4.3566885E+02
.24300	4.3610127E+02
.24400	4.3653015E+02
.24500	4.3695534E+02
.24600	4.3737697E+02
.24700	4.3779494E+02
.24800	4.3820934E+02
.24900	4.3862029E+02
.25000	4.3902776E+02

RHOU
(G/CM3)

C(RHOU, 0.4)
(SEC-1)

.25100	4.3943181E+02
.25200	4.3983253E+02
.25300	4.4022982E+02
.25400	4.4062379E+02
.25500	4.4101460E+02
.25600	4.4140196E+02
.25700	4.4178621E+02
.25800	4.4216716E+02
.25900	4.4254518E+02
.26000	4.4291991E+02
.26100	4.4329158E+02
.26200	4.4366034E+02
.26300	4.4402579E+02
.26400	4.4438850E+02
.26500	4.4474815E+02
.26600	4.4510477E+02
.26700	4.4545863E+02
.26800	4.4580958E+02
.26900	4.4615771E+02
.27000	4.4650303E+02
.27100	4.4684552E+02
.27200	4.4718529E+02
.27300	4.4752232E+02
.27400	4.4785657E+02
.27500	4.4818821E+02
.27600	4.4851721E+02
.27700	4.4884363E+02
.27800	4.4916732E+02
.27900	4.4948854E+02
.28000	4.4980730E+02
.28100	4.5012345E+02
.28200	4.5043711E+02
.28300	4.5074836E+02
.28400	4.5105707E+02
.28500	4.5136346E+02
.28600	4.5166739E+02
.28700	4.5196896E+02
.28800	4.5226821E+02
.28900	4.5256514E+02
.29000	4.5285981E+02
.29100	4.5315212E+02
.29200	4.5344224E+02
.29300	4.5373011E+02
.29400	4.5401580E+02
.29500	4.5429929E+02
.29600	4.5458058E+02
.29700	4.5485982E+02
.29800	4.5513685E+02
.29900	4.5541183E+02
.30000	4.5568473E+02

AQUEOUS

M = 0.8
H(CM) = 7.62
B = 0.00000

RHOU (G/CM3)	C.(RHOU, 0.8) (SEC-1)
.01100	5.2374026E+01
.01200	5.6822558E+01
.01300	6.1221383E+01
.01400	6.5571462E+01
.01500	6.9873175E+01
.01600	7.4126872E+01
.01700	7.8333542E+01
.01800	8.2493294E+01
.01900	8.6607124E+01
.02000	9.0675342E+01
.02100	9.4698257E+01
.02200	9.8676848E+01
.02300	1.0261140E+02
.02400	1.0650220E+02
.02500	1.1035023E+02
.02600	1.1415550E+02
.02700	1.1791899E+02
.02800	1.2164095E+02
.02900	1.2532162E+02
.03000	1.2896196E+02
.03100	1.3256220E+02
.03200	1.3612256E+02
.03300	1.3964396E+02
.03400	1.4312641E+02
.03500	1.4657083E+02
.03600	1.4997740E+02
.03700	1.5334635E+02
.03800	1.5668060E+02
.03900	1.5997527E+02
.04000	1.6323512E+02
.04100	1.6645904E+02
.04200	1.6964795E+02
.04300	1.7280138E+02
.04400	1.7592105E+02
.04500	1.7900655E+02
.04600	1.8205870E+02
.04700	1.8507692E+02
.04800	1.8806237E+02
.04900	1.9101552E+02
.05000	1.9393655E+02

RHOU (G/CM3)	C(RHOU, 0.8) (SEC-1)
.05100	1.9682586E+02
.05200	1.9968400E+02
.05300	2.0251118E+02
.05400	2.0530704E+02
.05500	2.0807288E+02
.05600	2.1080878E+02
.05700	2.1351585E+02
.05800	2.1619333E+02
.05900	2.1884145E+02
.06000	2.2146111E+02
.06100	2.2405202E+02
.06200	2.2661595E+02
.06300	2.2915137E+02
.06400	2.3166034E+02
.06500	2.3414075E+02
.06600	2.3659664E+02
.06700	2.3902509E+02
.06800	2.4142741E+02
.06900	2.4380417E+02
.07000	2.4615571E+02
.07100	2.4848161E+02
.07200	2.5078286E+02
.07300	2.5305933E+02
.07400	2.5531147E+02
.07500	2.5753993E+02
.07600	2.5974461E+02
.07700	2.6192569E+02
.07800	2.6408406E+02
.07900	2.6621876E+02
.08000	2.6833043E+02
.08100	2.7042014E+02
.08200	2.7248818E+02
.08300	2.7453422E+02
.08400	2.7655778E+02
.08500	2.7856068E+02
.08600	2.8054232E+02
.08700	2.8250261E+02
.08800	2.8444220E+02
.08900	2.8636181E+02
.09000	2.8826103E+02
.09100	2.9014018E+02
.09200	2.9200001E+02
.09300	2.9383937E+02
.09400	2.9566008E+02
.09500	2.9746152E+02
.09600	2.9924447E+02
.09700	3.0100815E+02
.09800	3.0275384E+02
.09900	3.0448099E+02
.10000	3.0619037E+02

