EG&G ORTEC FIELD PORTABLE GAMMA-RAY SPECTROMETER OPERATION

CONTENTS

CONTENTS (cont)

EG&G ORTEC FIELD PORTABLE GAMMA-RAY SPECTROMETER OPERATION

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) pertains to the set up, operation, analysis and data calculations performed with the EG&G ORTEC field portable gamma spectrometer. This system consists of a detector by which samples are analyzed and an analysis software package used to display data collected. The EG&G ORTEC gamma spectrometer is used for field and laboratory screening of environmental samples to calculate concentrations of radionuclides.

2.0 METHOD SUMMARY

The EG&G ORTEC gamma spectrometer can be operated using an internal battery or with its supplied power cord. This system has two detector capabilities, choice of which will depend on the application and results desired. In turn, the procedure for set up and operation will be different. Proper set up for each system must be followed, or the internal components will be seriously damaged and/or the data received will be unreliable. This instrument is a field portable system capable of detecting gamma radiation from a sample and quantifying the activity of radioisotopes. Gamma rays interact with either a Sodium Iodide (NaI) or a High Purity Germanium (HPGe) crystal, producing a scintillation. After amplification, the signal passes to an analog to digital converter (ADC) and is recorded in a multichannel analyzer (MCA). Sample (unknown) spectrums are compared to standard (known) spectrums. The activity of the unknown sample can then be calculated.

Analyses to calculate sample activity shall follow this order:

1. Spectrum Energy Calibration
2. Background Analysis
3. Reference Standard Analysis
4. Sample (unknown) Analysis

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The method used for radio isotopic quantification requires the analysis of a standard calibrated reference source. As the counts of the unknown sample are taken, the resulting spectrum is compared to the standard reference source of known activity. To eliminate variables caused by gamma interaction through different materials, it is optimal that the sample and reference source containers are as close in geometry as possible if not identical.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

4.1 NaI System

It is important to maintain the NaI crystal at a constant temperature while in operation. The crystal should not be subjected to temperature extremes. If this does occur, the crystal should be allowed to reach room or ambient temperature before performing analysis. If this is not accomplished prior to analysis, as the detector reaches room/ambient temperature the results will not be accurate. When using the NaI detector, it is important to realize that the peaks are very broad with a resulting low peak resolution. Therefore when identifying specific nuclides, it should be realized that gamma energies very close in energy may be encompassed into one peak. It is however practical to use the NaI for analysis when only one radioactive isotope or chain is known to be present. The NaI system also has the advantage of not requiring liquid

nitrogen cooling.

4.2 HPGe System

Great care must be employed when operating the HPGe system. The detector must not be exposed to shock, or be dropped or jolted in any manner. It is of extreme importance that the detector be cooled to operating temperatures before applying the bias (high voltage) to the detector. The system has an automatic bias shutdown in the event that the detector is turned on when not cooled or the temperature increases during analysis. However, the user should not rely on this mechanism, for if it fails the crystal may be permanently damaged. Never pack the system with any traces of liquid nitrogen still present in the Dewar. The HPGe system has a higher peak resolution than the NaI, therefore if properly calibrated it can be used to identify unknown radioisotopes in samples.

4.3 Background Noise

The gamma spectroscopy system analyzes for gamma rays. Since cosmic radiation is present everywhere, it will also interact with the detector; this naturally occurring radiation is called background. Also present throughout the system is noise, which includes pulses and electronic blips in the cabling system that can interfere with sample analysis. It is recommended, however, not required that in areas of high background radiation, shielding be used to reduce the background counts detected. Shielding, such as a lead cave, would be prudent, especially for use with the HPGe system. In turn, reducing the background counts, will also lower the detection limit.

5.0 EQUIPMENT/APPARATUS

The following equipment is required for the EG&G ORTEC gamma spectrometer operation:

- Nomad hardware component, with manual and power cord
- Screwdriver: Phillips and regular
- Tape
- Portable lap top computer with MAESTRO software installed
- NaI 2 x 2 crystal or HPGe crystal with liquid nitrogen Dewar attached
- Sample containers
- Preamp cable s/n 3752
- High voltage cord s/n 6936
- Bias shutdown cable
- ADCAM Interface with +5V connector
- Calculator
- Three tier tray cart (NaI)
- Field portable scale

6.0 REAGENTS

- Liquid Nitrogen supply (HPGe)
- U.S. EPA Radium-226 reference source, 50pCi/g
- Cesium-137 and Potassium-40 energy calibration standard sources

EG&G ORTEC FIELD PORTABLE GAMMA-RAY SPECTROMETER OPERATION

7.0 PROCEDURES

7.1 Liquid Nitrogen Filling (HPGe)

Prior to analysis with the HPGe detector, the crystal Dewar must be filled with liquid nitrogen and allowed to reach thermal equilibrium. If the detector is completely warm, fill the Dewar only 20-30% full, then fill completely in 15 minutes. Allow the temperature to equalize for 1.5 hours, then cap off with liquid nitrogen. See Figure 1, Liquid Nitrogen Filling Diagram, Appendix A.

CAUTION: PVC OR CRYOGENICALLY APPROVED GLOVES AND SAFETY GLASSES SHALL BE WORN AT ALL TIMES WHILE HANDLING LIQUID NITROGEN.

1. Place in the instrument in a horizontal position and unscrew the Dewar neck plug. Insert the fill tube into the Dewar.

2. Place the funnel support bracket over the Dewar neck and tighten the rectangular screw.

3. Pour liquid nitrogen into the funnel until it begins to trickle out the back.

4. Replace the Dewar neck plug upon completion.

7.2 Equipment/Cabling Set Up

1. Setting Channel Quantity

Each detector requires a specific channel quantity per spectrum. To ensure proper set up, locate the M2SETUP program in the MCA directory.

a. Turn the computer on and obtain the C prompt.
b. Change the directory to MCA, and type M2SETUP.
c. Select the following responses to the program prompts:

Select the number of MCBs --> 1
Select the MCB type --> 92x
Does system have Transistor Reset Preamp --> No
Select number of channels --> 2048 (NaI)
8192 (HPGe)

d. The system will automatically return to DOS upon completion.

2. Internal Bias Voltage Range

The Nomad base is utilized for both the NaI and the HPGe detectors. The operating voltage for each detector is different. Prior to enabling the high voltage, set the internal bias to the correct

range.

a. Turn the power off and remove the AC line cord. Set the battery slide switch to off. Wait at least one minute so that all the high voltage can discharge.
b. Remove the four #6/32 screws that hold the mounting plate to the suitcase. Do not remove the six screws that hold the battery in place. Gently lift the Nomad Mounting plate out of the suitcase and carefully place it upside down, on its handles.
c. Rotate the Nomad so that the bias supply printed wiring board is on your left (safety shield has a printed high voltage sign on it) and the amplifier wiring board is on your right. Carefully remove the bias supply safety shield.
d. Locate the high voltage polarity and range jumper board. This four inch long rectangular board is on the right side of the bias supply wiring board and is under a plastic retainer shield. Remove the plastic retainer shield.
e. Carefully lift the board until it is free of the board below; it is connected by a series of pins. The board can be placed in four locations, two of which concern this SOP. These positions are labeled on the printed wiring board on the upper right corner. The High Voltage board shall be set at "Positive Low" for the NaI system and "Positive High" for the HPGe. In the right hand position, nearest the amplifier board it is set for positive high voltage (HPGe). When it is in the up position, farthest away from the large red component, it is in the positive low voltage range. Place the board in the proper position and firmly place the pins into the sockets.
f. REMOUNT THE SAFETY SHIELD TO THE BIAS SHIELD. Reverse the procedure to install the Mounting plate.

3. Setting the Bias Voltage

The exact bias voltage is set using the dial potentiometer located at the lower right of the mounting plate on the Nomad base. The dial reads in kilo Volts (kV).

a. Turn the dial clockwise to set the voltage for the HPGe to 2500 Volts (V) (2.5kV) or 900 V (0.9kV) for the NaI.

4. Cabling the HPGe System

From the neck of the gamma crystal probe, six cables extend out. Connect the cables to the base of the Nomad in the following manner (Figure 2, Appendix A):

a. Connect the preamp (gray cable s/n 3752) to the preamp port on the gamma spec Nomad base.
b. Connect the high voltage cord (s/n 6936,RG59B/U) to the "High Voltage" pin port on the base.
c. Connect the bias shut down cable to the SD port on the Nomad base.
d. Connect the output to the preamp cable to the "Amp In" on the Nomad base.
e. Connect the computer ADCAM interface with the +5V connector cable to the "Duel Port Memory" and the +5V port to the nomad base and computer port.
f. Two cables, the Output and Test will not be connected to the Nomad. They should be secured as to insure no damage will occur to them.

