GAMMA ANALYSIS OF ENVIRONMENTAL SAMPLES FROM THE MARSHALL ISLANDS

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Abstract

Radiological studies of the fate of nuclear test related debris in the Marshall Islands conducted by members of the Lawrence Livermore National Laboratory generate large number of environmental samples. For more than 20 years, the Low-Level Gamma Spectroscopy Facility has been used to perform the analysis of gamma emitting radionuclides. A brief description of the facility, calibration, counting and analysis procedures is given.

Introduction

During 1946 to 1958 the United States conducted 66 nuclear tests in the Northern Marshall Islands. Several of these tests deposited near and intermediate range fallout on islands that have been historically inhabited or have been used for subsistence agriculture. On 1 March 1954, a nuclear weapons test code named BRAVO, was conducted at Bikini Atoll. The explosive yield greatly exceeded expectations resulting in Bikini, Rongelap, Rongerik, Ailinginae, Ailuk, Mejit and Utirik Atolls being contaminated with debris.

For more than 20 years, the Marshall Islands program at Lawrence Livermore National Laboratory (LLNL) has studied the fate of test debris in the tropical atoll environment. This program has been charged with characterizing the extent of the contamination, calculating radiological doses to man through various pathways and investigating remediation techniques. Several sampling trips per year are required to support this scope of work. Approximately 5000 environmental samples, representing constituents of the radiological pathway to man, are collected each year. Most of these samples are assayed for gamma emitting radioisotopes.

The Facility

The mission of the Low-Level Gamma Spectroscopy Facility (LLGSF) of the Health and Ecological Assessment (HEA) Division of LLNL is to provide the expertise and equipment to perform nondestructive assays of gamma emitting radionuclides contained in a variety of sample matrices. The HEA Division and its predecessors have had facilities since the 1960's to determine the concentrations of gamma emitting radionuclides found in the environment (Allen, 1994). These facilities have evolved into the LLGSF.

The facility is housed in Building 379, which was specifically designed and constructed for the purpose of housing the equipment required to perform low-level radionuclide activity measurements. This building was constructed in 1983 with carefully chosen low background materials. The floor pad rests on 10 cm of black serpentine aggregate selected for its low levels of naturally occurring radionuclides. The concrete mixture also contains the same serpentine instead of the local gravel. Special attention was given to the thermal insulation and heating

and cooling equipment in the counting bay. This reduces the variation in temperature and humidity, contributing to stability in the analytical systems. The electrical service is on emergency generator backup and is filtered and conditioned to lessen power disturbances.

The status of several conditions is monitored on a routine basis. The building power is monitored by a power line disturbance meter. The temperature and humidity are recorded. The detector background is checked weekly.

Analytical Systems

The current data collection system is the GENIE® system manufactured by Canberra - Nuclear Data¹. This system is designed for the collection of spectral data from several detectors while simultaneously being able to perform data reduction calculations on a Digital Equipment Corporation² (DEC) VAXStation® running DEC's VMS® operating system. Listed in Table 1 are the detectors currently in use.

Table 1. Detectors currently in use.

System Number	System Name	Detector Manufacturer and Type	Size (diameter × length)
1	Z094C09	Canberra HPGe	51 mm × 46.0 mm
2	S893A06	Canberra Ge(Li)	49.5 × 42.5
3	6H93A07	Canberra Ge(Li)	50.5 × 50.5
4	P794C09	Canberra HPGe	48.7 × 49.5
5	8P93A08	Ortec Ge(Li)	43 × 46
6	5Q93A08	Canberra Ge(Li)	49 × 42
7	7J93A08	Canberra Ge(Li)	53 × 52.5
8	DR93A08	Canberra HPGe	54.1 × 55
9	9T93A11	Canberra HPGe	52.2 × 57
10	4F94C08	Canberra HPGe	46.7 × 54
11	FE93A11	Canberra HPGe	51.3 × 44
12	0P94C08	Ortec HPGe	49.8 × 42.0
17	1B93A12	Canberra HPGe	50.4 × 51.3
18	UL93A12	Canberra HPGe	50.5 × 50
19	II93A12	Princeton Gamma-Tech HPGe with reverse electrode and Be window	51 × 45
20	Y293A20	Ortec Ge(Li)	45.42 × 55
21	HK93A21	Canberra Ge(Li)	50.4 × 41.1
22	L493A21	Canberra Ge(Li)	49.5 × 38.5
23	2D93A22	Canberra HPGe	49 × 47.5
24	EG93A22	Canberra Ge(Li)	53 × 45.5

¹ Canberra Industries Inc., Nuclear Data Systems Division, 150 Spring Lake Dr., Itasca, IL 60143-2096.

² Digital Equipment Corporation, Maynard, Massachusetts.

There are currently 20 up looking lithium drifted germanium (Ge(Li)) and high purity germanium (HPGe) gamma detectors operating. These detectors are contained in steel shields to reduce environmental background radiation. The detectors are connected to high voltage bias supplies and spectroscopy amplifiers. The outputs from the amplifiers are connected to mixer routers that multiplex the signals and allow the use of one analog to digital converter(ADC) per mixer router. The ADC signal goes to the acquisition interface module (AIM) where the pulse height analysis occurs. Each AIM has the capacity to store $2^{31}-1$ counts in each of 63,488 channels. The AIM communicates with the VAX via Ethernet. The Genie software running on the VAX provides for the display and manipulation of the spectral data.