RHOU (G/CM3)	C(RHOU, 0.8) (SEC-1)
.10100	3.0788210E+02
.10200	3.0955547E+02
.10300	3.1121199E+02
.10400	3.1285126E+02
.10500	3.1447371E+02
.10600	3.1607891E+02
.10700	3.1766743E+02
.10800	3.1923953E+02
.10900	3.2079602E+02
.11000	3.2233547E+02
.11100	3.2385942E+02
.11200	3.2536791E+02
.11300	3.2686076E+02
.11400	3.2833848E+02
.11500	3.2980039E+02
.11600	3.3124751E+02
.11700	3.3267971E+02
.11800	3.3409745E+02
.11900	3.3550052E+02
.12000	3.3688961E+02
.12100	3.3826400E+02
.12200	3.3962462E+02
.12300	3.4097158E+02
.12400	3.4230419E+02
.12500	3.4362365E+02
.12600	3.4492974E+02
.12700	3.4622241E+02
.12800	3.4750214E+02
.12900	3.4876883E+02
.13000	3.5002292E+02
.13100	3.5126392E+02
.13200	3.5249281E+02
.13300	3.5370917E+02
.13400	3.5491288E+02
.13500	3.5610478E+02
.13600	3.5728487E+02
.13700	3.5845315E+02
.13800	3.5960924E+02
.13900	3.6075424E+02
.14000	3.6188794E+02
.14100	3.6300998E+02
.14200	3.6412067E+02
.14300	3.6522056E+02
.14400	3.6630933E+02
.14500	3.6738719E+02
.14600	3.6845469E+02
.14700	3.6951142E+02
.14800	3.7055780E+02
.14900	3.7159387E+02
.15000	3.7261967E+02

RHOU (G/CM3)	C(RHOU, 0.8) (SEC-1)
.15100	3.7363499E+02
.15200	3.7464048E+02
.15300	3.7563642E+02
.15400	3.7662229E+02
.15500	3.7759836E+02
.15600	3.7856515E+02
.15700	3.7952229E+02
.15800	3.8047008E+02
.15900	3.8140873E+02
.16000	3.8233824E+02
.16100	3.8325863E+02
.16200	3.8416986E+02
.16300	3.8507269E+02
.16400	3.8596633E+02
.16500	3.8685152E+02
.16600	3.8772817E+02
.16700	3.8859622E+02
.16800	3.8945605E+02
.16900	3.9030769E+02
.17000	3.9115087E+02
.17100	3.9198601E+02
.17200	3.9281322E+02
.17300	3.9363272E+02
.17400	3.9444398E+02
.17500	3.9524748E+02
.17600	3.9604357E+02
.17700	3.9683183E+02
.17800	3.9761288E+02
.17900	3.9838635E+02
.18000	3.9915259E+02
.18100	3.9991164E+02
.18200	4.0066334E+02
.18300	4.0140792E+02
.18400	4.0214566E+02
.18500	4.0287621E+02
.18600	4.0360014E+02
.18700	4.0431703E+02
.18800	4.0502748E+02
.18900	4.0573101E+02
.19000	4.0642812E+02
.19100	4.0711864E+02
.19200	4.0780289E+02
.19300	4.0848063E+02
.19400	4.0915210E+02
.19500	4.0981742E+02
.19600	4.1047648E+02
.19700	4.1112939E+02
.19800	4.1177660E+02
.19900	4.1241750E+02
.20000	4.1305270E+02

RHOU (G/CM3)	C(RHOU, 0.8) (SEC-1)
.20100	4.1368217E+02
.20200	4.1430565E+02
.20300	4.1492346E+02
.20400	4.1553584E+02
.20500	4.1614238E+02
.20600	4.1674334E+02
.20700	4.1733897E+02
.20800	4.1792931E+02
.20900	4.1851415E+02
.21000	4.1909375E+02
.21100	4.1966805E+02
.21200	4.2023728E+02
.21300	4.2080140E+02
.21400	4.2136038E+02
.21500	4.2191431E+02
.21600	4.2246332E+02
.21700	4.2300745E+02
.21800	4.2354667E+02
.21900	4.2408101E+02
.22000	4.2461074E+02
.22100	4.2513580E+02
.22200	4.2565623E+02
.22300	4.2617193E+02
.22400	4.2668320E+02
.22500	4.2718982E+02
.22600	4.2769201E+02
.22700	4.2818989E+02
.22800	4.2868336E+02
.22900	4.2917247E+02
.23000	4.2965734E+02
.23100	4.3013803E+02
.23200	4.3061448E+02
.23300	4.3108679E+02
.23400	4.3155506E+02
.23500	4.3201924E+02
.23600	4.3247941E+02
.23700	4.3293564E+02
.23800	4.3338793E+02
.23900	4.3383634E+02
.24000	4.3428094E+02
.24100	4.3472168E+02
.24200	4.3515862E+02
.24300	4.3559204E+02
.24400	4.3602164E+02
.24500	4.3644753E+02
.24600	4.3687000E+02
.24700	4.3728873E+02
.24800	4.3770392E+02
.24900	4.3811564E+02
.25000	4.3852392E+02