5. Cabling the NaI System

When using the NaI crystal for stationary sample analysis, set up the three tier tray cart, placing the tray with the larger cut-out hole on top. Set the NaI crystal through the hole so that the detector faces up and the connecting wires will extend down. Set up the NaI detector and cabling system in the following manner (Figure 2, Appendix A):

a. Insert the photomultiplier base with preamp cylinder to the base of the NaI crystal. There is a small notch-hole along the inner port that should be aligned with the notch on the NaI base. Use caution when inserting the crystal end prongs. Care should be taken as not to bend the metal clamps in the photomultiplier ports.
b. Attach the preamp cable (already attached to the photomultiplier base) to the PREAMP port on the Nomad base.
c. Connect the high voltage cable from the detector base port labeled Pos High Voltage to the Nomad port labeled HV.
d. Connect the preamp cable to the Preamp pin on the photomultiplier base to the pin labeled AMP IN on the Nomad base.
e. Place the computer on the Nomad base, aligned with the Velcro strips. Connect the computer ADCAM interface with the +5V connector to the duel port memory and the +5V port on the Nomad base and computer port.
f. Insure the metal pin-cap is covering the SD port on the Nomad base, or the high voltage will not be enabled onto the detector.
g. Connect the power cord to the Nomad base and an external power supply.
h. Connect the Compaq power cord to the computer port and an external power supply.

7.3 NaI/HPGe System Start up

1. Turn the Nomad power to on. The red light above the power switch will light to indicate power is supplied to the system.

2. Turn computer power on. The computer should call up the SYSTEM MANAGER Main Menu automatically.

a. To obtain the SYSTEM MANAGER Main Menu from DOS, obtain the USER directory from the C prompt. At C:\USER type "call ORTECMNU STARTB30". You will then be in the ORTEC Main Menu.

3. At main menu select MAESTRO. Hit enter. The MAESTRO Spectrum Display should now be on the screen (Figure 3, Appendix A). To the right of the screen is the display parameters, indicating the location of the spectrum (MCB or Buffer), location of channel marker (Vertical (Vt) and Horizontal (Hz)), count time in seconds and presets, as well as current date and time. Along the top of the spectrum display, seven menus are listed horizontally. Three to the right (Presets, Acquire and Display) are MCB menu options. The left four are Buffer functions. Note that the menus will only be an option depending on the location of the spectrum. Furthermore, if a Buffer menu is selected while in MCB, the spectrum program will automatically switch to the Buffer WITHOUT transferring the spectrum.

4. Apply the bias to the detector.

   a. Select the Services menu. By hitting <ALT> S you will also retrieve this menu.
   b. Select 92X ControL. Hit enter. A menu will appear on the screen listing the parameter set up for the system. It should read as follows:

      Coarse Gain --> 10
      Fine Gain ----> 0.5001
      Shaping Time -> short
      Det Bias -----> +2500V for HPGe or +900V for NaI
      Auto PZ ------> Trigger

   c. Change any of the parameters that do not appear as above, by toggling with the arrow keys to highlight the desired function and press enter.
   d. The detector bias is set using the potentiometer located at the right bottom corner of the Nomad base. You should have already turned the potentiometer to the desired voltage reading and thus that value should be indicated in this menu as the Det Bias. See section 7.2.3 for the procedure.
   e. Enable the bias by toggling down to the Det Bias line. Hit enter.
   f. Select On from the next menu. Be sure the HPGe system has been properly cooled with liquid nitrogen.
   g. The red light labeled High Voltage On, located on the right side of the Nomad base will turn on to indicate that bias has been put on the detector.

5. Auto PZ - Amplifier Pole Zeroed. The amplifier should be pole zeroed anytime the detector is changed, the shaping time is changed or the power to the module is turned off.

   a. Place near the detector, a radioactive source of sufficient activity to produce a relatively high count rate. A 1µCi, Cs-137 source will be sufficient.
   b. Toggle to the PZ trigger option and press enter. A message of "Auto PZ complete" appearing at the bottom of the screen, will indicate when pole zeroing has been completed. Hit the Esc key to exit out of this menu.

6. Display Parameters

   a. Change the spectrum display to "full" by selecting the Display menu and toggling down to Full/Expand. Hit enter. The displayed menu on the right side of the screen will indicate a change in the parameter chosen. To the right of the Display prompt should read Expand.
   b. To move up and down the spectrum channels, use the appropriate right or left arrow keys. To change the y-axis, use the up or down arrows or page up, page down keys. The MAESTRO II computer software also has "hot keys" that enable rapid movement up and down the spectrum (Figure 4, Appendix A).
   c. Select the Presets menu to change the live time. Toggle down to Live time, and input the number of seconds for analysis. Live time indicates actual sample analysis time, taking into consideration the detector dead time.

7.4 Spectrum Energy Calibration

1. Center the K-40 and Cs-137 source in front of the detector probe, placing the K-40 closest to the detector. If necessary, apply a little tape to hold the Cs-137 check source button centered on the K-40 container.
2. Select the Acquire menu. Select Clear to erase the previous spectrum on the current MCB.
3. Select the Acquire menu. Select StarT. As data is being collected, the spectrum will continually update the acquisition on the monitor. The right hand side display menu, lower right corner indicates the display time including the percent dead time.
4. Upon completion switch to the buffer by selecting the Acquire menu. Toggle down to MCB>Buffer. Hit enter. When the spectrum has been transferred, the Display menu along the right side of the screen will be updated and the "Buffer" position will be highlighted. You may have to select one of the buffer menu choices (ex. File) to move the spectrum to the buffer. The spectrum will then transfer to the buffer and you may perform work on the spectrum. If you do not physically transfer the spectrum to the buffer and just select one of the buffer menu items, the spectrum will not be transferred over.
5. Scan the spectrum with the right and left arrow keys. Locate two peaks from the calibration standard spectrum. When using, K-40 and Cs-137, locate the 661.7 keV gamma from Cs-137 and the 1460.8 keV from K-40. It may be necessary to also toggle the up and down arrow keys to increase or decrease the y-axis scale. To become proficient in locating the peaks, it may take some practice to become familiar with their location.
6. Place a Region of Interest (ROI) to encompass each peak.

    a. Move the cursor to the channel at the beginning of the first peak for the first calibration point. Typically, three channels to include background before and after the peak are included in the ROI.
    b. Select the ROI menu. Toggle down to Begin. Hit enter. Move the cursor to the end of the peak and select the ROI menu and toggle down to End. Hit enter. The points encompassing the peak will be indicated by a shaded feature. Repeat this same procedure to place a ROI around the second peak. Record both ROI ranges.
    c. Place the cursor inside the first ROI shaded area. Select the Calculate menu. Toggle down to Calibrate. Hit enter. The program will prompt an answer for the peak in channel #. Enter the energy of the first peak. When using Cs-137, the peak energy is 661.7. Hit enter. Cursor to the next peak and repeat above procedure. When using K-40, the second peak energy will be 1460.8. Hit enter. Enter the units as "keV" for the next prompt. The system will now be calibrated. Generally speaking, the spectrum is calibrated between the two energies used as calibration points. Therefore, an ideal calibration standard is one that would encompass the energy of the isotope for quantification in the samples.

7. Save the Spectrum

    All spectrums should be saved before returning to the MCB. If you do not save before exiting the buffer the information and all changes will be lost in transition.

    a. Select the File menu. Toggle to the Save function. Hit enter. Respond to the prompt

"Enter file mane to be SAVED". Eight letter/number maximum. Hit enter.

b. Respond to the next prompt "Enter the SAMPLE DESCRIPTION". Note that when the spectrum is retrieved, this description will be displayed.

7.5 Background Analysis

Background analyses are typically performed prior to sample analysis and in the area of sample analysis to best represent the background levels.

1. Remove all radioactive sources and samples from the vicinity of the detector during background analysis. Start an acquisition.

   a. Select the Acquire menu.
   b. Select Clear to erase the previous spectrum on the current MCB.
   c. Select Acquire. Select StarT. As data is being collected, the spectrum will continually update the acquisition on the monitor. The right hand side display menu, lower right corner indicates the display time including the percent dead time.

2. Transfer the spectrum to the buffer.

   a. Select the Acquire menu.
   b. Select MCB/Buffer.

3. Save the spectrum.

   a. Select the File menu.
   b. Select Save. Enter a relevant file name and description.

7.6 Reference Standard and Sample Analysis

Be sure to calibrate the spectrum prior to sample analysis. Without a calibrated spectrum the data collected will be useless. Perform the reference standard analysis prior to analyzing a sample (unknown) for determination of activity.

1. Place the sample (standard or unknown) in front of the detector probe.

   a. Clear out the old spectrum. Begin the acquisition by selecting the Acquire menu. Select StarT.
   b. Upon completion transfer spectrum to the buffer by selecting the Acquire menu. Select MCB>Buffer.

2. Create a ROI to encompass the gamma peak of interest from the reference standard or the unknown. Record this region.

   a. Move the cursor to channel of the beginning of the peak for the first calibration point. Typically, three channels to include background are included in the peak.
   b. Select the ROI menu. Toggle down to Begin. Hit enter. Move the cursor to the end

of the peak and select the ROI menu and toggle down to End. Hit enter. The points encompassing the peak will be indicated by a shaded feature. Record this ROI.

3. Save the spectrum.

   a. Select the File menu.
   b. Select Save. Enter a relevant file name and description.

4. Determine the net area in the peak after stripping background.

   a. Move the cursor inside the peak ROI. Select the Calculate menu. Select StriP. Hit enter. Select the current background file to strip off the current spectrum. Hit enter. Enter "0" for time ratio as the strip multiplier.
   b. Move the cursor inside the ROI. Select the Calculate menu. Select Net Area. The net area under the peak will be indicated along the bottom portion of the computer screen. Record this value as (C_r) for the reference standard or (C_s) for the sample.

5. Determine the sample mass.

   a. Tare a field scale with an empty sample container on the balance. Obtain the mass of the sample and record this value as (M_s).