Calibration

Calibration is the process of identifying and documenting the characteristic parameters of a detector and signal processing system. Our current calculation scheme relies on having the calibration standards as similar as possible in geometry and material composition as the samples of interest. With this system, there are two basic calibrations required for sufficient detector characterization. They are the energy *versus* channel number relationship that includes a full width at half peak maximum (FWHM) characterization and an efficiency *versus* energy calibration. Two characterizations that are not performed are the count pile-up correction and the coincidence summing error correction. Pulse pile up occurs when two gamma rays arrive at the detector within the width of the amplifier's output pulse. The low emission rates of the typical environmental level samples (much less than the 1000 s^{-1} specified in ANSI, 1991) allow us to neglect the error contributions from pulse pile-up. Coincidence summing is radionuclide, geometry and detector dependent. When analyzing samples that emit coincident gamma rays at window to sample distances less than 10 cm, a graph of summing correction *versus* detector to sample distance is constructed. The factors read from this graph are used to correct the activities (Brunk, 1995). The major isotope of interest, ^{137}Cs , does not emit coincident gamma rays.

The energy *versus* channel number calibration describes the relationship between the channel number and the gamma energy. The calibration software provided with the GENIE system calculates offset, slope and quadratic factors. The FWHM describes the peak shape. This shape varies with peak energy and is a function of the physical construction of the detector and the bias voltage. The detector efficiency describes the relationship between number of gamma rays emitted at a particular energy that deposit all of their energy in the detector and number of the counts detected. The program calculates an efficiency for each of the described gamma rays in the standard and fits a curve to the set of energy - efficiency pairs. This efficiency curve may be described in one of two ways. The software vendor refers to these as empirical, which is calculated via cubic splines, and non-empirical, which is calculated using a least square fit routine. The spline method assumes that with N calibration energies, N-1 third order polynomials exist such that the first and second

derivatives are continuous at each of the energies. By definition, the resulting curve passes through each of the energy points. This method is very local in nature causing a maximum extrapolation of 10 keV at the ends of the curve. The least squares fit method does not have this extrapolation restriction. (Canberra, 1989)

Analysis And Data Reduction

Marshall Islands samples come to the facility in boxes of 72 to 100 samples depending on the sample container. The groups of samples have been separated by experiment or priority and contain blind quality control samples. They are contained in one of three containers. (See Table 2 for the list of the containers used.)

Table 2. Container geometry designations.

Designation	Container Material	Dimensions
F	steel	8.4 cm diameter × 4.2 cm high
P	plastic	3.7 cm diameter × 4.4 cm high
T	plastic	2.8 cm diameter × 11.6 cm high

Routine Analytical Procedure

1. A limited number of samples are received and are stored away from the detector room prior to analysis. By keeping only a small inventory a distance from the detectors the possibility that radiation from the stored samples will raise the background is minimized.
2. Samples are selected for analysis. We prefer to analyze groups of samples that contain similar amounts of activity so that sample throughput can be maximized. The sample name, detector name, sample weight and zero time for each of the samples are entered on the log sheet. Any errors are lined out and initialed.
3. The sample data are keyed or scanned in to the computer and the samples are placed on the detectors. A Digital Command Language (DCL) command procedure, `start_bk.com`, starts the analyzers. (See Appendix A)
4. Generally, the samples are analyzed for a specific length of time or for a specified counting error for a particular peak. The routine preset count time is for a minimum of 1000 minutes or four percent counting statistic in the ^{137}Cs peak. Samples that are suspected to contain an extremely low level of activity are counted for a longer time. This might be as long as 6000 minutes. Lower activity samples might require a longer count time to achieve the required statistical error if the samples are being counted to a specific counting error. (ASTM, 1987. NCRP, 1985)

5. After the time or statistical error criteria have been met, the analyzers are stopped and the data are transferred to disk storage. The analyzed samples are returned to the experimenter.

Non - Routine Analytical Procedure

Occasionally, the experimenter will specify special analysis conditions that are different from those used for the routine analysis. The flexibility of the data collection system allows for the rapid change in counting criteria. A common situation is the analysis of ^{40}K in vegetation samples. The stopping parameter is to terminate the count after the counting statistic for the 1460 keV gamma ray goes below ten percent. Another common situation is the desire to analyze the sample multiple times for the same stopping criteria. In this case, the sample is simply added to the counting stream as many times as necessary. A third situation occasionally occurs when samples are contained in a non-standard geometry. In this case, the appropriate standard is constructed and a calibration is performed.

Data Reduction

The spectra are inspected for correct channel - energy relationship and the fit coefficients are adjusted if necessary with the calibration program supplied by Canberra. The DCL command files necessary for analysis are created so that the spectra are conveniently ordered and the file are submitted to the VMS batch processing facility for calculation. A nuclide library containing isotopes that have been found historically in samples from the Pacific Proving Grounds is used to identify the radionuclides in the sample spectra. (See Appendix B) The command procedure `new_calc.com` causes the nuclides to be identified, activities calculated, weighted means calculated for isotopes having more than one gamma ray and minimum detectable activity limits to be calculated. (See Appendix A) This procedure creates a printout and two disk files containing the activities and the minimum detectable activities in abbreviated form. The results are checked for data entry errors and defects in the measurement process. If the report appears correct, the data are released to the experimenter. If the sample input data are not correct, the incorrect information is replaced with an editing program supplied by Canberra and the spectrum is reanalyzed. If there has been a defect in the spectra due to equipment malfunction, the sample is reanalyzed.