RHOU (G/CM3)	C(RHOU, 0.8) (SEC-1)
.25100	4.3892870E+02
.25200	4.3933028E+02
.25300	4.3972840E+02
.25400	4.4012321E+02
.25500	4.4051476E+02
.25600	4.4090296E+02
.25700	4.4128801E+02
.25800	4.4166983E+02
.25900	4.4204857E+02
.26000	4.4242411E+02
.26100	4.4279667E+02
.26200	4.4316612E+02
.26300	4.4353259E+02
.26400	4.4389606E+02
.26500	4.4425657E+02
.26600	4.4461399E+02
.26700	4.4496867E+02
.26800	4.4532039E+02
.26900	4.4566938E+02
.27000	4.4601548E+02
.27100	4.4635885E+02
.27200	4.4669944E+02
.27300	4.4703721E+02
.27400	4.4737242E+02
.27500	4.4770492E+02
.27600	4.4803467E+02
.27700	4.4836194E+02
.27800	4.4868657E+02
.27900	4.4900855E+02
.28000	4.4932814E+02
.28100	4.4964509E+02
.28200	4.4995965E+02
.28300	4.5027169E+02
.28400	4.5058128E+02
.28500	4.5088852E+02
.28600	4.5119322E+02
.28700	4.5149565E+02
.28800	4.5179571E+02
.28900	4.5209349E+02
.29000	4.5238898E+02
.29100	4.5268220E+02
.29200	4.5297316E+02
.29300	4.5326184E+02
.29400	4.5354838E+02
.29500	4.5383272E+02
.29600	4.5411480E+02
.29700	4.5439487E+02
.29800	4.5467277E+02
.29900	4.5494857E+02
.30000	4.5522231E+02

SOURCE LISTINGS OF DATA ANALYSIS AND OUTPUT SUBROUTINES

```

00001 C
00002 C ANALYZ: PEAKS, AREA, ANALYZ, POLYNM, TESTS
00003 C
00004 C*****
00005 C PEAKS
00006 C
00007 C      COMPUTE ROI INTEGRAL AND THREE PEAKS
00008 C      Y-12
00009 C
00010 C
00011 C
00012 C      SSJ 18-JUN-81
00013 C      REV. 10-NOV-83 1622 JKSJ
00014 C
00015 C*****
00016 C
00017 C      SUBROUTINE PEAKS
00018 C
00019 C
00020 C      INCLUDE 'COMMON.SA:1'
00021 C
00022 C      COMMON Y-12 VERSION II REV. 21-NOV-83 JKSJ
00023 C
00024 C
00025 C
00026 C
00027 C      SET THE MATH FLAG TO OK
00028 C      SET ALL RESULTS TO A NON-MEANINGFUL VALUE
00029 C
00030 C      MTHACK = 1
00031 C      MTHBOK = 1
00032 C
00033 C
00034 C      P1S = GARBAG
00035 C      P2S = GARBAG
00036 C      P1SB= GARBAG
00037 C      P2SB= GARBAG
00038 C      SIGP1S = GARBAG
00039 C      SIGP2S = GARBAG
00040 C
00041 C
00042 C      P1C = GARBAG
00043 C      P2C = GARBAG
00044 C      P1CB= GARBAG
00045 C      P2CB= GARBAG
00046 C      SIGP1C = GARBAG
00047 C      SIGP2C = GARBAG
00048 C
00049 C
00050 C      UGML = GARBAG
00051 C      UGMLB= GARBAG
00052 C      SIGU = GARBAG
00053 C      SIGUB = GARBAG
00054 C      MOLAR = GARBAG
00055 C
00056 C
00057 C      CNTSEC = GARBAG
00058 C      CTSECB = GARBAG
00059 C
00060 C
00061 C      COMPUTE ROI SUMS FOR ALL ROIS
00062 C
00063 C
00064 C      DO 10 J=1,NROI
00065 C      CALL GETROI(SPECTR,NROI(J),MROI(J),SUMROI(J))

```

```

00107 C
00108 C PEAK 1 = 60 KEV, PEAK 2 = 186 KEV
00109 C GET AREA OF PEAK 1 USING THE STANDARD
00110 C TRAPEZOIDAL BACKGROUND METHOD
00111 C ALSO PEAK 2 IF USING 2 BACKGROUND REGIONS
00112 C IF PEAK 1 IS TIME , ITS SIGMA IS SET TO 1 (+/- 1 SEC)
00113 C
00114 C          CALL AREA(2,P1S,SIGP1S)
00115 C          CALL AREA(8,P1SB,SGP1SB)
00116 C
00117 C GET AREA OF PEAK 2 & 4 USING ONLY ONE BACKGROUND REGION AND
00118 C A CONSTANT (CP2)
00119 C
00120 20      PERAW = SUMROI(5)
00121 C          BK = SUMROI(4)
00122 C          IF(LRGTBK) BK = SUMROI(6)
00123 C          P2S = PERAW - CP2 * BK
00124 C          VAR = PERAW + CP2**2 * BK
00125 C          IF(VAR .GT. 0.0) GO TO 40
00126 C
00127 C MATH PROBLEM CHANNEL A
00128 C
00129 C          MTHAOK = -1
00130 C          GOTO 50
00131 40      SIGP2S = SQRT(VAR)
00132 50      BK=SUMROI(10)
00133 C          IF(LRGTBK) BK = SUMROI(12)
00134 C          P2SB = SUMROI(11)-CP2*BK
00135 C          VAR = SUMROI(11) + CP2*CP2*BK
00136 C          IF (VAR .LT. 0.0) GOTO 400
00137 C          SGP2SB = SQRT(VAR)
00138 C          GO TO 500
00139 C
00140 C MATHEMATICAL PROBLEM
00141 C
00142 400      MTHBOK = -1
00143 C
00144 C
00145 500      RETURN
00146 C          END

