Instructions for Calibrating Gamma Detectors using the Canberra - Nuclear Data Genie Gamma Spectroscopy System

James L. Brunk

Health and Ecological Assessment Division

September 1995

Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

MASTER

3183

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Table of Contents

Note.....	1
Computer Conventions.....	1
Abstract.....	1
Introduction and Background.....	2
Calibration Principles.....	3
System Architecture.....	5
Preparation for Calibration.....	5
Standards	5
Calibration Steps	7
Initial Steps.....	7
Standards	7
Background	8
The Energy and FWHM Calibration.....	8
The Efficiency Calibration.....	8
Comparison of the Results from the Rest of the Standard Set.....	9
Record Keeping	9
Notes on Quality Control.....	9
References.....	11
Appendix A --Required Files for the Standardization Procedure.....	A-12
Appendix B -- Calibration Check List and Commands.....	B-15
Appendix C -- Detector Installation and Counter Information Sheet.....	C-18
Appendix D -- Supplemental Command Procedures and Programs	D-22
Appendix E -- Results an Initial Calibration.....	E-32
Appendix F -- Results of an Update Calibration	F-35
Appendix G -- Data Handling Codes and Databases.....	G-39

Note

Computer Conventions

- Descriptions of actions performed on various computers are interspersed throughout this report. Bold print denotes the names of programs and other commands. CALIB /INIT is an example of this usage.
- All commands to the various programs end with an implied carriage return, labeled on some keyboards as enter.
- Both the VAX/VMS and IBM PC operating systems are case insensitive with respect to program names and operating system commands. However, when the codes and programs are requesting information, the computer stores the data requested just as it receives it and thus these data are case sensitive.
- Items enclosed in angle brackets (< >) are user supplied data that are variable in nature and may change with each occurrence. An example of this construction is CALIB/INIT <detector name>.
- Information pertaining to a particular gamma spectrum is stored together in one place in a basic entity referred to as a configuration (Canberra, 1990). This configuration information is media independent; it can exist as a disk file, in an archive or stored in a semiconductor ADC memory area. The configuration files that contain the specific calibration information for a particular detector system and geometry combination reside on the VAX's system disk. Since this information is important at later times, the system is programmed to mark them read only automatically in the VMS log in command file. This gives some protection against accidental erasure. Be aware, however, that the system manager's account contains all privileges including the one to override write protection. Thus, the system manager must guard against inadvertently erasing these files during a global file purge.
- The Digital Equipment VMS computer system stores the name and location information about isotope property library files, spectral configurations, files describing the radiological properties of the standards and other needed files in Digital Command Language (DCL) logical names and system symbols. The data manipulation programs create and use these logical names and symbols as default program parameters. This provides a convenient method to shorten the commands required to calculate a desired result when using a string of operations.

Abstract

A straight forward protocol provides a way to guide the calibration of a gamma detector for a particular geometry and material. Several programs have used the

Low Level Gamma Counting Facility of the Health and Ecological Assessment Division of the Lawrence Livermore National Laboratory to count a variety of large environmental samples contained in several unique geometries. The equipment and calibration requirements needed to analyze these types of samples are explained. This document describes the calibration protocol that has been developed and describes how it is used to calibrate the detectors.

Introduction and Background

The mission of the Low Level Gamma Counting Facility of the Health and Ecological Assessment (HEA) Division of the Lawrence Livermore National Laboratory (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 to determine the concentrations of gamma emitting radionuclides found in the environment since the 1960's (Allen, 1994). These facilities have evolved into the Low Level Gamma Counting Facility.

Recently, due to changes in the central LLNL computing environment and the impending obsolescence of the data collection systems, changes to the counting system architecture and analysis scheme had to be made. After investigation of several systems, the GENIE® system manufactured by Canberra - Nuclear Data¹ was selected. This system allows for the collection of spectral data from several detectors while simultaneously doing data reduction calculations on a Digital Equipment Corporation² (DEC) VAXStation® running DEC's VMS® operating system.

This new system has the advantage of a great decrease in the amount of time required to calibrate a geometry when compared with the previous method (Brunk, 1989). With the prior method, several standards were counted and a time consuming manual procedure took many days of effort to produce the required calibration parameters. With this new system, a standard is counted and three programs supplied by the manufacturer calculate the calibration parameters in a manner of minutes. This empirical approach eliminates the need to calculate many of the parameters that the previous method required. The trade off for this ease of calibration is that if the experimenter's samples do not substantially match the standard in elemental composition and geometry, the measured activities will deviate from the correct ones by an uncharacterized amount. This effect is compensated for by carefully selecting the materials that make up the calibration standards taking care to match the physical properties of the samples as closely as possible.

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

² Digital Equipment Corporation, Maynard, Massachusetts.

Calibration Principles

Calibration is the process of identifying and documenting the characteristic parameters of a detector and signal processing system. The effort required to calibrate a system varies with the demands of the calculation scheme. The previous code, GAMANAL, a code written by members of the LLNL Nuclear Chemistry Division, calculated the answers using a complete mathematical description of the various system variables that involved a time consuming calibration procedure (Gunnink, 1972; Brunk, 1989). Our current calculation scheme relies on having the calibration standards as close as possible in geometry and material composition as the samples of interest.