As the VAX's disks become full, the calculated data and spectra are archived. Before the archive process is started, the files produced by the analysis codes are checked for completeness. Results are recalculated for any sample not complete. The analytical result data files are transferred over the Ethernet to a local computer and to the group's central file server. The spectra and the data files are written to magnetic tape and to the LLNL long term archive system. This multi-step archiving process is described in the check list found in Appendix C.

Sample Management

The main sample tracking mechanisms use the log sheet that is filled out as the sample count is started and an action file that the termination procedure makes as it executes. The log sheet contains space for the sample identifier, sample description, sample type, sample location, quantity and units, zero time, start date, detector, spectrum identification and the date the data was released to the experimenter. (See Appendix D) The action file created by the count terminating command procedure contains an electronic record of the count parameters. The spectrum identification, detector name, user code, sample identification, start date and time and the count live time are recorded. (See Appendix E)

Quality Control

Quality Control (QC) is the process undertaken to provide confidence that a process will produce a particular result. The quality control program in use at the facility has two major parts. The first part deals with the accuracy, precision and freedom from contamination of the whole sample process. The second deals with the consistency of the procedures and equipment used for the analysis. Each part is the responsibility of a separate group of individuals.

Sample Process Quality Control

The experimental program staff take steps to implement the first part, measuring how well the facility analyzes the sample set. Blind duplicates, blanks and external standards are added to the sample sets sent for analysis. This blind method provides a level of checking that thoroughly tests the facility's capabilities. The QC standards contain well-characterized amounts of isotopes chosen for their usefulness in testing channel - energy shifts and efficiency changes. The blanks contain extremely low levels of activity to test the level of contamination of the analytical systems. Usually several isotopes are included in the standard to give a range of gamma ray energies. The activities reflect those of the routine samples. The results of these standard determinations show how accurate the measurements are. The duplicate samples allow the experimenter to compare the precision of several measurements. The blanks show if contamination is present. Tabulated results are provided by the Quality Control Manager to close the information loop.

Analytical Facility Internal Quality Control

The other part of the QC program is performed at the analytical facility. Special attention is paid to the calibration process making sure that a detector system is not put into service until it performs consistently within the desired precision and accuracy levels. After a system is put into service, weekly measurements designed to detect deviations from these levels are made as part of the routine schedule. The purpose of the procedure is to monitor the performance of the detector systems and make any needed adjustments to the software parameters or electronics to produce

the correct results for known standards. Background counts are performed once a week to ensure that the detectors and caves are not contaminated by leaky samples.

The computer codes and procedures are documented. Changes made during software development and maintenance are recorded to keep records of the algorithms in use and noting changes in coding or logic. This allows for tracking changes that may affect analytical results.

Interlaboratory Comparison

Between these two QC efforts, the probability of careless errors in the analysis process becomes less likely. To enhance the confidence level further, world wide intercomparison standards are analyzed. An external organization picks a material with the appropriate level of activity to use in the study. Participating laboratories receive aliquots for analysis. The laboratories analyze the sample and report the activity levels to the study's authors who then tabulate and distribute the results to the participants. Comparison of the data demonstrates the competence of a facility with respect to the other participants. (Kehl, 1995)

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Appendix A - Command Procedures

START_BK.COM

```

$! START_BK.COM - a command procedure to start detectors for Bikini type samples (Ones that
have the sample name type of f9110spr42f000)
$! By Jim Brunk
$! Started 18 Feb 1993
$! Last Edit 17 Aug 1994
$!
$! 17 Aug 1994 added preset live time
$!
$! First get online detectors
$!
$ detector_count= 1 ! The number of the detector to be acted on
$ max_detector = 0 ! The maximum number of detectors to be started
$ start_count = 0 ! Initialize the start count
$!
$ detector_loop:
$ online = online 'detector_count'
$ detector = detector 'detector_count'
$ if online
$ then
$ inquire answer "Start detector 'f$extract(0,2,detector)' ?" ! type out the first
two letters of the detector
$ if answer .eqs. "" then goto end ! <CR> means end...
$ if answer
$ then
$ max_detector = max_detector+1 ! Increment the maximum number
$ start_count = start_count + 1 ! Increment the start count
$ start 'start_count' = "'detector'" ! If online put detector name in the list
$ endif
$ endif
$ detector_count=detector_count+1 ! Increment the number of detector
$ if detector_count .eq. 16 then detector_count=detector_count+1 ! There is no
Detector 16
$ if detector_count .gt. 24 then goto endlst ! Exit the Loop
$ goto detector_loop
$
$ endlst:
$ detector = 0 ! Initialize the detector number
$ outloop:
$ detector=detector+1
$ if detector .gt. max_detector then goto bye
$ start=start 'detector'
$ write sys$output ""
$ write sys$output " 'start' [Number 'detector' of 'max_detector' detectors.]"
$ call startit 'start'
$ goto outloop
$bye:
$exit
$
$ startit: subroutine
$! Command procedure to start spectra
$! by Jim Brunk
$! started 20 March 1992
$! last edit - 16 April 1993
$! *****
$ det_name = pl ! Pass the detector name
$ inquire sample_name "Enter the sample name" ! Ask for the Sample name
$! ! Figure out the date
$ geometry=f$extract(0,1,sample_name)+"-"+f$extract(0,2,det_name) ! Get geometry
$ type =f$extract(5,3,sample_name) ! Get the sample type
$ location=f$extract(8,3,sample_name) ! Get the sample location
$!
$ if f$extract(3,2,sample_name) .eqs. "01" then mon ="jan"
$ if f$extract(3,2,sample_name) .eqs. "02" then mon ="feb"
$ if f$extract(3,2,sample_name) .eqs. "03" then mon ="mar"
$ if f$extract(3,2,sample_name) .eqs. "04" then mon ="apr"
$ if f$extract(3,2,sample_name) .eqs. "05" then mon ="may"
$ if f$extract(3,2,sample_name) .eqs. "06" then mon ="jun"
$ if f$extract(3,2,sample_name) .eqs. "07" then mon ="jul"
$ if f$extract(3,2,sample_name) .eqs. "08" then mon ="aug"
$ if f$extract(3,2,sample_name) .eqs. "09" then mon ="sep"
$ if f$extract(3,2,sample_name) .eqs. "10" then mon ="oct"
$ if f$extract(3,2,sample_name) .eqs. "11" then mon ="nov"
$ if f$extract(3,2,sample_name) .eqs. "12" then mon ="dec"
$ year= f$extract(1,2,sample_name)
$ tzero = "1-'mon'-'f$string(year)" ! Set up the T zero
$!
$ write sys$output "The sample type is: 'type'" ! show the sample type