6. Identifying Unknowns

   a. Refer to APPENDIX B, Table of Gamma-Ray Nuclides Common to Environmental Analysis, to locate the energy of the unknown gamma peaks. Keep in mind the limitations specified in section 4.0 of this SOP. Generally speaking, a proper spectrum calibration should be insured before attempting to correctly identify unknown radionuclides. In addition, knowledge of environmental radioactivity is often recommended to assess the credibility of a find.

7.7 Detector Shutdown

Before removing power from the system, you must first remove the high voltage from the detector and then quit out of the MAESTRO software. To do this:

1. Select the Services Menu. Toggle down to 92X ControL.

2. Toggle through next menu to Det Bias. Hit enter.

3. Select "Off" at next prompt.

4. Select the Services Menu. Toggle down to Quit. This will bring you to the MAESTRO Main Menu. Toggle down to "Exit to System". Enter yes to the next prompt if the current file has been saved.

5. Remove power from the Nomad base. Disconnect all cables.

8.0 CALCULATIONS

8.1 Calculation of the Lower Limit of Detection (LLD)

It is often important to calculate the value below which, the instrument can not accurately detect. The general calculation used to calculate the lower limit of detection is:

$$LLD = \left(B^{1/2}\right) \times .66$$

where:

LLD = Lower limit of detection
B = Background counts in ROI for gamma of interest

8.2 Determination of Sample Activity

The general formula for calculation of sample activity is:

$$A_S = \frac{(C_s)(A_r)(M_r)(K_{Rn})}{(C_r)(M_s)}$$

where:

M_r= Reference Mass (g)
M_s= Sample Mass (g)
C_r= Reference Counts in Peak ROI after Strip
C_s= Sample Counts in Peak ROI after Strip
A_r= Activity of Reference Standard (pCi/g)
A_s= Activity of Sample (pCi/g)
K_{Rn}= Estimated Radon-222 Escape Factor for Radium quantification when using the Bi-210, 609 keV gamma peak to calculate for Radium

9.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

There are no specific quality assurance activities which apply to the operation of the EG&G/ORTEC gamma spectrometer. However, the following general QA procedures apply:

All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkouts and calibration activities must occur prior to analysis operation and they must be documented. As a means of quality assurance, a health physicist or radiation professional should be consulted prior to field work analyzing for radionuclides, who can thoroughly assess the parameters on site and any interferences and check that proper calculations are being made with the data.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When handling hazardous materials, follow United States Environmental Protection Agency, Occupational Safety and Health Administration, and corporate health and safety practices.

When handling radioactive samples, the exposures shall be kept as low as reasonably achievable. Refer to ERT/SERAS SOP #3014, Radiation Protection Programs.

12.0 REFERENCES

EG&G ORTEC, Maestro II Software Operator's Manual, Version 1.4

EG&G ORTEC Solid-State Photon Detector Operators Manual - Gamma Gage

EG&G ORTEC Solid State Photon Detector Operators Manual - GEM Series

EG&G ORTEC Nomad Portable Spectroscopy System Model 92X-P Hardware Reference Manual