```

```

00001 C*****
00002 C AREA
00003 C
00004 C      COMPUTE AREA OF A PEAK
00005 C
00006 C
00007 C      CALL AREA(J,PEAK,SIGPK)
00008 C
00009 C      J: INTEGER - NUMBER OF THE PEAK ROI
00010 C              (IN)      NOTE: LOW BACKGROUND IS ASSUMED ROI J-1
00011 C                      HIGH BACKGROUND IS ASSUMED ROI J+1
00012 C
00013 C      PEAK: REAL - PEAK VALUE
00014 C              (OUT)
00015 C
00016 C      SIGPK: REAL - PEAK SIGMA
00017 C              (OUT)
00018 C
00019 C
00020 C
00021 C      HSUE 28-DEC-78
00022 C      METHOD - J. PARKER
00023 C
00024 C      REV. 10-NOV-83      1625      JKSJ
00025 C
00026 C*****
00027 C
00028 C      SUBROUTINE AREA(J,PEAK,SIGPK)
00029 C
00030 C
00031 C      INCLUDE 'COMMON.SA:1'
00032 C
00033 C      COMMON Y-12 VERSION II REV. 21-NOV-83 JKSJ
00034 C
00035 C
00036 C      GET ROI BOUNDARIES LEFT (L) AND RIGHT(R) FOR
00037 C      LOW BACKGROUND (LB), PEAK (PK), AND HIGH BACKGROUND (HB)
00038 C
00039 C      MLBL = MROI(L,J-1)
00040 C      MLER = MROI(R,J-1)
00041 C      MPKL = MROI(L,J)
00042 C      MPKR = MROI(R,J)
00043 C      MHBL = MROI(L,J+1)
00044 C      MHBR = MROI(R,J+1)
00045 C
00046 C
00047 C      GET THE SUMS FOR LOW BACKGROUND, PEAK AND HIGH BACKGROUND
00048 C
00049 C      SUMLB = SUMROI(J-1)
00050 C      SUMPK = SUMROI(J)
00051 C      SUMHB = SUMROI(J+1)
00052 C
00053 C
00054 C      IF PEAK IS TIME THEN NO BKG SUBTRACT
00055 C
00056 C
00057 C      IF (MPKL .EQ. 0) GOTO 300
00058 C
00059 C
00060 C      COMPUTE ROI WIDTHS (N), AVERAGE CHANNELS (X)
00061 C      AND THE DISTANCE (DY) RECIPROCAL BETWEEN THE AVERAGES
00062 C
00063 C

```

```

00107      NLB = MLBR - MLBL + 1
00108      NPK = MPKR - MPKL + 1
00109      NHB = MHBR - MHL + 1
00110 C
00111      XLB = (MLBL + MLBR) * 0.5
00112      XHB = (MHL + MHBR) * 0.5
00113      DIST = XHB - XLB
00114      IF (DIST .LE. 0.0 .OR. NLB .LE. 0 .OR. NHB .LE. 0
00115 &      .OR. NPK .LE. 0) GO TO 400
00116      DXHL = 1.0/DIST
00117      XNPK = NPK
00118      XNLB = NLB
00119      XNHB = NHB
00120 C
00121 C   DETERMINE THE AVERAGE COUNTS (Y) IN THE BACKGROUNDS
00122 C   CONSTRUCT A LINE BETWEEN (XLB,YLB) AND (XHB,YHB)
00123 C
00124      YLB = SUMLB / NLB
00125      YHB = SUMHB / NHB
00126      SLOPE = (YHB - YLB) * DXHL
00127      YINTRC = YHB - SLOPE * XHB
00128 C
00129 C   FIND THE INTERSECTIONS OF THIS LINE WITH THE PEAK BOUNDARIES
00130 C
00131      YPKL = SLOPE * MPKL + YINTRC
00132      YPKR = SLOPE * MPKR + YINTRC
00133 C
00134 C   FIND THE AREA OF A TRAPEZOID FORMED UNDER THIS LINE
00135 C   AND SUBTRACT THIS FROM THE PEAK SUM TO GIVE THE PEAK
00136 C
00137      BACK = (YPKL + YPKR) * XNPK * 0.5
00138      PEAK = SUMPK - BACK
00139 C
00140 C   CALCULATE THE VARIANCE OF BACKGROUND
00141 C   USE A WEIGHT FACTOR DEPENDENT ON DISTANCE OF BACKGROUND
00142 C   REGIONS FROM THE PEAK
00143 C   (WEIGHTS = 1.0 IF EQUIDISTANT)
00144 C
00145      WL = (MPKL - XLB) * DXHL
00146      WR = (MPKR - XHB) * DXHL
00147      WHB = WL + WR
00148      WLB = 2.0 - WHB
00149      V = (WHB**2 * SUMHB) / (XNHB*XNHB) + (WLB**2 * SUMLB)
00150 &      (XNLB*XNLB)
00151      VAREK = V * XNPK*XNPK * 0.25
00152 C
00153 C   COMPUTE SIGMA OF PEAK
00154 C   (VARIANCE(P) = P)
00155 C
00156      VARPK = SUMPK + VAREK
00157      IF (VARPK .LT. 0.0) GO TO 400
00158      SIGPK = SQRT(VARPK)
00159 C
00160      GO TO 500
00161 C
00162 C   PEAK IS TIME ,,, ACCURATE TO +/- 1 SEC
00163 C
00164      300 PEAK = SUMPK
00165      SIGPK = 1.
00166      GOTO 500
00167 C
00168 C   MATHEMATICAL PROBLEM
00169 C
00170 400      IF (J .EQ. 2) MTHACK = -1
00171          IF (J .EQ. 8) MTHBOK = -1
00172 C
00173 500      RETURN
00174          END