```

```

$      write sys$output "The sample Location is: ''location''"      ! Show the location
$      inquire sample_quan "Enter the sample quantity"      ! Get the amount of the sample
$      sample_unit="gm"      ! Set up default units
$      write sys$output "The units of the quantity are gm."      ! Show the units
$      write sys$output "The T-zero is: ''tzero''"      ! Show the Zero Time
$      pars/command 'det_name' stitle="Not_Finished!"      ! Indicate that the sample has not
been dumped
$      plive="0 00:00:00.0"      ! reset infinite live time
$      pars/command 'det_name' sident='sample_name'      - ! Put the sample name in the sample
identification
$      sgeomtry='geometry'      -! Put the first character of the sample name in geometry
$      stype='type'      - ! Put in the type of sample
$      sloctn='location'      - ! Put in the location of the Sample
$      squant='sample_quan'      - ! Put in the sample size
$      sunits='sample_unit'      - ! Put in the units
$      stime='tzero'      ! Put in the zero time
$
$      mca off 'det_name'      ! Stop the detector if it is going
$      mca erase 'det_name'      ! Clear the adc data
$      mca on 'det_name'      ! Turn the adc on
$      mca delete/region 'det_name'      ! Delete all ROIs
$      mca create/region 'det_name' 650 670 1 /energy      ! set a ROI around Cs-137 peak
$      write sys$output "Detector " + det_name + " started...." ! Let them know what
happened
$      write sys$output ""      ! Out a blank line
$ set noverify
$ return

```

NEW_CALC.COM

```

$set noverify !
$! NEW_CALC.COM Calculation Command file
$!
$!   Jim Brunk
$!   Started   : 16 Apr 1993
$!   Last edit: 16 Nov 1994
$!
$!   16 Nov 1994 - changed the start channel to 90
$!                 Changed the printer to tta: (laser que)
$!
$! Usage:
$!       new_calc p1 p2 p3 p4
$!
$! P1 is the sample configuration
$! P2 is the Library
$! P3 is the background configuration
$! P4 is the calibration configuration
$!
$set noon                      ! make sure that we go on if there are errors
$!
$   move/partial 'p4'/efficiency/processing 'p1'          ! Add calibration parameters
$   write sys$output "Moving the efficiency data from 'p4' to 'p1'"
$!
$   pars 'p1' peakstart=90                                ! Start the peak search in channel 90
$   enback
$       /clear
$       /bkgnd='p3'
$       /list=tta2: 'p1'                                ! Correct for background
$   write sys$output "ENBACK is subtracting 'p3' from 'p1'"
$!
$   pars 'p1' activunits="pCi" activmult=1e6             ! 1e6 pCi/uCi
$   call do_it 'p1' 'p2' 'p3' 'p4' pci
$!
$   write sys$output ""                                    ! Write a blank line
$   exit
$!
$ do_it: subroutine
$!
$! Usage:
$!       do_it p1 p2 p3 p4 p5
$!
$! P1 is the sample configuration
$! P2 is the Library
$! P3 is the background configuration
$! P4 is the calibration configuration
$! P5 is the header file
$!
$   wtmean
$       /library='p2'
$       /report=activity
$       /list=tta2:
$       /header='p5' 'p1'                                ! Calculate weighted means
$   write sys$output "Calculating the weighted means for 'p1' with Library 'p2'"
$run punchfile              ! writes the txt file
$!
$   minact
$       /library='p2'
$       /report=mda
$       /list=tta2:
$       /header='p5' 'p1'                                ! Calculate rest of the stuff
$   write sys$output "MINACT 'p1' with Library 'p2' and Header file 'p5'"
$run mdafile
$set noveri              ! Make the MDA file
$ return

```

Appendix B - ETAK Library Nuclide Listing

Library Title : From NVO-140 Isotopes
Library file name : SYSSSYSDEVICE:[GAMMA]ETAKALPHA.NLB;1
Date printed : 18-MAY-1994 10:57:55.14
Number of nuclides : 36
Number of lines : 259

Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
BE-7	53.50D		*	477.40 keV	10.30 %
NA-22	2.58Y			511.00 keV	100.00 %
			*	1274.55 keV	99.94 %
K-40	1.26E+09Y		*	1460.76 keV	10.83 %
MN-54	312.30D		*	834.82 keV	100.00 %
CO-60	5.27Y		*	1173.23 keV	100.00 %
				1332.51 keV	100.00 %
ZN-65	245.00D		*	1115.52 keV	49.00 %
NB-95	35.10D			204.11 keV	2.34 %
			*	235.68 keV	24.90 %
ZR-95	65.00D			724.20 keV	43.00 %
				756.72 keV	54.60 %
			*	765.80 keV	99.00 %
RH-101	3.01Y			127.20 keV	84.00 %
			*	197.90 keV	90.00 %
				325.10 keV	18.00 %
RH-102M	2.90Y			418.80 keV	11.20 %
			*	475.10 keV	93.00 %
				628.20 keV	7.00 %
				631.40 keV	52.00 %
				697.60 keV	43.20 %
				767.00 keV	33.00 %
				1046.80 keV	31.00 %
				1103.30 keV	4.50 %
				1112.90 keV	18.00 %
RU-103	39.60D		*	497.09 keV	90.00 %
				610.31 keV	5.60 %
RH-106	30.36S		*	511.80 keV	20.50 %
				616.30 keV	0.81 %
				622.10 keV	9.80 %
				873.80 keV	0.44 %
				1050.70 keV	1.40 %
AG-108M	126.99Y			79.12 keV	5.20 %
			*	433.61 keV	92.00 %
				614.04 keV	92.00 %
				632.74 keV	0.11 %
				722.73 keV	92.00 %

Library title : From NVO-140 Isotopes
Library file name : SYS\$SYSDEVICE:[GAMMA]ETAKALPHA.NLB;1
Date printed : 18-MAY-1994 10:57:55.14
Number of nuclides : 36
Number of lines : 259

Page : 2

Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
AG-110M	253.00D			446.20 keV	3.50 %
				620.10 keV	2.50 %
			*	657.60 keV	93.00 %
				677.50 keV	12.20 %
				686.80 keV	7.50 %
				706.60 keV	16.00 %
				744.20 keV	4.33 %
				763.80 keV	22.00 %
				817.90 keV	6.95 %
				884.50 keV	71.00 %
				937.30 keV	33.60 %
				1384.30 keV	24.00 %
				1475.90 keV	3.70 %
				1505.20 keV	12.60 %
				1562.50 keV	1.10 %
CD-113M	13.70Y		*	263.71 keV	0.02 %
SB-125	2.77Y			176.43 keV	7.20 %
			*	380.44 keV	1.52 %
				427.88 keV	30.40 %
				463.38 keV	10.70 %
				600.60 keV	18.10 %
				606.70 keV	5.15 %
				635.92 keV	11.50 %
				671.41 keV	1.82 %
BA-133	10.51Y			53.16 keV	2.28 %
				79.60 keV	2.60 %
				81.00 keV	33.60 %
				160.61 keV	0.64 %
				276.33 keV	7.20 %
				302.75 keV	18.40 %
			*	355.90 keV	62.40 %
				383.75 keV	8.94 %
CS-134	2.04Y			475.34 keV	1.54 %
				563.22 keV	8.82 %
				569.33 keV	15.80 %
				604.70 keV	98.00 %
			*	795.79 keV	89.00 %
				801.87 keV	9.50 %
				1038.61 keV	1.06 %
				1167.91 keV	1.85 %
				1365.13 keV	3.00 %
CS-137	30.03Y		*	661.65 keV	85.00 %
CE-144	284.60D			80.10 keV	1.48 %
			*	133.50 keV	11.00 %
				696.50 keV	1.33 %

Library title : From NVO-140 Isotopes
Library file name : SYS\$SYSDEVICE:[GAMMA]ETAKALPHA.NLB;1
Date printed : 18-MAY-1994 10:57:55.14
Number of nuclides : 36
Number of lines : 259

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Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
EU-152	14.02Y		*	121.78 keV	28.16 %
				244.70 keV	7.50 %
				251.60 keV	0.05 %
				271.00 keV	0.07 %
				295.97 keV	0.47 %
				315.40 keV	0.05 %
				324.70 keV	0.09 %
				329.30 keV	0.15 %
				344.27 keV	26.60 %
				367.76 keV	0.86 %
				385.92 keV	0.00 %
				411.10 keV	2.24 %
				416.00 keV	0.11 %
				443.94 keV	3.12 %
				488.70 keV	0.41 %
				503.45 keV	0.15 %
				563.80 keV	0.05 %
				566.20 keV	0.01 %
				586.20 keV	0.47 %
				656.40 keV	0.15 %
				674.35 keV	0.18 %
				678.60 keV	0.46 %
				688.80 keV	0.87 %
				712.90 keV	0.10 %
				719.30 keV	0.34 %
				764.90 keV	0.17 %
				769.00 keV	0.04 %
				778.85 keV	13.00 %
				810.24 keV	0.32 %
				841.40 keV	0.21 %
				867.30 keV	4.21 %
				896.92 keV	0.00 %
				919.10 keV	0.43 %
				930.20 keV	0.06 %
				964.00 keV	14.63 %
				1005.10 keV	0.65 %
				1085.70 keV	10.10 %
				1089.50 keV	1.73 %
				1111.90 keV	13.60 %
				1212.80 keV	1.42 %
				1249.70 keV	0.19 %
				1292.60 keV	0.10 %
				1298.97 keV	1.64 %
				1407.92 keV	20.94 %
				1457.60 keV	0.50 %
				1528.20 keV	0.27 %
				1606.70 keV	0.02 %
				1648.20 keV	0.01 %
				1769.90 keV	0.01 %