The Health Physics and Radiological Health Handbook, Nucleon Lectern Associates

APPENDIX A
Figures
SOP #1716
January 1995

FIGURE 1. Liquid Nitrogen Filling Diagram

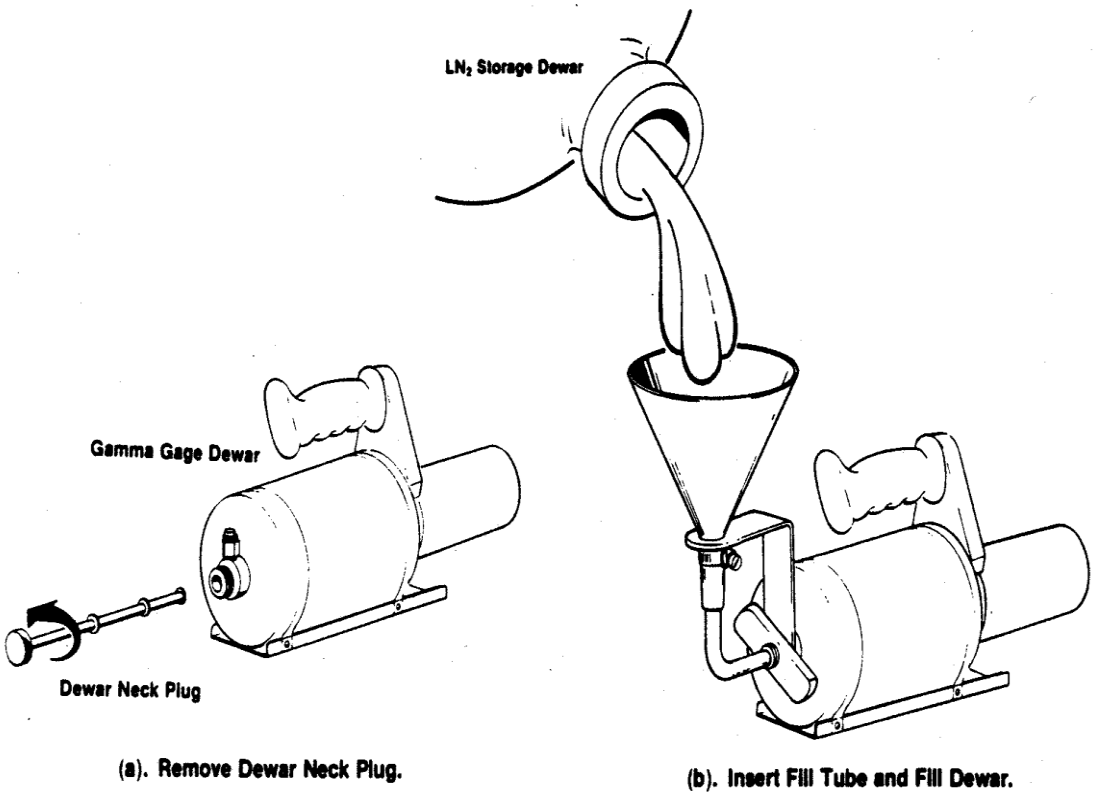


FIGURE 2. Cabling the NaI and HPGe systems

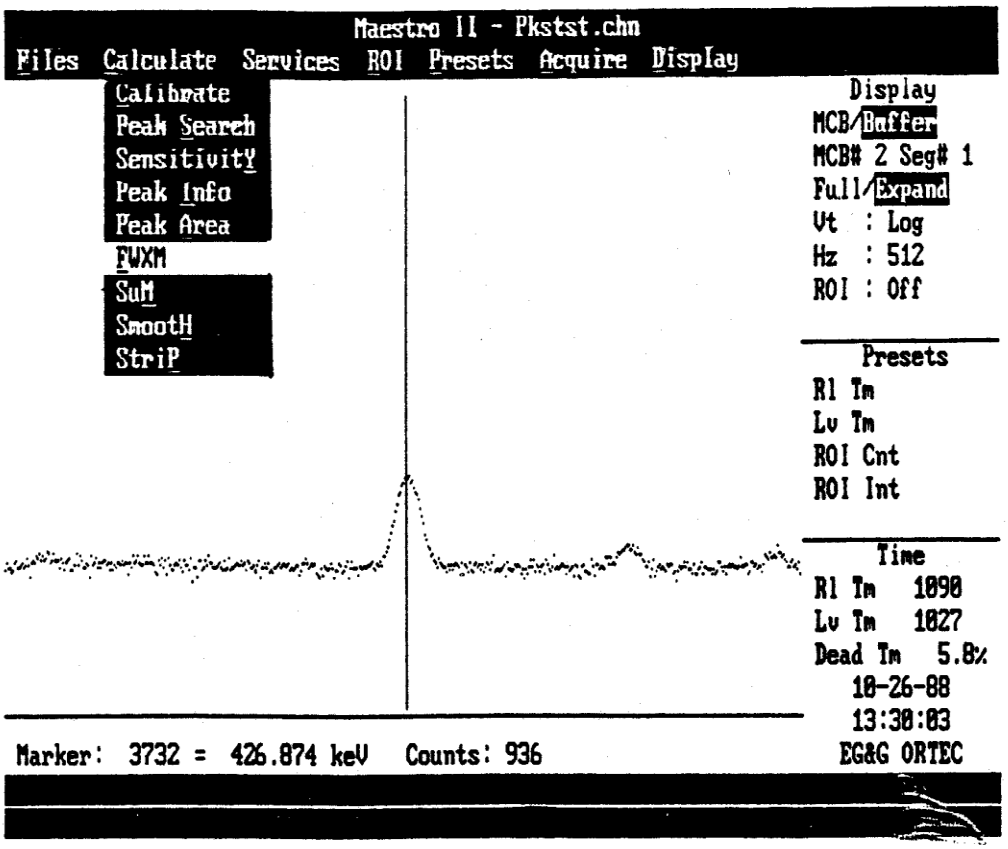


FIGURE 3. MAESTRO Spectrum Display

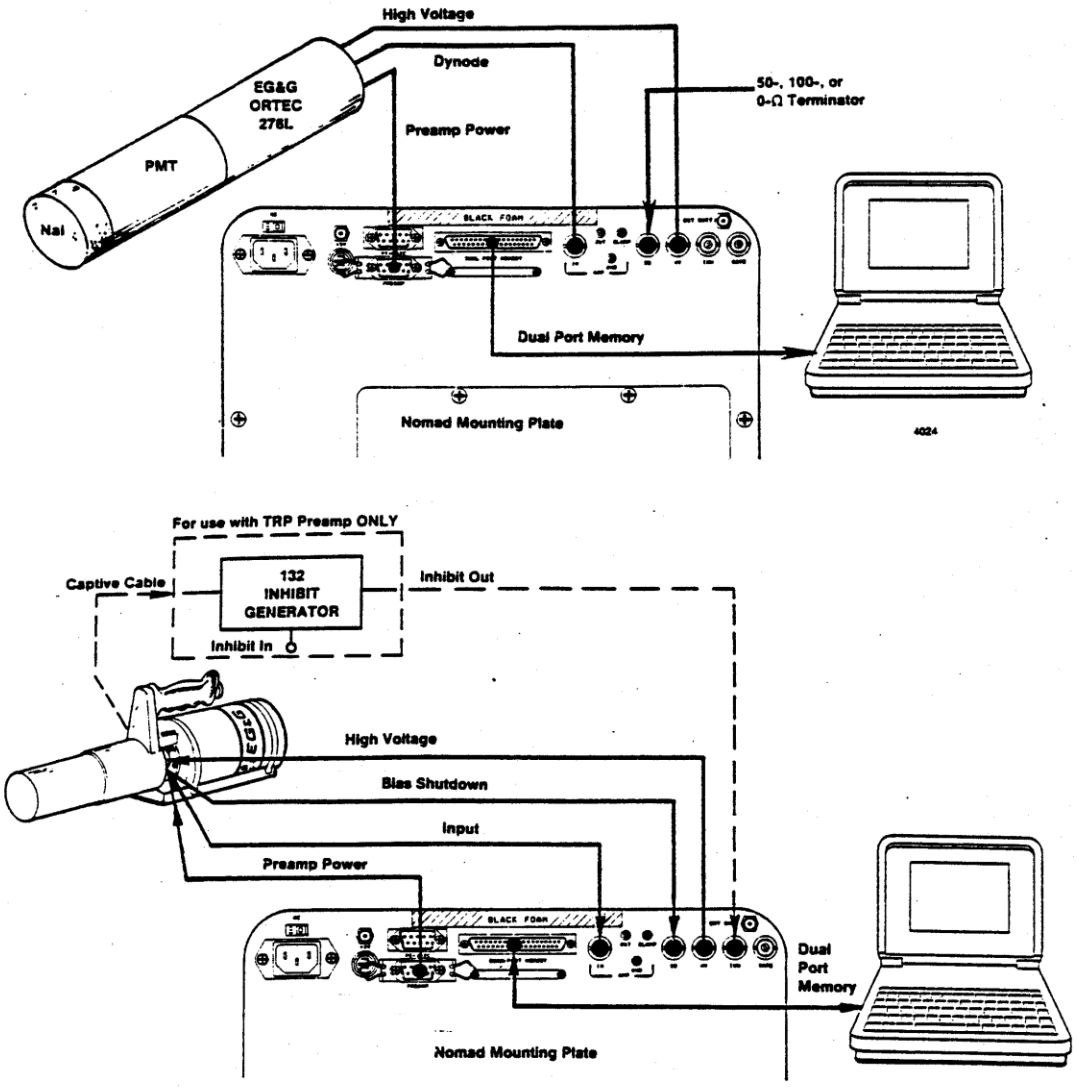
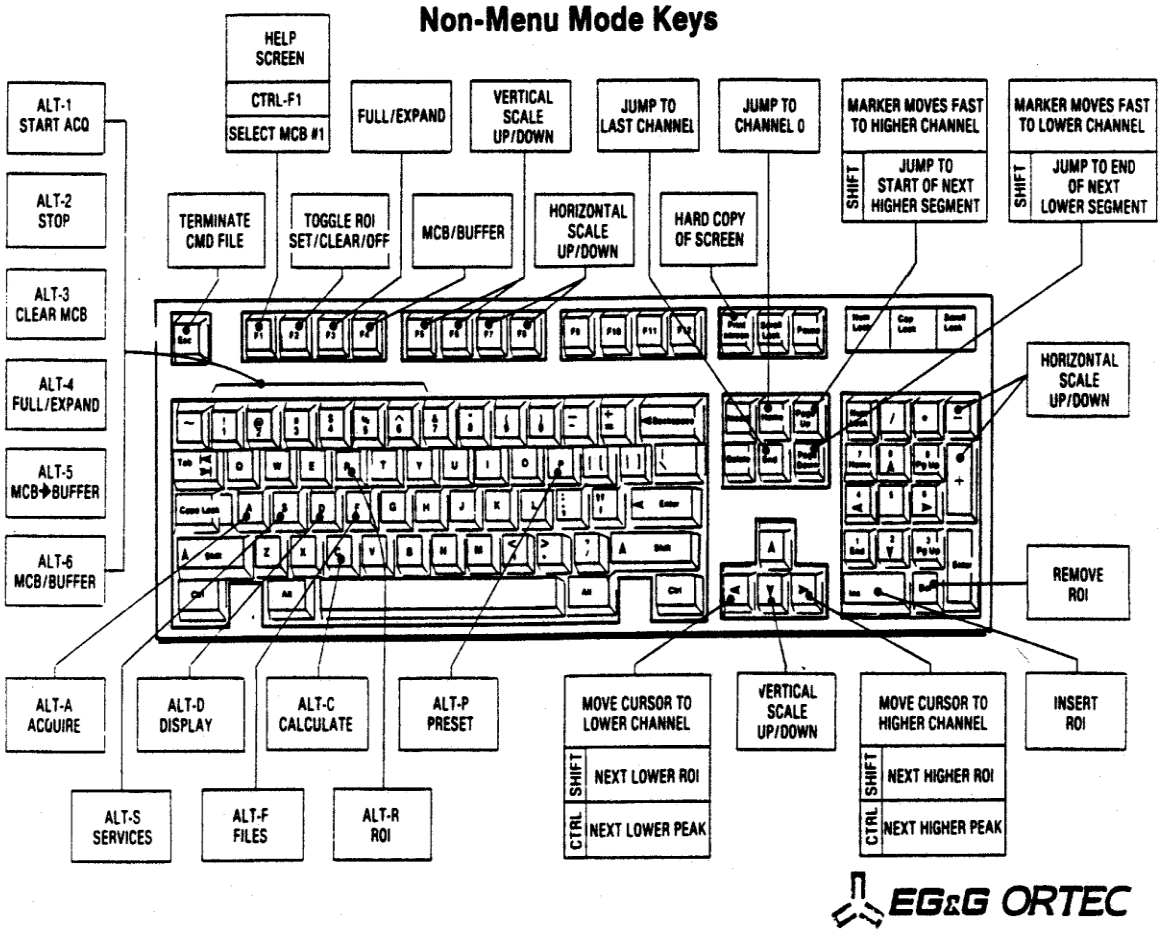


FIGURE 4. MAESTRO Hot Keys



APPENDIX B
Table of Gamma-Ray Nuclides Common to Environmental Analysis
SOP #1716
January 1995

EG&G ORTEC FIELD PORTABLE GAMMA-RAY SPECTROMETER OPERATION

Table of Gamma-Ray Nuclides Common To Environmental Analyses

Energy	Nuclide	%	T ½	E2	%	E6	%	Origin
14.4	^{57}Co	9.5	272D	122.1	85.5	136.5	10.7	Activity
26.3	^{241}Am	2.4	433Y	59.5	35.7	17.0LX	38.7	^{241}Pu
30.0	^{140}Ba	13.6	12.8D	162.7	6.2	304.9	4.3	Fallout
39.6	^{129}I	7.5	1.6E7	30.0KX	70.8			Fission
39.9	^{212}Bi	1.1	Long	727.3	6.7	1620.7	1.5	^{232}Th
40.6	^{99}Mo	1.1	65.9H	18.3X	3.2	140.5	3.5	Fallout
46.5	^{210}Pb	4.1	22.3Y					^{238}U
49.8	^{132}Te	14.4	78.2H	30.0KX	70.9	111.9	1.9	Fallout
53.2	^{133}Ba	2.2	10.5Y	81.0	34.2	31.0KX	101.3	Activity
59.5	^{237}U	32.8	6.75D	101.1	26.0	208.0	22.0	Fallout
59.5	^{241}Am	35.7	433Y	26.3	2.4	17.0LX	38.7	^{241}Pu
60.0	^{155}Eu	1.1	4.96Y	86.5	30.4	105.3	20.6	Fallout
61.5	^{239}Np	1.0	2.36D	14.3LX	56.1	101.0KX	38.9	Fallout
63.3	^{234}Th	3.8	Long	92.6D	5.4			^{238}U
66.9	^{136}Cs	12.5	13.2D	34.0KX	17.6	86.4	6.3	Fission
74.8X	^{214}Pb	6.5	Long	77.1X	11.0	87.3X	3.9	^{238}U
74.8X	^{212}Pb	10.5	Long	77.1X	17.7	87.2	6.3	^{232}Th
75.0X	^{208}Tl	3.6	Long	72.8X	2.1	84.8X	1.3	^{232}Th
77.1X	^{214}Pb	11.0	Long	74.8X	6.5	87.2X	3.9	^{238}U
77.1X	^{212}Pb	17.7	Long	74.8X	10.5	87.2X	6.3	^{232}Th
79.6	^{133}Ba	3.2	10.5Y	53.2	2.2			Activity
80.1	^{144}Ce	1.1	285D	133.5	11.1	696.5	1.3	Fallout
80.2	^{131}I	2.6	8.04D	364.5	81.2	284.3	6.1	Fission
81.0	^{133}Ba	34.2	10.5Y	276.4	7.3	79.6	3.2	Activity
81.0	^{133}Xe	37.0	5.25D	79.6	0.2	31.0KX	40.1	Fission
84.3X	^{228}Th	1.2	1.91Y	12.3X	3.1			^{232}Th