```

```

00001 C*****
00002 C ANALYZ
00003 C
00004 C          URANIUM CONCENTRATION ANALYSIS
00005 C
00006 C
00007 C
00008 C          SSJ 17-JUN-81
00009 C          REV. 10-NOV-83 1626 JKSJ
00010 C
00011 C*****
00012 C
00013 C          SUBROUTINE ANALYZ
00014 C
00015 C
00016 C          INCLUDE 'COMMON.SA:1'
00017 C
00018 C          COMMON Y-12 VERSION II  REV. 21-NOV-83 JKSJ
00067 C
00068 C          FOR DECAY CORRECTIONS, FIGURE THE DAYS SINCE THE 0TH DAY
00069 C
00070 C          ENCODE 1000,NOWTIM
00071 1000  FORMAT(9A2)
00072 C          DECODE 1001,1MONTH,1DAY,1YEAR
00073 1001  FORMAT(12,1X,12,1X,12)
00074 C          NDAYS = 365DAY*(1MONTH,1DAY,1YEAR)
00075 C          FACTOR = 1.
00076 C          IF(LECA.LE. 0.) GO TO 30
00077 C          TLAMDA = (0.69315 / (LECA * 365.25)) * NDAYS
00078 C          FACTOR = EXP(TLAMDA)
00079 30  CONTINUE
00080 C
00081 C          CORRECT THE NORMALIZATION PEAK (1) FOR DECAY
00082 C          DON'T CORRECT IF HALFLIFE = 0.0 OR IF PEAK 1 IS TIME
00083 C
00084 C
00085 C          SKIP IF MATH PROBLEMS WITH A
00086 C
00087 C          IF(.NOT. MTHAD) GO TO 100
00088 C
00089 C          P1C = P1S
00090 C          SIGP1C = SIGP1S
00091 C          IF(MROIL(2).EQ. 0) GO TO 30
00092 C          P1C = P1S * FACTOR
00093 C          SIGP1C = SIGP1S * FACTOR
00094 30  CONTINUE
00095 C
00096 C          NORMALIZE PEAK 2 TO PEAK 1
00097 C
00098 C          IF(P1C.LE. 0.0) GO TO 30
00099 C          P2N = P2S / P1C - DP2
00100 C          VAR = (SIGP2S/P1C)**2 + (P2S*SIGP1C/P1C**2)**2
00101 C          IF(VAR.LT. 0.0) GO TO 30
00102 C          SIGP2N = SQRT(VAR)
00103 C
00104 C          USE CALIBRATION POLYNOMIAL A TO COMPUTE CONCENTRATION AND ITS ERROR
00105 C          NORMALIZE P2N FIRST
00106 C

```

```

00107          IF(P2N .EQ. 0.0) GO TO 90
00108          P2NN = P2N * ANORM
00109          SGP2NN = SIGP2N * ANORM
00110          CALL POLYNM(NAQDRD, ACALIB, P2NN, SGP2NN, UGML, SIGU)
00111          GOTO 100
00112 C
00113 C   MATH PROBLEM WITH A
00114 C
00115 90      MTHAOK = -1
00116 C
00117 C   NOW FOR B
00118 C
00119 100     P1CB = P1SB
00120     SGP1CB = SGP1SB
00121     IF(MROIL(C) .EQ. 0) GOTO 130
00122     P1CB = P1SB * FACTOR
00123     SGP1CB = SGP1SB * FACTOR
00124 C
00125 C   NORMALIZE PEAK 2 TO 1
00126 C
00127     130 IF(P1CB .LE. 0.) GOTO 190
00128     P2NB = P2SB / P1CB - DP2B
00129     VAR = (SGP2SB/P1CB)**2 + (P2SB*SGP1CB/P1CB**2)**2
00130     IF(VAR .LE. 0.) GOTO 190
00131     SGP2NB = SQRT(VAR)
00132 C
00133 C   USE CALIB POLYNOMIAL B
00134 C
00135     IF(P2NB .EQ. 0.) GOTO 190
00136     P2NN = P2NB * BNORM
00137     SGP2NN = SGP2NB * BNORM
00138     CALL POLYNM(NBORDR, BCALIB, P2NN, SGP2NN, UGMB, SIGUB)
00139     GOTO 500
00140 C
00141 C   MATHEMATICAL PROBLEM IN B
00142 C
00143 190     MTHBOK = -1
00144 C
00145 500     RETURN
00146         END