With the current 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 gammas 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 counting 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. Factors read from this graph are used to correct the activities.

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 so that the following equation describes the relationship (Canberra, 1989).

$$\text{energy} = \text{offset} + (\text{slope} \cdot \text{channel}) + (\text{quadratic} \cdot \text{channel})^2$$

Energy is the calculated energy at the specified channel. The units are determined by the entry in the file that describes the standard's characteristics (See Appendix A).

Channel is the multi - channel analyzer (MCA) channel number in which the centroid of the peak resides.

Offset is the number of channels the spectrum is shifted.

Slope and *quadratic* are the calculated fit coefficients.

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 system uses the following equation to calculate the FWHM (Canberra, 1989).

$$FWHM = offset + slope \cdot \sqrt{energy}$$

FWHM is the difference in energy between the two points on the peak curve that occupy the half the maximum peak height. The units are the same as those used for reporting the peak energy.

Energy is the value of the energy at the centroid of the peak.

Offset and slope are the calculated coefficients.

The detector efficiency coefficient describes the relationship between number of gamma rays emitted at a particular energy that deposit all of its energy in the detector and number of the counts detected.

$$\epsilon = \frac{P}{Q \cdot R \cdot T_1} \cdot e^{\lambda T_r} \cdot \frac{\lambda \cdot T_r}{(1 - e^{-\lambda T_r})}$$

Where:

ϵ is the gamma photo peak efficiency in counts/g

P is the integrated peak area in counts

Q is the calibration source mass or volume quantity in grams, ml, etc.

R is the calibration source emission rate at a particular reference time in $\gamma/\text{second}/(\text{mass or volume quantity})$

T_1 is the elapsed time during which the detector system can process gamma rays measured in seconds (referred to as live time)

T_r is the real time in seconds which is the elapsed live count time plus the time that the system is incapable of processing a second gamma ray (referred to as dead time)

T_s is the source decay time (the acquisition start time subtracted from the calibration source zero time)

λ is the decay constant in seconds⁻¹ (also equal to $\ln 2$ divided by the nuclide half life, $t_{1/2}$)

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 the 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. The equation is a global analytical function of the form:

$$\ln(\varepsilon) = a_2 + a_3 \cdot x + a_4 \cdot x^2 + a_5 \cdot x^3 + a_6 \cdot x^4 + a_7 \cdot x^5$$

Where:

ε is the calculated efficiency in counts/ γ

x is $\ln(a_1/E)$

E is the peak energy at which the efficiency is calculated in keV

a_1 is $(E_1 - E_2)/2$

E_1 is the energy of the least energetic gamma ray in the standard

E_2 is the energy of the more energetic gamma ray in the standard

a_2 through a_7 are the fit parameters

The calibration software starts with three degrees of freedom and calculates the fit parameters. The program uses a reduced chi squared test to inspect the curve. If the test is close to 1.0, the curve fits the data set well. If the test is below 0.8, the set is over determined and fewer fit parameters are needed. If the test is over 2.0, the set is underdetermined and more parameters are needed. The software iterates this process until a convergence occurs, a chi square of greater than 2.0 with a fifth order polynomial occurs, a chi square of less than 0.8 with a second order polynomial occurs or if one fit gives a chi squared of less than 0.8 and the next order fit gives a test of over 2.0. In the last case, the fit with less than 0.8 is used (Canberra, 1989).

System Architecture

The facility currently has 20 gamma detectors in use. The types used are lithium drifted germanium (Ge(Li)) and high purity germanium (HPGe) detectors. Each detector has its own high voltage power supply and spectroscopy amplifier. The output from each amplifier connects to one of the input ports of an eight port mixer router module. The output of the routers connects to a fast analog to digital converter (ADC) that is connected to a communication control interface that transmits the digital data over thin Ethernet to the VAX computer. All of the instrumentation bins are bonded to a common ground point via a heavy wire bus to prevent ground loops. This bus is connected to the building ground at only one point so all the instrumentation shares the same ground potential.

The spectroscopy package runs on a time share basis and processes the spectral information for real time display. At the conclusion of the count, the computer stores the data on the local disk for subsequent processing. As part of the data security program, an automatic tape backup occurs each night for both the system and data disks.