D - Following half life indicates days
H - Following half life indicates hours
Y - Following half life indicates years
M - Following half life indicates minutes
X - Following energy indicates X-Ray
D - Following energy indicates a doublet

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (cont'd)

Energy	Nuclide	%	$T_{1/2}$	E2	%	E3	%	Origin
86.4	^{136}Cs	6.3	13.2D	66.9	12.5	153.3	7.5	Fission
86.5	^{155}Eu	34.0	4.96Y	105.3	20.6	60.0	1.1	Fallout
87.2X	^{214}Pb	3.9	Long	77.1X	11.0	241.9	7.5	^{238}U
87.2X	^{212}Pb	6.3	Long	238.6	43.6	77.1X	17.7	^{232}Th
88.0	^{109}Cd	3.6	463D	23.0KX	99.8			Activity
90.0X	^{228}Ac	3.4	Long	93.4X	5.6	99.6	1.3	^{232}Th
91.1	^{147}Nd	28.0	11.0D	38.5KX	37.4	319.4	2.0	Fallout
92.6D	^{234}Th	5.4	Long	63.3	3.8			^{238}U
93.4X	^{228}Ac	5.6	Long	90.0X	3.4	99.6	1.3	^{232}Th
97.1	^{237}U	16.0	6.75D	101.0	26.0	208.0	22.0	Fallout
99.6	^{228}Ac	1.3	Long	129.0	2.9	209.4	4.1	^{232}Th
101.1	^{237}U	26.0	6.75D	59.5	32.8	208.0	22.0	Fallout
105.3	^{155}Eu	20.6	4.96Y	86.5	34.0	60.0	1.1	Fallout
105.4X	^{228}Ac	2.0	Long	99.6	1.3	129.0	2.9	^{232}Th
106.1	^{239}Np	22.7	2.36D	61.5	1.0	117.0KX	11.6	Fallout
109.2	^{235}U	1.5	70E7Y	93.4KX	5.5	143.8	10.5	Natural
111.9	^{132}Te	1.9	78.2H	49.8	14.4	116.4	1.9	Fallout
113.9	^{237}U	25.0	6.75D	101.1	26.0	208.0	22.0	Fallout
116.3	^{132}Te	1.9	78.2H	111.9	1.9	228.3	88.2	Fallout
121.8	^{152}Eu	28.4	13.3Y	344.3	26.6	244.7	7.5	Fallout
122.1	^{57}Co	85.5	273D	136.5	10.7	14.4	9.5	Activity
123.1	^{154}Eu	40.5	8.8Y	248.0	6.6	591.8	4.8	Fallout
127.2	^{101}Rh	73.0	3.3Y	198.0	70.8	325.2	13.4	Fallout
129.0	^{228}Ac	2.9	Long	99.6	1.3	209.4	4.1	^{232}Th

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	$T_{1/2}$	E2	%	E3	%	Origin
133.5	^{144}Ce	11.1	285D	696.5	1.3	80.1	1.1	Fallout
136.5	^{57}Co	10.7	272D	122.1	85.5	14.4	9.5	Activity
138.0	^{138}Cs	1.5	32.2M	227.7	1.5	462.8	30.7	^{138}Xe
140.5	^{99}Mo	3.5	65.9H	40.6	1.1	181.1	6.1	Fallout
140.5	^{99m}Tc	87.2	6.01H	18.4X	6.1	20.6X	1.2	^{99}Mo
143.8	^{235}U	10.5	70E7Y	109.2	1.5	163.4	4.7	Natural
145.4	^{141}Ce	48.4	32.5D	37.0KX	17.4			Fission
151.2	^{85m}Kr	75.2	4.48H	304.9	13.7			Fission
153.3	^{136}Cs	7.5	13.2D	86.4	6.3	164.0	4.6	Fission
153.9	^{138}Xe	6.0	14.1M	242.7	3.5	258.4	31.5	Fission
162.7	^{140}Ba	6.2	12.8D	304.9	4.3	30.0	13.6	Fallout
163.4	^{235}U	4.7	70E7Y	143.8	10.5	185.7	53.0	Natural
164.0	^{136}Cs	4.6	13.2D	153.3	7.5	176.6	13.6	Fission
165.9	^{139}Ce	79.9	138D	34.0KX	79.5			Activity
166.0	^{88}Kr	3.1	2.84H	196.3	26.0	362.3	2.3	Fission
176.3	^{125}Sb	6.8	2.73Y	427.9	29.4	380.4	1.5	Fallout
176.6	^{136}Cs	13.6	13.2D	164.0	4.6	273.7	12.7	Fission
181.1	^{99}Mo	6.1	65.9H	140.5	3.5	366.4	1.2	Fallout
185.7	^{235}U	53.0	70E7Y	143.8	10.5	205.3	4.7	Natural
186.1	^{226}Ra	3.3	1600Y					Natural
192.3	^{59}Fe	3.1	44.5D	1099.3	56.5	1291.6	43.2	Activity
196.3	^{88}Kr	26.0	2.84H	362.3	2.3	166.0	3.1	Fission
198.0	^{101}Rh	70.8	3.3Y	127.2	73.0	325.2	13.4	Fallout
205.3	^{235}U	4.7	70E7Y	185.7	53.0	143.8	10.5	Natural
208.0	^{237}U	22.0	6.75D	59.5	32.8	101.1	26.0	Fallout
209.4	^{228}Ac	4.1	Long	129.0	2.9	270.3	3.8	^{232}Th
227.7	^{138}Cs	1.5	32.2M	138.0	1.5	409.0	4.7	^{138}Xe
228.2	^{239}Np	10.7	2.36D	106.1	22.7	277.6	14.2	Fallout

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	$T_{1/2}$	E2	%	E3	%	Origin
228.3	^{132}Te	88.2	78.2H	116.4	1.9	111.9	1.9	Fallout
233.2	^{133m}Xc	10.3	2.19D	30.0KX	56.3			Fission
238.6	^{212}Pb	43.6	Long	300.0	3.3			^{232}Th
240.8	^{224}Ra	3.9	Long					^{232}Th
241.9	^{214}Pb	7.5	Long	295.1	19.2	352.0	37.1	^{238}U
242.7	^{138}Xe	3.5	14.1M	153.9	6.0	258.4	31.5	Fission
244.7	^{152}Eu	7.5	13.3Y	121.8	28.4	344.3	26.6	Fallout
248.0	^{154}Eu	6.6	8.8Y	123.1	40.5	591.8	4.8	Fallout
249.8	^{135}Xe	90.0	9.10H	608.2	2.9	31.0KX	5.2	Fission
258.4	^{138}Xe	31.5	14.1M	242.7	3.5	396.6	6.3	Fission
262.8	^{132}I	1.4	2.28H	505.9	5.0	522.7	16.1	^{132}Te
270.3	^{228}Ac	3.8	Long	209.4	4.1	328.0	3.5	^{232}Th
273.7	^{136}Cs	12.7	13.2D	176.6	13.6	340.6	48.6	Fission
276.4	^{133}Ba	7.1	10.5Y	302.9	18.4	81.0	34.2	Activity
277.3	^{208}Tl	2.4	Long	510.6	7.8	583.0	30.9	^{232}Th
277.6	^{238}Np	14.2	2.36D	228.2	10.7	315.9	1.6	Fallout
279.2	^{203}Hg	81.5	46.6D	74.6X	12.9			Fallout
284.3	^{131}I	6.1	8.04D	364.5	81.2	80.2	2.6	Fission
295.1	^{214}Pb	19.2	Long	351.9	37.1	241.9	7.5	^{238}U
300.0	^{212}Pb	3.3	Long	238.6	43.6			^{232}Th
302.9	^{133}Ba	18.4	10.5Y	276.4	7.1	356.0	62.2	Activity
304.9	^{140}Ba	4.3	12.8D	162.7	6.2	423.7	3.1	Fallout
304.9	^{85m}Kr	13.7	4.48H	151.2	75.1			Fission
315.9	^{239}Np	1.6	2.36D	277.6	14.2	334.3	2.1	Fallout
319.4	^{147}Nd	2.0	11.0D	439.9	1.2	91.1	28.0	Fallout
320.1	^{51}Cr	9.8	27.7D					Activity
325.2	^{101}Rh	13.4	3.3Y	127.2	73.0	198.0	70.8	Fallout
328.0	^{228}Ac	3.5	Long	270.3	3.8	338.4	12.4	^{232}Th