```

```

00001 C
00002 C*****
00003 C POLYNM
00004 C
00005 C      COMPUTE A POLYNOMIAL
00006 C
00007 C*****
00008 C
00009 C      SUBROUTINE POLYNM(IORDR,CALIB,X,SIGX,V,SIGV)
00010 C
00011 C      DIMENSION CALIB(11)
00012 C
00013 C
00014 C      IF(IORDR.LT. 0) GO TO 500
00015 C      V = 1.0
00016 C      SIGV = 0.0
00017 C      DO 100 IL=0,IORDR
00018 C          I = IORDR-IL
00019 C          V = V * X + CALIB(I+1)
00020 100    SIGV = SIGV * X + I * CALIB(I+1)
00021 C      SIGV = SIGV / X * SIGX
00022 C
00023 500    RETURN
00024 C      END

```



```

00001 C*****
00002 C TESTS
00003 C
00004 C     MEASUREMENT CONTROL TESTS ON THE NORMALIZATION PEAKS
00005 C     SSJ 17-JUN-81
00006 C     REV. 10-NOV-83    1720    JKSJ
00007 C
00008 C     MROI = ROI NUMBER      2 IMPLIES LOWER HALF      (IN)
00009 C                               8          UPPER
00010 C
00011 C     MCASE = 1 FOR LOWER DATA      (IN)
00012 C             2          UPPER
00013 C
00014 C     DMEAN = CENTROID OF PEAK      (OUT)
00015 C
00016 C     DSIGMN = PRECISION OF CENTROID ?      (OUT)
00017 C
00018 C     DRESOL = RESOLUTION OF PEAK (RELATIVE)      (OUT)
00019 C
00020 C*****
00021 C
00022 C     SUBROUTINE TESTS(MROI,MCASE,DMEAN,DSIGMN,DRESOL)
00023 C
00024 C     DIMENSION DDEXZ(2),DEXPCZ(2),RESZ(2)
00025 C
00026 C     INCLUDE 'COMMON.SA:1'
00027 C
00028 C     COMMON Y-12 VERSION II REV. 21-NOV-83 JKSJ
00029 C
00030 C     EQUIVALENCE (DDEX, DDEXZ), (DEXPC, DEXPCZ), (RES, RESZ)
00031 C
00032 C     SET ALL THE FLAGS TO OK
00033 C
00034 C     LPROCK = 1
00035 C     LPOSOK = 1
00036 C     LRESOK = 1
00037 C     LMCK = 1
00038 C
00039 C     INITIALIZE THE RESULTS TO GARBAG
00040 C
00041 C     DMEAN = GARBAG
00042 C     DSIGMN = GARBAG
00043 C     DRESOL = GARBAG
00044 C
00045 C     GET THE SUMS FOR THE NORMALIZATION PEAK
00046 C     SKIP THESE CALCULATIONS IF PEAK 1 IS ELAPSED TIME
00047 C     NOTE: M IS THE CHANNEL NUMBER (C), COUNT IS THE CHANNEL COUNT (N)
00048 C
00049 C     MFIRST = MROI(MROI)
00050 C     MLAST = MROI(MROI)
00051 C     IF(MFIRST.EQ. 0) GO TO 250
00052 C     SUMN = 0.
00053 C     SUMNC = 0.
00054 C     SUMNC2 = 0.
00055 C     DO 100 M=MFIRST,MLAST
00056 C         XM = M
00057 C         CALL GETROI (SPCTRM, M, M, COUNT)
00058 C         SUMN = SUMN + COUNT

```

```

00107          SUMNC = SUMNC + COUNT * XM
00108          SUMNC2 = SUMNC2 + COUNT * XM * XM
00109 100      CONTINUE
00110 C
00111 C   COMPUTE MEAN CHANNEL, SIGMA AND SIGMA OF THE MEAN
00112 C
00113          IF (SUMN .LE. 0.0) GO TO 400
00114          DMEAN = SUMNC / SUMN
00115          VAR = SUMNC2 / SUMN - DMEAN**2
00116          IF (VAR .LT. 0.0) GO TO 400
00117          CSIG = SQRT (VAR)
00118          VAR = VAR / SUMN
00119          IF (VAR .LT. 0.0) GO TO 400
00120          DSIGMN = SQRT (VAR)
00121          IF (DMEAN .LE. 0.0) GO TO 400
00122          DRESOL = CSIG / DMEAN * 100.0
00123          IF (DMEAN .GT. 512.) DRESOL = CSIG / (DMEAN - 512.)*100.
00124 C
00125 C   TEST THE POSITION PRECISION
00126 C
00127          IF (DSIGMN .GT. (DCEXZ(MCASE) / 3.0)) LPROCK = -1
00128 C
00129 C   TEST THE PEAK POSITION
00130 C
00131          IF (DMEAN .GT. (CEXPZ(MCASE) + DCEXZ(MCASE)) .OR.
00132      &      DMEAN .LT. (CEXPZ(MCASE) - DCEXZ(MCASE))) LPOSOK = -1
00133 C
00134 C   TEST THE PEAK RESOLUTION
00135 C
00136          IF (DRESOL .GT. RESZ(MCASE)) LRESOK = -1
00137 C
00138 C   SEE IF ANY MEASUREMENT CONTROL TESTS FAILED
00139 C
00140          IF ((.NOT. LPROCK) .OR. (.NOT. LPOSOK) .OR. (.NOT. LRESOK))
00141      &      LMCOK = -1
00142 C
00143 C   CHECK COUNTS/SEC IF THIS IS A CALIBRATION
00144 C   DO NOT DO THIS FOR AN ASSAY BECAUSE IT MAY CONSUME TIME
00145 C
00146 250      CONTINUE
00147 C   THIS IS SLOPPY BUT IS DONE ON EACH PASS ''
00148          CALL GETROI (SPCTRM, 1, 511, CNTSEC)
00149          CALL GETROI (SPCTRM, 512, 1023, CTSECB)
00150          IF (NSECCY .LE. 0) GO TO 400
00151          CNTSEC = CNTSEC / NSECCY
00152          CTSECB = CTSECB / NSECCY
00153 C
00154 300      GO TO 500
00155 C
00156 C   MATHEMATICAL PROBLEM
00157 C
00158 400      IF (MCASE .EQ. 1) MTHACK = -1
00159          IF (MCASE .EQ. 2) MTHBOK = -1
00160 C
00161 500      RETURN
00162      END