Library title : From NVO-140 Isotopes
Library file name : SYSSYSDEVICE:[GAMMA]ETAKALPHA.NLB;1
Date printed : 18-MAY-1994 10:57:55.14
Number of nuclides : 36
Number of lines : 259

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Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
EU-154	7.84Y		*	123.14 keV	40.50 %
				248.04 keV	6.59 %
				591.74 keV	4.84 %
				692.41 keV	1.70 %
				723.30 keV	19.70 %
				756.87 keV	4.34 %
				873.19 keV	11.50 %
				996.32 keV	10.30 %
				1004.76 keV	17.30 %
				1274.39 keV	33.50 %
				1596.48 keV	1.67 %
				60.01 keV	1.32 %
				86.55 keV	32.20 %
				105.32 keV	22.80 %
EU-155	4.68Y		*	72.80 keV	59.88 %
				74.97 keV	100.00 %
				84.80 keV	34.89 %
PB-XRAY	32.41Y		*	87.30 keV	10.96 %
				569.62 keV	98.00 %
				1063.65 keV	77.00 %
BI-207	32.03Y		*	1770.18 keV	6.82 %
				46.50 keV	4.10 %
				186.14 keV	4.00 %
PB-210	22.30Y		*	241.96 keV	7.90 %
				295.20 keV	20.20 %
				351.92 keV	40.10 %
RA-226	1621.10Y		*	609.27 keV	48.40 %
				665.40 keV	1.65 %
				742.48 keV	0.00 %
				768.35 keV	5.32 %
				785.80 keV	1.21 %
				806.16 keV	1.31 %
				934.06 keV	3.34 %
				1120.28 keV	16.00 %
				1155.17 keV	1.82 %
				1238.13 keV	6.20 %
				1280.98 keV	1.56 %
				1377.64 keV	4.18 %
				1401.44 keV	1.44 %
				1407.98 keV	2.60 %
				1509.22 keV	2.30 %
				1661.24 keV	1.21 %
				1729.55 keV	3.07 %
				1764.49 keV	16.60 %
				1838.33 keV	0.41 %
				1847.44 keV	2.20 %
2118.52 keV	1.23 %				
2204.14 keV	5.30 %				
2447.63 keV	1.65 %				

Library title : From NVO-140 Isotopes
 Library file name : SYS\$SYSDEVICE:[GAMMA]ETAKALPHA.NLB;1
 Date printed : 18-MAY-1994 10:57:55.14
 Number of nuclides : 36
 Number of lines : 259

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Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
AC-228	6.13D			129.04 keV	2.67 %
				153.95 keV	0.84 %
				209.23 keV	4.38 %
				270.23 keV	3.80 %
				327.95 keV	0.34 %
				338.31 keV	12.60 %
				340.91 keV	0.48 %
				409.42 keV	2.18 %
				462.99 keV	4.88 %
				562.50 keV	0.92 %
				726.83 keV	0.75 %
				755.23 keV	1.12 %
				772.25 keV	1.58 %
				794.89 keV	4.70 %
				830.38 keV	0.60 %
				835.64 keV	1.78 %
				840.30 keV	0.98 %
				904.13 keV	0.79 %
			*	911.14 keV	28.40 %
				964.69 keV	5.45 %
				968.91 keV	17.30 %
				1244.70 keV	0.06 %
				1247.10 keV	0.57 %
				1459.04 keV	0.80 %
				1495.84 keV	0.95 %
				1501.50 keV	0.51 %
				1557.10 keV	0.20 %
				1580.43 keV	0.64 %
				1588.05 keV	3.44 %
				1624.84 keV	0.27 %
				1630.52 keV	1.72 %
				1638.15 keV	0.50 %
				1666.30 keV	0.19 %
				1685.70 keV	0.11 %
				1887.26 keV	0.10 %
TH-228	1.91Y		*	238.63 keV	44.80 %
				240.98 keV	4.14 %
				277.34 keV	2.30 %
				300.11 keV	3.42 %
				510.72 keV	8.34 %
				583.14 keV	30.90 %
				727.27 keV	6.65 %
				785.46 keV	1.10 %
				860.49 keV	4.53 %
				1592.69 keV	0.00 %
				1620.62 keV	1.51 %
				2614.71 keV	35.96 %

Library title : From NVO-140 Isotopes
 Library file name : SYSSSYSDEVICE:[GAMMA]ETAKALPHA.NLB;1
 Date printed : 18-MAY-1994 10:57:55.14
 Number of nuclides : 36
 Number of lines : 259

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Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
U-235	7.13E+08Y			143.77 keV	10.70 %
				163.37 keV	4.85 %
			*	185.72 keV	56.10 %
				202.10 keV	1.07 %
				205.33 keV	4.87 %
U-238	4.51E+09Y			63.28 keV	3.46 %
			*	92.58 keV	4.29 %
				1001.10 keV	0.83 %
NP-239M	27.40Y			57.30 keV	0.15 %
				61.47 keV	1.32 %
				99.46 keV	12.30 %
				103.65 keV	19.60 %
			*	106.07 keV	25.20 %
				116.20 keV	2.48 %
				117.20 keV	4.63 %
				120.60 keV	1.93 %
				209.73 keV	3.30 %
				228.14 keV	10.95 %
				277.60 keV	14.00 %
PU-239	24405.00Y			94.66 keV	0.01 %
			*	98.44 keV	0.02 %
				129.28 keV	0.01 %
				203.52 keV	0.00 %
				375.02 keV	0.00 %
				413.69 keV	0.00 %
AM-241	433.42Y		*	59.54 keV	35.90 %
				99.00 keV	0.02 %
				103.00 keV	0.02 %
PU-241	14.50Y			148.60 keV	0.00 %
				164.59 keV	0.00 %
			*	207.97 keV	0.00 %
AM-243	7665.80Y		*	74.67 keV	66.00 %

Reference

United States Atomic Energy Commission (October 1973), Walter E. Nervik and Roger Ray, editors, *Enewetak Radiological Survey*, NVO-140, Vol. 1.