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
328.8	^{140}La	20.7	40.3H	432.5	3.0	487.0	45.9	Fallout
334.3	^{239}Np	2.1	2.36D	315.9	1.6	61.5	1.0	Fallout
338.4	^{228}Ac	12.4	Long	328.0	3.5	409.6	2.2	^{232}Th
340.6	^{136}Cs	48.6	13.2D	273.7	12.7	818.6	99.8	Fission
344.3	^{152}Eu	26.6	13.3Y	244.7	7.5	411.1	2.2	Fallout
352.0	^{214}Pb	37.1	Long	241.9	7.5	295.1	19.2	^{238}U
356.0	^{133}Ba	62.2	10.5Y	302.9	18.4	383.8	8.9	Activity
362.3	^{88}Kr	2.3	2.84H	196.3	26.0	834.9	13.0	Fission
364.5	^{131}I	81.2	8.04D	637.0	7.3	284.3	6.1	Fission
366.4	^{99}Mo	1.2	65.9H	181.1	6.1	739.5	12.1	Fallout
380.4	^{125}Sb	1.5	2.73Y	176.3	6.8	427.9	29.4	Fallout
383.8	^{133}Ba	8.9	10.5Y	356.0	62.2	302.9	18.4	Activity
396.6	^{138}Xe	6.3	14.1M	258.4	31.5	401.5	2.2	Fission
401.5	^{138}Xe	2.2	14.1M	434.6	20.3	396.6	6.3	Fission
402.6	^{87}Kr	49.6	76.3M	845.5	7.3	673.9	1.9	Fission
409.0	^{138}Cs	4.7	32.3M	227.7	1.5	462.8	30.7	^{138}Xe
409.6	^{228}Ac	2.2	Long	338.4	12.4	463.1	4.6	^{232}Th
411.1	^{152}Eu	2.2	13.3Y	344.3	26.6	444.0D	3.1	Fallout
415.3	^{102}Rh	2.1	2.89Y	418.5	10.6	420.4	3.2	Fallout
418.5	^{102}Rh	10.6	2.89Y	415.3	2.1	420.4	3.2	Fallout
420.4	^{102}Rh	3.2	2.89Y	418.5	10.6	475.1	95.0	Fallout
423.7	^{140}Ba	3.1	12.8D	437.6	1.9	304.9	4.3	Fallout
427.9	^{125}Sb	29.4	2.73Y	380.4	1.5	463.4	10.5	Fallout
432.5	^{140}La	3.0	40.3H	487.0	45.9	328.8	20.7	Fallout
434.6	^{138}Xe	20.3	14.1M	401.5	2.2	1114.3	1.5	Fission
437.6	^{140}Ba	1.9	12.8D	537.3	24.4	423.7	3.1	Fallout
439.9	^{147}Nd	1.2	11.0D	319.4	2.0	531.0	13.1	Fallout
444.0D	^{152}Eu	3.1	13.3Y	411.1	2.2	778.9	13.0	Fallout

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	$T_{1/2}$	E2	%	E3	%	Origin
446.8	^{110m}Ag	3.8	250D	657.8	94.6	620.4	2.8	Activity
462.8	^{138}Cs	30.7	32.2M	547.0	10.8	409.0	4.7	^{138}Xe
463.1	^{228}Ac	4.6	Long	409.6	2.2	755.3	1.3	^{232}Th
463.4	^{125}Sb	10.5	2.73X	427.9	29.4	600.5	17.8	Fallout
468.7	^{102m}Rh	2.9	207D	475.1	46.0	556.6	1.9	Fallout
475.1	^{102m}Rh	46.0	207D	468.7	2.9	556.6	1.9	Fallout
475.1	^{102}Rh	95.0	2.89Y	628.1	8.5	420.5	3.2	Fallout
475.4	^{134}Cs	1.5	2.06Y	563.2	8.4	569.3	15.4	Fission
477.6	^{7}Be	10.3	53.2D					Cosmic
487.1	^{140}La	45.5	40.2H	751.9	4.3	432.6	2.9	Fallout
497.1	^{103}Ru	89.5	39.6D	610.3	5.6			Fallout
505.9	^{132}I	5.0	2.28H	262.8	1.4	522.7	16.1	^{132}Te
510.6	^{208}T1	7.8	Long	277.3	2.4	583.0	30.9	^{232}Th
511.0	^{65}Zn	2.9	244D	1115.5	50.8			Activity
511.0	^{58}Co	30.0	70.9D	810.8	99.5			Activity
511.0	^{22}Na	180.8	2.60Y	1274.5	99.9			Cosmic
511.9	^{106}Ru	20.7	372D	1050.4	1.5	621.9	9.8	Fallout
514.0	^{85}Sr	99.3	64.8D	13.4KX	50.6	15.0KX	8.7	Activity
522.7	^{132}I	16.1	2.28H	505.9	5.0	547.0	1.3	^{132}Te
526.6	^{135m}Xe	81.2	15.7M	30.0KX	14.0			Fission
531.0	^{147}Nd	13.1	11.0D	439.9	1.2	319.4	2.0	Fallout
537.3	^{140}Ba	24.4	12.8D	437.6	1.9	423.7	3.1	Fallout
547.0	^{138}Cs	10.8	32.2M	462.8	30.7	871.7	5.1	^{138}Xe
547.0	^{132}I	1.3	2.28H	522.7	16.1	621.2	~2.0	^{132}Te
556.6	^{102m}Rh	1.9	207D	475.1	46.0	628.1	5.5	Fallout
563.2	^{134}Cs	8.4	2.06Y	475.4	1.5	569.3	15.4	Fission
569.3	^{134}Cs	15.4	2.06Y	563.2	8.4	604.7	97.6	Fission
569.2	^{207}Bi	97.8	32.3Y	1063.1	74.9	1769.7	6.9	Fallout

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
583.0	^{208}T1	30.9	Long	510.6	7.8	860.3	4.3	^{232}Th
591.8	^{154}Eu	4.8	8.8Y	248.0	6.6	692.5	1.7	Fallout
600.5	^{125}Sb	17.8	2.73Y	463.4	10.5	606.6	5.0	Fallout
602.7	^{124}Sb	97.8	60.2D	645.9	7.4	709.3	1.4	Fallout
604.7	^{134}Cs	97.6	2.06Y	795.9	85.4	569.3	15.4	Fission
606.6	^{125}Sb	5.0	2.73Y	600.5	17.8	635.9	11.3	Fallout
608.2	^{135}Xe	2.9	9.10H	249.8	90.0	31.6KX	5.2	Fission
609.3	^{214}Bi	46.1	Long	665.4	1.6	768.4	4.9	^{238}U
610.3	^{103}Ru	5.6	39.3D	497.1	88.7			Fallout
620.4	^{110m}Ag	2.8	250D	657.8	94.6	446.8	3.8	Activity
621.2	^{132}I	~2.0	2.28H	547.1	1.3	630.3	13.8	^{132}Te
621.9	^{106}Ru	9.8	372D	511.9	20.7	1050.4	1.5	Fallout
628.1	^{102m}Rh	5.5	207D	556.6	1.9	1103.2	2.9	Fallout
628.1	^{102}Rh	8.5	~2.9Y	475.1	95.0	631.3	56.0	Fallout
630.3	^{132}I	13.8	2.28H	621.2	~2.0	650.6	2.7	^{132}Te
631.3	^{102}Rh	56.0	~2.9Y	628.1	8.5	692.4	1.8	Fallout
635.9	^{125}Sb	11.3	2.73Y	606.6	5.0	671.4	1.8	Fallout
637.0	^{131}I	7.3	8.04D	364.5	81.2	722.9	1.8	Fission
645.9	^{124}Sb	7.4	60.2D	602.7	97.8	709.3	1.4	Fallout
650.6	^{132}I	2.7	2.28H	630.3	13.8	667.7	98.7	^{132}Te
657.8	^{110m}Ag	94.6	250D	620.4	2.8	677.6	10.4	Activity
661.7	^{137}Cs	85.2	30.0Y	33.0KX	7.1			Fallout
665.4	^{214}Bi	1.6	Long	609.3	46.1	768.4	4.9	^{238}U
667.7	^{132}I	98.7	2.28H	650.6	2.7	669.9	4.9	^{132}Te
669.9	^{132}I	4.9	2.28H	667.7	98.7	671.6	5.2	^{132}Te
671.4	^{125}Sb	1.8	2.73Y	635.9	11.3	606.6	5.0	Fallout
671.6	^{132}I	5.2	2.28H	669.9	4.9	727.D	5.4	^{132}Te
673.9	^{87}Kr	1.9	76.3M	845.5	7.3	402.6	49.6	Fission
677.6	^{110m}Ag	10.4	250D	657.8	94.6	687.0	6.4	Activity