```

```

00001 C
00002 C  ASSAY: ASSAY, OUTPT1, OUTPT2, AVERG
00003 C
00004 C*****
00005 C
00006 C  ASSAY
00007 C
00008 C      DO REPEATED ASSAYS OR CALIBRATIONS
00009 C          Y-12
00010 C
00011 C      SSJ 24-JUN-81
00012 C      REV. 10-NOV-83 1345 JKSJ
00013 C
00014 C*****
00015 C
00016 C      SUBROUTINE ASSAY
00017 C
00018 C
00019 C      INCLUDE 'COMMON.SA:1'
00020 C
00021 C  COMMON Y-12 VERSION II REV. 21-NOV-83 JKSJ
00070 C
00071 C
00072 C  START FIRST DATA COLLECTION
00073 C
00074 C      CALL ACQUIR
00075 C
00076 C  WAIT FOR ACQUISITION TO END
00077 C  IF IT ENDED NORMALLY, START NEXT COLLECTION BEFORE
00078 C  STARTING ANALYSIS
00079 C
00080 10      CALL ACWAIT(LSTOPD)
00081          IF(LSTOPD) GO TO 500
00082          CALL ACQUIR
00083 C
00084 C  COMPUTE PEAK AREAS
00085 C
00086 C      CALL PEAKS
00087 C      IF(.NOT. LLP) GOTO 20
00088 C      CALL OPENLP
00089 C      CALL OUTPT1(LP)
00090 20      IF(.NOT. LLP422) GOTO 30
00091          CALL OPN422
00092          CALL OUTPT1(LP422)
00093 30      CONTINUE
00094 C
00095 C  ANALYZE FOR VALUES
00096 C  PERFORM MEASUREMENT CONTROL TESTS
00097 C      FIRST ON LOWER HALF (A), THEN ON UPPER HALF (B)
00098 C
00099 C      CALL ANALYZ
00100 C      CALL TESTS(2,1,CMEAN,CSIGMN,CRESOL)
00101 C      CALL TESTS(8,2,CMEANB,CSGMNB,CRESLB)
00102 C
00103 C  PRINT RESULTS
00104 C
00105 C      IF(.NOT. LLP) GOTO 40
00106 C      CALL OUTPT2(LP)

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```

00107      CALL CLOSLP
00108 40     IF(.NOT. LLP422) GOTO 50
00109      CALL OUTPT2(LP422)
00110      CALL CLS422
00111 50     CONTINUE
00112 C
00113 C SEND OUTPUT TO REMOTE PANEL AND STRIP CHART
00114 C
00115      IF(LREMOT) CALL PALARM (UGML,USOLHI,USOLLO,ILSTAT)
00116      IF(LREMOT) CALL UBAR (UGML,UBARMN,UBARDL,ILSTAT)
00117      IF(LSTRIP) CALL USTRIP (UGML,USTRMX,USTRMN,1)
00118 C
00119 C PERFORM SPECTRUM DUMP IN DUMP MODE
00120 C
00121      IF(LDUMP) CALL DUMPSP
00122 C
00123      GO TO 10
00124 C
00125 500     RETURN
00126      END