Appendix C - Data Backup Procedure

VAX Gamma Data Archive Check List

Note: The \$ is the VAX prompt (which may not be a \$ at all, it may be something like EVNLLG >...) and is not to be entered. The > and FTP> are prompts for the PC and are not to be entered. Commands to the computers are written in italics. The user is assumed to know how to use the appropriate VAX DCL, FTP, dBase and Novell procedures.

Archive	Action	Commands
	Run the batch file ARCH_DIR to make the file ARCH.TXT. This runs the VAX directory command with the date and time qualifiers and creates an output file (ARCH.TXT).	On the VAX: \$ @ARCH_DIR<cr> [To watch it happen] or \$ submit ARCH_DIR<CR> [To run it as a batch]
	Get the ARCH.TXT file on the PC with FTP. Rename the arch file to ARCHxx.TXT, where xx is the archive number.	On The PC: >FTP evnllg <cr> username gamma<cr> password <password><cr> FTP> get arch.txt <cr> FTP> quit <cr>
	Run the PC program ARCHIVE to create the ARCHxx.COM and ARCHxx.DB files. The program will ask for the archive number. This is the next serial number in line. (check the log book.)	On the PC: > ARCHIVE ARCHxx.TXT<cr>
	Use FTP to put the file ARCHxx.COM on the VAX.	On The PC: > FTP evnllg <cr> username gamma<cr> password <password><cr> FTP> put archxx.com <cr> FTP> bye <cr>
	Run the ARCHxx.COM on the VAX. This renames the various files from their original subdirectories to the DISK\$DATA:[GAMMA.DONE] subdirectory.	On the VAX: \$ @archxx <cr> [To run it as a batch]
	Check to make sure that there is a .MDA file for every .txt file. Copy the .TXT and .MDA files from the various VAX subdirectories to the appropriate subdirectories on the PC with FTP. The list of files may have to be broken up into smaller jobs due to FTP limitations on the number of files to be brought over in a batch. One may use the -e filename -i switches to use a batch file.	On The PC.: >FTP evnllg <cr> FTP> user gamma<cr> FTP> password <password><cr> FTP> cd disk\$data:[gamma.xx]<cr> [xx = code] FTP> mget *.txt <cr> FTP> mget *.mda<cr> FTP> bye <cr>
	Copy the .TXT and .MDA files from the various subdirectories on the PC to the appropriate subdirectories on the file server.	Log on to the file server (You may have to reboot the computer the Ethernet connection.) Get into the proper subdirectory on the PC: NCOPY/S *.txt <file server drive letter> NCOPY/S *.mda <file server drive letter> Or Use the protected copy function of DF
	Rename the .TXT and .MDA files from the various VAX subdirectories (DISK\$DATA:[GAMMA.xx]) to the DISK\$DATA:[GAMMA.DONE] subdirectory.	On the VAX (in the appropriate subdirectory): \$rename *.txt disk\$data:[gamma.done] <cr> \$rename *.mda disk\$data:[gamma.done] <cr>
	Add the data to the ARCHIVE data base on the file server from the file ARCHxx.DB. The ARCHIVE data base is found in the /datafiles/counting directory. Print out the Archive report and put into the binder.	On the PC in dBase: append from ARCHxx.DB type delimited with blank<cr>
	Recheck all the VAX subdirectories to make sure something is not being left out.	On the VAX: \$dir *.txt<cr> \$dir *.mda<cr> \$dir *.cnt/size<cr>
	Using VMS BACKUP, copy the [gamma.done] sub directory to magtape. Make sure that the tape name is a maximum of six characters.	On the VAX: \$ backup /verify /log DISK\$DATA:[GAMMA.DONE]:* MKB500:AR0000.BCK /label=arch0000/rewind/ignore=label_processing<CR> Fill in the appropriate number for 0000.
	Use the BACKUP/LIST command to make a listing of the tape for the hard copy record book. Put the list in the binder.	On the VAX: \$dismount mkb500:<cr> then[To watch it happen] \$ Backup/list=\$printer mkb500:/rewind<cr> or [To run it as a batch] \$ submit list_backup<cr>
	Use FTP to write the data to the long term archive, OCFARCH. Make sure the transfer is the type binary. Use the MKDIR command to make a sub directory for the new set of files.	On the VAX: \$ FTP OCFARCH.LLNL.GOV<cr> (128.115.1.16) >user jbrunk >password <password> > etc.
	Delete the files from the DISK\$DATA:[GAMMA.DONE] sub directory.	On The VAX: Del/log disk\$data:[gamma.done]*.*;<cr>
	Record the archive number and date in the log book.	

Appendix D - Counter Log Sheet

B379 Genie Sample Log Sheet

	Sample Name	Sample Description	Sample Type	Sample Location	Quantity	Units	Zero Time DD-MMM-YYYY	Start Date	Detector	Spectrum ID	Printout Delivered
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

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Submitted by: _____ Analyst: _____ Account: _____ User: _____

Appendix E - Extract From an Action File

The action file is a record generated at the time a sample count is terminated. The essential counting particulars are recorded. The spectrum identification, detector name, sample name, count start date and time, and count live time.