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
687.0	^{110m}Ag	6.4	250D	677.6	10.4	706.7	16.4	Activity
692.4	^{102}Rh	1.8	~2.9Y	631.3	56.0	695.6	2.7	Fallout
692.5	^{154}Eu	1.7	8.8Y	591.8	4.8	723.4	19.7	Fallout
695.6	^{102}Rh	2.7	~2.9Y	692.4	1.8	697.6	45.7	Fallout
696.5	^{144}Ce	1.3	285D	133.5	11.1	80.1	1.1	Fallout
697.6	102Rh	45.7	~2.9Y	766.9	34.0	695.6	2.7	Fallout
706.7	^{110m}Ag	16.4	250D	687.0	6.4	744.3	4.7	Activity
709.3	^{124}Sb	1.4	60.2D	645.9	7.4	713.8	2.3	Fallout
713.8	^{124}Sb	2.3	60.2D	709.3	1.4	722.8	10.9	Fallout
722.8	^{124}Sb	10.9	60.2D	713.8	2.3	968.2	1.9	Fallout
722.9	^{131}I	1.8	8.04D	364.5	81.2	637.0	7.3	Fission
723.4	^{154}Eu	19.7	8.8Y	692.5	1.7	756.8	4.3	Fallout
724.2	^{95}Zr	44.1	64.0D	756.7	54.5			Fallout
727.0D	^{132}I	5.4	2.28H	671.6	5.2	728.7	1.1	^{132}Te
727.3	^{212}Bi	6.7	Long	39.9	1.1	1620.7	1.5	^{232}Th
728.7	^{132}I	1.1	2.28H	727.0D	5.4	772.7	76.2	^{132}Te
739.5	^{99}Mo	12.1	65.9H	366.4	1.2	777.9	4.4	Fallout
744.3	^{110m}Ag	4.7	250D	706.7	16.4	763.9	22.3	Activity
751.7	^{140}La	4.3	40.3H	487.0	45.9	815.8	23.6	Fallout
755.3	^{228}Ac	1.3	Long	463.1	4.6	772.3	1.1	^{232}Th
756.7	^{95}Zx	54.5	64.0D	724.2	44.1			Fallout
756.8	^{154}Eu	4.3	8.8Y	723.4	19.7	873.2	11.5	Fallout
763.1	^{208}Tl	0.6	Long	583.0	30.9	860.3	4.3	^{232}Th
763.9	^{110m}Ag	22.3	250D	744.3	4.7	818.0	7.3	Activity
765.8	^{95}Nb	99.8	35.0D					Fallout
766.9	^{102}Rh	34.0	~2.9Y	697.6	45.7	1046.6	34.0	Fallout
768.4	^{214}Bi	5.0	Long	665.6	1.6	786.4D	0.3	^{238}U
772.3	^{228}Ac	1.1	Long	755.3	1.3	794.8	4.6	^{232}Th
772.7	^{132}I	76.2	2.28H	728.7	1.1	780.1	1.2	^{132}Te
777.9	^{99}Mo	4.4	65.9H	739.5	12.1	366.4	1.2	Fallout

EG&G ORTEC FIELD PORTABLE GAMMA-RAY SPECTROMETER OPERATION

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	$T_{1/2}$	E2	%	E3	%	Origin
778.9	^{152}Eu	13.0	13.3Y	444.0D	3.1	867.4	4.2	Fallout
780.1	^{132}I	1.2	2.28H	772.7	76.2	809.8	2.9	^{132}Te
785.5	^{212}Bi	1.1	Long	727.3	6.7	1620.7	1.5	^{232}Th
794.8	^{228}Ac	4.6	Long	772.3	1.1	830.6	0.6	^{232}Th
786.4	^{214}Bi	0.3	Long	768.4	4.9	806.2	1.2	^{238}U
795.8	^{134}Cs	85.4	2.06Y	604.7	97.8	801.9	8.7	Fission
802.0	^{134}Cs	8.7	2.06Y	795.9	85.4	1038.6	1.0	Fission
806.2	^{214}Bi	1.2	Long	786.4	0.3	934.0	3.2	^{238}U
809.8	^{132}I	2.9	2.28H	780.1	1.2	812.3	5.6	^{132}Te
810.8	^{58}Co	99.5	70.9D	511.0	30.0			Activity
812.3	^{132}I	5.6	2.28H	809.8	2.9	877.2	1.1	^{132}Te
815.8	^{140}La	23.6	40.3H	751.7	4.3	867.8	5.6	Fallout
818.0	^{110m}Ag	7.3	250D	763.9	22.3	884.7	72.7	Activity
818.6	^{136}Cs	99.8	13.2D	340.6	48.6	1048.1	79.7	Fission
830.6	^{228}Ac	0.6	Long	794.8	4.6	835.6	1.7	^{232}Th
834.8	^{54}Mn	100.0	312.2D					Fallout
834.9	^{88}Kr	13.0	2.84H	362.3	2.3	985.8D	1.3	Fission
835.6	^{228}Ac	1.7	Long	830.6	0.6	840.4	0.9	^{232}Th
840.4	^{228}Ac	0.9	Long	835.6	1.7	904.3	0.9	^{232}Th
845.5	^{87}Kr	7.3	76.3M	673.9	1.9	1175.5	1.1	Fission
860.3	^{208}Tl	4.3	Long	2614.4	35.8	583.0	30.9	^{232}Th
867.4	^{152}Eu	4.2	13.3Y	778.9	13.0	964.1	14.5	Fallout
867.8	^{140}La	5.6	40.3H	815.8	23.6	919.6	2.7	Fallout
871.7	^{138}Cs	5.1	32.2M	547.0	10.8	1009.8	29.8	^{138}Xe
873.2	^{154}Eu	11.5	8.8Y	756.8	4.3	996.3	10.3	Fallout
877.2	^{132}I	1.1	2.28H	812.3	5.6	954.6	18.1	^{132}Te
884.7	^{110m}Ag	72.7	250D	818.0	7.3	937.5	34.4	Activity
898.1	^{88}Y	92.7	107D	1836.1	99.4			Activity
898.0	^{88}Rb	14.1	17.8M	1836.1	21.4	2677.9	2.0	^{88}Kr
904.3	^{228}Ac	0.9	Long	840.4	0.9	911.2	29.0	^{232}Th

Table of Gamma-Rays and Nuclices Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
911.2	^{228}Ac	29.0	Long	966.0D	23.2	840.4	0.9	^{232}Th
919.6	^{140}La	2.7	40.3H	867.8	5.6	925.2	7.0	Fallout
925.2	^{140}La	7.1	40.3H	487.0	45.9	919.6	2.7	Fallout
934.0	^{214}Bi	3.2	Long	1120.3	15.0	806.2	1.2	^{238}U
937.5	^{110m}Ag	34.4	250D	1384.3	24.3	884.7	72.7	Activity
954.6	^{132}I	18.1	2.28H	877.2	1.1	1136.2	3.0	^{132}Te
964.1	^{152}Eu	14.5	13.3Y	1085.9	9.9	867.4	4.2	Fallout
964.6	^{228}Ac	5.8	Long	969.0	17.4	911.2	29.0	^{232}Th
968.2	^{124}Sb	1.9	60.2D	1045.1	1.9	722.8	10.9	Fallout
969.0	^{228}Ac	17.4	Long	911.2	29.0	1459.2	1.1	^{232}Th
985.8	^{88}Kr	1.3	2.84H	1141.4	1.3	834.9	13.0	Fission
996.3	^{154}Eu	10.3	8.8Y	1004.8	17.9	873.2	11.5	Fallout
1001.0	^{234m}Pa	0.7	Long	766.4	0.2	742.8	0.1	^{238}U
1004.8	^{154}Eu	17.9	8.8Y	1274.5	35.5	996.3	10.3	Fallout
1009.8	^{138}Cs	29.8	32.2M	1147.3	1.2	871.7	5.1	^{138}Xe
1038.6	^{134}Cs	1.0	2.06Y	1167.9	1.8	802.0	8.7	Fission
1045.1	^{124}Sb	1.9	60.2D	1325.5	1.6	968.2	1.9	Fallout
1046.6	^{102}Rh	33.0	2.9Y	1103.2	4.4	766.9	34.0	Fallout
1048.1	^{136}Cs	79.7	13.2D	818.6	99.8	1235.4	19.8	Fission
1050.4	^{106}Ru	1.5	372D	511.9	20.7	621.9	9.8	Fallout
1063.1	^{207}Bi	74.9	32.2Y	569.2	97.8	1769.7	6.9	Fallout
1085.9	^{152}Eu	9.9	13.3Y	1112.1	13.6	964.1	14.5	Fallout
1099.3	^{59}Fe	56.5	44.5D	1291.6	43.2	192.3	3.1	Fallout
1103.2	^{102m}Rh	2.9	207D	556.6	1.9	628.1	5.5	Fallout
1103.2	^{102}Rh	4.4	2.9Y	1046.6	33.0	1112.9	18.9	Fallout
1112.1	^{152}Eu	13.6	13.3Y	1085.9	9.9	1212.9	1.4	Fallout
1112.9	^{102}Rh	18.9	2.9Y	1046.6	33.0	1103.2	4.4	Fallout
1114.3	^{138}Xe	1.5	14.1M	1768.4	16.7	434.6	20.3	Fission
1115.5	^{65}Zn	50.8	244D	511.0	2.9			Activity