```

```

00001 C
00002 C*****
00003 C
00004 C   OUTPT1
00005 C
00006 C       PRINT FIRST HALF OF RESULTS (PEAK AREAS) ON PRINTER
00007 C
00008 C       IDEVCE = LUN
00009 C
00010 C       REV.   10-NOV-83   1345   JKSJ
00011 C
00012 C*****
00013 C
00014 C       SUBROUTINE OUTPT1(IDEVCE)
00015 C
00016 C
00017 C       INCLUDE 'COMMON.SA:1'
00018 C
00019 C   COMMON Y-12 VERSION II   REV. 21-NOV-83 JKSJ
00020 C
00021 C
00022 C   GET THE CURRENT DATE & TIME
00023 C
00024 C       LVERIFY = -1
00025 C       CALL DATTIM(LVERIFY)
00026 C
00027 C   OPEN THE LINE PRINTER
00028 C
00029 C       WRITE(IDEVCE,1000) NSECCY,NOWTIM
00030 1000   FORMAT(I8,' SECOND RUN ENDING   ',9A2/)
00031 C
00032 C   PRINT THE ROI SUMS FOR THE CALIBRATION
00033 C
00034 C       IDUM(1) = NROI/2
00035 C       DO 100 J=1, IDUM(1)
00036 C           TEMPA = ROUND(SUMROI(J),15,0)
00037 C           TEMPB = ROUND(SUMROI(J+6),15,0)
00038 100   WRITE(IDEVCE,1001) ROINAM(J),TEMPA,TEMPB
00039 1001   FORMAT(1X,A4,2(F15.0))
00040 C           WRITE(IDEVCE,1002)
00041 1002   FORMAT(9X,'DETECTOR A',5X,'DETECTOR B')
00042 C           WRITE(IDEVCE,1001)
00043 C
00044 C   PRINT COMPUTED PEAKS
00045 C
00046 C       TEMPA = ROUND(P1S,10,2)
00047 C       TEMPB = ROUND(SIGP1S,7,2)
00048 C       TEMPC = ROUND(P1SB,10,2)
00049 C       TEMPD = ROUND(SGP1SB,7,2)
00050 C       WRITE(IDEVCE,1003) TEMPA,TEMPB,TEMPD,TEMPC
00051 1003   FORMAT('P1(SIG)',2(F10.2,' (' ,F7.2,') '))
00052 C       TEMPA = ROUND(P2S,10,2)
00053 C       TEMPB = ROUND(SIGP2S,7,2)
00054 C       TEMPC = ROUND(P2SB,10,2)
00055 C       TEMPD = ROUND(SGP2SB,7,2)
00056 C       WRITE(IDEVCE,1004) TEMPA,TEMPB,TEMPD,TEMPC
00057 1004   FORMAT('P2(SIG)',2(1X,F10.2,' (' ,F7.2,') '))
00058 C       CALL PRIBK(IDEVCE)
00059 C
00060 C   RETURN
00061 C
00062 C   END

```

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00001 C*****
00002 C OUTPT2
00003 C
00004 C      PRINT SECOND HALF OF RESULTS ON LINE PRINTER
00005 C      IDEVCE = LUN
00006 C
00007 C  REV 10-NOV-83      1410      JKJSJ
00008 C
00009 C*****
00010 C
00011 C      SUBROUTINE OUTPT2(IDEVCE)
00012 C
00013 C
00014 C      INCLUDE 'COMMON.SA:1'
00015 C
00016 C  COMMON Y-12 VERSION II  REV. 21-NOV-83 JKJSJ
00017 C
00018 C
00019 C  PRINT CORRECTED AND NORMALIZED PEAKS
00020 C
00021 C      WRITE(IDEVCE,1001) P1C,SIGP1C,P1CB,SGP1CB
00022 1001  FORMAT('P1' (SIG)',2(F10.0,' (' ,F7.0,' )'))
00023 1001  WRITE(IDEVCE,1002) P2N,SIGP2N,P2NB,SGP2NB
00024 1002  FORMAT('P2' (SIG)',2(F10.4,' (' ,F7.4,' )'))
00025 C
00026 C  PRINT THE MEASUREMENT CONTROL VALUES
00027 C
00028 C      WRITE(IDEVCE,1003) CMEAN,CSIGMN,CMEANB,CSGMNB
00029 1003  FORMAT('P1 MEAN ',2(F10.2,' (' ,F7.2,' )'))
00030 1003  WRITE(IDEVCE,1004) CRESOL,CRESLB
00031 1004  FORMAT('RESLTN ',2(F15.4,' %'))
00032 C
00033 C      WRITE(IDEVCE,1005) CNTSEC,CTSECB
00034 1005  FORMAT('COUNTS/SEC',F15.2,2X,F15.2)
00035 C
00036 C  PRINT THE CONCENTRATION, SIGMA
00037 C
00038 C      TEMPA = ROUND(UGML,10,2)
00039 C      TEMPB = ROUND(UGMLB,10,2)
00040 C      WRITE(IDEVCE,1006) TEMPA,SIGL,TEMPB,SIGLB
00041 1006  FORMAT('G/L(SIG)',2(1X,F10.2,' (' ,F7.2,' )'))
00042 C
00043 C  TEST FOR ASSAY ERRORS
00044 C
00045 300  IF(.NOT. MTHACK) WRITE(IDEVCE,1007)
00046 1007  FORMAT(/5X,'**** MATH ERROR **  DET A ****')
00047 C
00048 1007  IF(.NOT. MTHBOK) WRITE(IDEVCE,1007)
00049 1007  FORMAT(/5X,'**** MATH ERROR **  DET B ****')
00050 C
00051 1012  IF(.NOT. LARCON) WRITE(IDEVCE,1012)
00052 1012  FORMAT(/5X,'**** POSITION PRECISION IS BAD ****')
00053 C
00054 1013  IF(.NOT. LPOSOK) WRITE(IDEVCE,1013)
00055 1013  FORMAT(/5X,'**** PEAK POSITION IS BAD ****')
00056 C
00057 1014  IF(.NOT. LRESOK) WRITE(IDEVCE,1014)
00058 1014  FORMAT(/5X,'**** PEAK RESOLUTION IS BAD ****')
00059 C
00060 C
00061 C      RETURN
00062 C
00063 C      END

```