Extract

224925	Z094C09	BK	F9411SPR24E04708	2-JUL-1995	10:48:16.39	0	20:49:39.00
224926	S893A06	BK	F9411SPR24E04714	2-JUL-1995	10:48:42.38	0	20:49:32.00
224927	6H93A07	BK	F9411SPR24E04717	2-JUL-1995	10:48:58.21	0	20:49:06.00
224928	8P93A08	BK	F9411SPR24E04719	2-JUL-1995	10:49:08.87	0	20:49:12.00
224929	5Q93A08	BK	F9411SPR24E04728	2-JUL-1995	10:49:26.29	0	20:49:17.00
224930	7J93A08	BK	F9411SPR24E04736	2-JUL-1995	10:49:42.09	0	20:48:56.00
224931	DR93A08	BK	F9411SPR24E04740	2-JUL-1995	10:49:54.40	0	20:49:02.00
224932	9T93A11	BK	F9411SPR24E04746	2-JUL-1995	10:50:13.06	0	20:48:52.00
224933	FE93A11	BK	F9411SPR24E04753	2-JUL-1995	10:50:27.19	0	20:49:01.00
224934	UL93A12	BK	F9411SPR24E04757	2-JUL-1995	10:50:38.99	0	20:48:47.00
224935	Y293A20	BK	F9411SPR24E04760	2-JUL-1995	10:51:02.61	0	20:48:33.00
224936	HK93A21	BK	F9411SPR24E04763	2-JUL-1995	10:51:16.76	0	20:48:33.00
224937	L493A21	BK	F9411SPR24E04766	2-JUL-1995	10:51:32.63	0	20:48:18.00
224938	2D93A22	BK	F9411SPR24E04770	2-JUL-1995	10:51:47.06	0	20:48:15.00
224939	EG93A22	BK	F9411SPR24E04772	2-JUL-1995	10:51:57.80	0	20:48:08.00
224940	Z094C09	QA	BACKGROUND	3-JUL-1995	13:08:26.45	1	18:33:44.00
224941	S893A06	QA	BACKGROUND	3-JUL-1995	13:08:34.11	1	18:33:28.00
224942	6H93A07	QA	BACKGROUND	3-JUL-1995	13:08:41.11	1	18:33:42.00
224943	P794C09	QA	BACKGROUND	3-JUL-1995	13:08:48.19	1	18:32:15.00
224944	8P93A08	QA	BACKGROUND	3-JUL-1995	13:08:56.02	1	18:33:40.00
224945	5Q93A08	QA	BACKGROUND	3-JUL-1995	13:09:03.06	1	18:33:57.00
224946	7J93A08	QA	BACKGROUND	3-JUL-1995	13:09:10.46	1	18:33:38.00
224947	DR93A08	QA	BACKGROUND	3-JUL-1995	13:09:17.62	1	18:33:41.00
224948	9T93A11	QA	BACKGROUND	3-JUL-1995	13:09:25.06	1	18:33:44.00
224949	4F94C08	QA	BACKGROUND	3-JUL-1995	13:09:32.08	1	18:34:12.00
224950	FE93A11	QA	BACKGROUND	3-JUL-1995	13:09:45.46	1	18:34:09.00
224951	0P94C08	QA	BACKGROUND	3-JUL-1995	13:09:52.49	1	18:34:03.00
224952	UL93A12	QA	BACKGROUND	3-JUL-1995	13:10:29.33	1	18:33:26.00
224953	Y293A20	QA	BACKGROUND	3-JUL-1995	13:10:44.11	1	18:33:16.00
224954	HK93A21	QA	BACKGROUND	3-JUL-1995	13:10:51.15	1	18:33:31.00
224955	L493A21	QA	BACKGROUND	3-JUL-1995	13:10:58.11	1	18:33:30.00
224956	2D93A22	QA	BACKGROUND	3-JUL-1995	13:11:05.22	1	18:33:26.00
224957	EG93A22	QA	BACKGROUND	3-JUL-1995	13:11:13.00	1	18:33:17.00
224958	Z094C09	BK	F9411SPR24E04713	5-JUL-1995	08:00:01.10	0	23:47:16.00
224959	S893A06	BK	F9411SPR24E04718	5-JUL-1995	08:00:09.41	0	23:46:55.00
224960	6H93A07	BK	F9411SPR24E04748	5-JUL-1995	08:00:17.57	0	23:47:16.00
224961	8P93A08	BK	F9411SPR24E04739	5-JUL-1995	08:00:25.89	0	23:47:11.00
224962	5Q93A08	BK	F9411SPR24E04729	5-JUL-1995	08:00:34.06	0	23:47:15.00
224963	7J93A08	BK	F9411SPR24E04720	5-JUL-1995	08:00:42.20	0	23:46:57.00
224965	DR93A08	BK	F9411SPR24E04750	5-JUL-1995	08:01:15.08	0	23:46:46.00
224966	9T93A11	BK	F9411SPR24E04755	5-JUL-1995	08:01:06.94	0	23:47:32.00
224967	FE93A11	BK	F9411SPR24E04709	5-JUL-1995	08:00:58.83	0	23:47:50.00
224968	UL93A12	BK	F9411SPR24E04756	5-JUL-1995	08:00:50.40	0	23:48:12.00
224969	Y293A20	BK	F9411SPR24E04705	5-JUL-1995	08:01:23.20	0	23:47:36.00