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
1120.3	^{214}Bi	15.0	Long	1155.2	1.7	934.0	3.2	^{238}U
1136.2	^{132}I	3.0	2.28H	954.6	18.1	1143.6	1.4	^{132}Te
1141.4	^{88}Kr	1.3	2.84H	1369.4	1.5	985.8D	1.3	Fission
1143.6	^{132}I	1.4	2.28H	1136.2	3.0	1173.3	1.1	^{132}Te
1147.3	^{138}Cs	1.2	32.2M	1009.8	29.8	1343.6	1.1	^{138}Xe
1155.2	^{214}Bi	1.7	Long	1238.1	5.9	1120.3	15.0	^{238}U
1167.9	^{134}Cs	1.8	2.06Y	1038.6	1.0	1365.2	3.0	Fission
1173.2	^{60}Co	99.9	5.27Y	1332.5	100.0			Activity
1173.3	^{132}I	1.1	2.28H	1143.6	1.4	1290.8	1.1	^{132}Te
1175.5	^{87}Kr	1.1	76.3M	1740.6	2.0	845.5	7.3	Fission
1212.9	^{152}Eu	1.4	13.3Y	1112.1	13.6	1299.2	1.6	Fallout
1235.4	^{136}Cs	19.8	13.2D	818.6	99.8	1048.1	79.7	Fission
1238.1	^{214}Bi	5.9	Long	1155.2	1.7	1281.0	1.5	^{238}U
1274.5	^{22}Na	99.9	2.60Y	511.0	181.0			Cosmic
1274.5	^{154}Eu	35.5	8.8Y	1004.8	17.9	1596.6	1.8	Fallout
1281.0	^{214}Bi	1.5	Long	1238.1	5.9	1377.7	4.0	^{238}U
1290.8	^{132}I	1.1	2.28H	1173.3	1.1	1295.4	2.0	^{132}Te
1291.6	^{59}Fe	43.2	44.5D	1099.3	56.5	192.3	3.1	Activity
1293.6	^{41}Ar	99.2	1.83H					Activity
1295.4	^{132}I	2.0	2.28H	1290.8	1.1	1372.1	2.5	^{132}Te
1299.2	^{152}Eu	1.6	13.3Y	1212.9	1.4	1408.0	20.8	Fallout
1325.5	^{124}Sb	1.6	60.2D	1045.1	1.9	1368.2	2.7	Fallout
1332.5	^{60}Co	100.0	5.27Y	1173.2	99.9			Activity
1343.6	^{138}Cs	1.1	32.2M	1147.3	1.2	1435.8	76.3	^{138}Xe
1365.2	^{134}Cs	3.0	2.06Y	1167.9	1.8	1038.6	1.0	Fission
1368.2	^{124}Sb	2.7	60.2D	1325.5	1.6	1436.7	1.3	Fallout
1368.6	^{24}Na	100.0	14.7H	2754.1	99.9			Activity
1369.4	^{88}Kr	1.5	2.84H	1141.4	1.3	1518.4	2.2	Fission
1372.1	^{132}I	2.5	2.28H	1295.4	2.0	1398.6	7.1	^{132}Te

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
1377.7	^{214}Bi	4.0	Long	1281.0	1.5	1401.5	1.4	^{238}U
1384.3	^{110m}Ag	24.3	250D	1475.8	4.0	937.5	34.4	Activity
1398.6	^{132}I	7.1	2.28H	1372.1	2.5	1442.5	1.4	^{132}Te
1401.5	^{214}Bi	1.4	Long	1377.7	4.0	1408.0	2.5	^{238}U
1408.0	^{214}Bi	2.5	Long	1401.5	1.4	1509.2	2.2	^{238}U
1408.0	^{152}Eu	20.8	13.3Y	1299.2	1.6	1212.9	1.4	Fallout
1435.8	^{138}Cs	76.3	32.2M	1343.6	1.1	2218.0	15.2	^{138}Xe
1436.6	^{124}Sb	1.3	60.2D	1368.2	2.7	1691.0	47.1	Fallout
1442.5	^{132}I	1.4	2.28H	1398.6	7.1	1921.1	1.2	^{132}Te
1459.2	^{228}Ac	1.1	Long	1499.0D	1.6	969.0	17.4	^{232}Th
1460.8	^{40}K	10.7	1.3E9					Natural
1475.8	^{110m}Ag	4.0	250D	1384.3	24.3	1505.0	13.0	Activity
1499.0D	^{228}Ac	1.6	Long	1459.2	1.1	1588.2	3.6	^{232}Th
1505.0	^{110m}Ag	13.0	250D	1475.8	4.0	1562.3	1.0	Activity
1509.2	^{214}Bi	2.2	Long	1408.0	2.5	1661.3	1.2	^{238}U
1518.4	^{88}Kr	2.2	2.84H	1369.4	1.5	1529.8	10.9	Fission
1529.8	^{88}Kr	10.9	2.84H	1518.4	2.2	2029.9	4.5	Fission
1588.2	^{228}Ac	3.6	Long	1499.0D	1.6	1630.5	2.0	^{232}Th
1596.5	^{140}La	95.4	40.3H	487.0	45.9	2571.7	3.4	Fallout
1596.6	^{154}Eu	1.7	8.8Y	1274.5	35.5	1004.8	17.9	Fallout
1620.7	^{212}Bi	1.5	Long	727.3	6.7	785.5	1.1	^{232}Th
1630.5	^{228}Ac	2.0	Long	1588.2	3.6	1499.0D	1.6	^{232}Th
1661.3	^{214}Bi	1.2	Long	1509.2	2.2	1729.6	3.1	^{238}U
1691.0	^{124}Sb	47.1	60.2D	2090.9	5.5	1436.7	1.3	Fallout
1729.6	^{214}Bi	3.1	Long	1764.5	15.9	1661.3	1.2	^{238}U
1740.6	^{87}Kr	2.0	76.3M	1175.5	1.1	2011.9	2.9	Fission
1764.5	^{214}Bi	15.9	Long	1729.6	3.1	1847.4	2.1	^{238}U
1768.4	^{138}Xe	16.7	14.1M	1114.3	1.5	1850.9	1.4	Fission
1769.7	^{207}Bi	6.9	32.2Y	1063.1	74.9	569.2	97.8	Fallout

Table of Gamma-Rays and Nuclides Common To Environmental Analyses (Cont'd)

Energy	Nuclide	%	T ½	E2	%	E3	%	Origin
1836.1	^{88}Rb	21.4	17.8M	2677.9	2.0	898.1	14.1	^{88}Kr
1836.1	^{88}Y	99.4	107D	898.1	92.7			Other
1847.4	^{214}Bi	2.1	Long	1764.5	15.9	2118.5	1.2	^{238}U
1850.9	^{138}Xe	1.4	14.1M	1768.4	16.7	2004.8	5.4	Fission
1921.1	^{132}I	1.2	2.28H	1442.5	1.4	2002.4	1.1	^{132}Te
2002.4	^{132}I	1.1	2.28H	1921.1	1.2	1442.5	1.4	^{132}Te
2004.8	^{138}Xe	5.4	14.1M	1850.9	1.4	2015.9	12.3	Fission
2011.9	^{87}Kr	2.9	76.3M	1740.6	2.0	2556.0D	13.1	Fission
2015.9	^{138}Xe	12.3	14.1M	2004.8	5.4	2079.3	1.4	Fission
2029.9	^{88}Kr	4.5	2.84H	1529.8	10.9	2035.5	3.7	Fission
2035.5	^{88}Kr	3.7	2.84H	2029.9	4.5	2195.8	13.2	Fission
2079.3	^{138}Xe	1.4	14.1M	2015.9	12.3	2252.3	2.3	Fission
2090.9	^{124}Sb	5.5	60.2D	1436.6	1.3	1691.0	47.1	Fallout
2118.5	^{214}Bi	1.2	Long	1847.4	2.1	2204.1	5.0	^{238}U
2195.8	^{88}Kr	13.2	2.84H	2035.5	3.7	2231.8	3.4	Fission
2204.1	^{214}Bi	5.0	Long	2447.7	1.6	2118.5	1.2	^{238}U
2217.8	^{138}Cs	15.2	32.2M	1435.8	76.3	2639.4	7.6	^{138}Xe
2231.8	^{88}Kr	3.4	2.84H	2195.8	13.2	2392.1	34.6	Fission
2252.3	^{138}Xe	2.3	14.1M	2079.3	1.4	2015.9	12.3	Fission
2392.1	^{88}Kr	34.6	2.84H	2231.8	3.4	2195.8	13.2	Fission
2447.7	^{214}Bi	1.6	Long	2204.1	5.0	2118.5	1.2	^{238}U
2521.7	^{140}La	3.4	40.3H	1596.5	96.4	487.0	45.9	Fallout
2556D	^{87}Kr	13.1	76.3M	2011.9	2.9	1740.6	2.0	Fission
2614.4	^{208}T1	35.8	Long	860.3	4.3	583.0	30.9	^{232}Th
2639.4	^{138}Cs	7.6	32.2M	2217.8	15.2	1435.8	76.3	^{138}Xe
2677.9	^{88}Rb	2.0	17.8M	1836.1	21.4	898.1	14.1	^{88}Kr
2754.0	^{24}Na	99.9	14.7H	1368.6	100.0			Activity
6129.2	^{16}N	68.8	7.13S	7115.2	4.7			Other
7115.2	^{16}N	4.7	7.13S	6129.2	68.8			Other

APPENDIX C
Troubleshooting Guide
SOP #1716
January 1995

Troubleshooting Guide

PROBLEM	PROBABLE CAUSE	ACTION
Message: No Duel Port Memory	ADCAM interface not plugged into the computer or Nomad base properly	Check all connections
Low or High energy side	Incorrect Pole Adjustment tailing and poor resolution	See section 7.3.4
Wandering Peaks or multiple peaks observed with pulse height analyzer	Unstable electronics, bad cable or or connector	Check each electronic component and cables
Detector loses liquid nitrogen or warms up quickly	Break in Dewar	Repair
Poor gamma ray resolution	Power line noise, RF pick up	Eliminate ac power line noise by isolation or filtration. If operation in a high RF field consider more shielding.