Preparation for Calibration

Standards

Since the result of a calculation is very dependent on the sample geometry and composition, the calibration scheme requires at least one standard for each sample

geometry (Canberra, 1990). A set of standards prepared in such a way as to be very close to identical in composition containing a particular material in a particular geometry are used. Currently there are calibrations for four materials; a water phantom made of epoxy resin, ammonium molybdophosphate microcrystals (AMP), shredded macaroon coconut, flaked dehydrated potato granules and coral soil. These materials cover a range of densities (0.5 to 2.0 g cm⁻³) and elemental makeup of environmental sample materials. (Kehl, 1995) A steel can and a plastic vial, act as the primary counting containers. The construction of the standard materials requires a great deal of experience and care. (ANSI, 1991, NCRP, 1985.) Bulk standard ingredients were prepared to our specifications by contractors not associated with this laboratory. This permitted the specification of the isotopes, the activity levels and degree of homogeneity for the standard materials. National Institute of Standards and Technology (NIST) traceability of the standard materials was an important requirement. For the initial calibration effort, the contracting laboratory was Isotope Products Laboratory.³ This vendor provided approximately 50 kg of each standard matrix in bulk form. Final calibration standards were constructed by canning aliquants of the bulk material using the same procedures used to can experimental samples.

The term calibration implies traceability to a universally recognized value. The standard formulation contract between LLNL and the external contractor specified that all final standard materials would be traceable to NIST. The contracting vendor complied with this requirement by participating in the Radioactivity Measurements Assurance Program conducted by NIST in cooperation with the US. Council of Energy Awareness (USCEA). In the program, NIST provided blind samples for assaying by the participating labs, with the results sent back to NIST. NIST reported back the difference between the NIST certified value and the lab's value. In addition to this program, the vendor also sends finished products to NIST for product verification and calibration. (IPL, 1993.) The procurement specifications required a certificate of calibration for each batch of standard material. These certificates provided statements of traceability and complete descriptions of the physical and nuclear properties of the materials.

The calibration codes require files containing the radiological information about the standards. These files, called certificate files, contain the sample mass, zero time, sample identification and radiological characteristics of each isotope present in the standard source. Since individual standards differ slightly in construction, each must have its own certificate file created for it using the software vendor's Certificate File Editor (CFE) (Canberra, 1990). See appendix A for a discussion of certificate files. A library describing the isotopes in the standard must exist. The Nuclide Library Editor program (NLE), supplied by the software vendor does this task (Canberra, 1990). See appendix A for an example of a library output listing.

³ Isotope Products, Corporate and Sales Offices, 3017 N. San Fernando Blvd., Burbank, CA 91504.

Calibration Steps

Refer to appendix B for a synopsis of the calibration protocol.

Initial Steps

The detector is set up as described in appendix C. The first stage in the calibration procedure requires that the amplifier be brought into rough energy calibration. This is done as described above during the detector set up by counting a standard containing ^{60}Co and inspecting the spectrum for the correct channel *versus* energy relationship. The amplifier gain controls are adjusted until the centroid of the 1332 keV peak is located in channel 2665. This indicates that the channel - energy relationship of the spectra is about 0.5 keV per channel. In the current scheme, a full spectrum uses 4096 channels which equates to approximately 2 MeV for the whole spectrum. The zero adjustment on the analog to digital converter (ADC) acts to position the spectra at the low energy end. Due to the current electronic setup with up to eight detectors sharing the ADC input through a mixer - router module, the adjustment to the zero control occurs once at the ADC's initial installation. This common control affects the position of the spectra from all the detectors on a particular mixer/router combination. (ASTM, 1993, ASTM, 1987)

Standards

When calibrating a detector system for a particular geometry and sample material, an appropriate set of like standards is counted. One standard of the set is selected as a particular detector's calibrating standard. The activities from this particular standard are used as the benchmarks to compare the activities calculated from rest of the set. This protocol requires that each member of the set be counted for approximately the same live time. The factors determining the count time are the activities of the isotopes present, taking into account the branching ratio of the least abundant gamma ray of interest, and the time since the reference date of the standard. The standards are counted until the least abundant peak described in the calibration certificate file has a peak error below one percent.

Several pieces of identifying information are necessary to set up the various command procedures needed to calibrate a geometry. These other pieces of data such as the sample weight, sample name, count time, zero time, detector name and geometry are extracted from the configuration file. The VMS command procedure `make_info.com` extracts this information about the count by inspecting its configuration and extracting the needed data items. (see appendix D) This procedure creates a text file containing a list of the items of interest. The data is checked for validity paying close attention to the detector name, geometry, sample name and the sample quantity. Any corrections are made with the `pars/screen` program. The data extracted from this file is used as input data to create the command files with programs like `infoec.com`. (see appendix D)

Background

Samples with amounts of activity approaching limits of detection often require long count times. The side effect of long count times is that background radiation shows up in the spectra. The radionuclides contained in the building and cave construction materials as well as those naturally occurring in the soil and surroundings contribute to this environmental background. This effect is accounted for by subtracting the time weighted activity of a long (approximately 6000 minute) background count from the activity of a sample. The background count consists of a spectrum taken with nothing in the sample holder. This approach differs from other methods involving counting an empty container or a container filled with water. The channel position - peak energy relationship of the spectrum is inspected with the vendor supplied peak program. The centroids from a few peaks from the commonly occurring background isotopes, such as ^{40}K and ^{228}U daughters, are compared with the expected channel values. Any needed adjustment in the expected channel location *versus* energy relationship is made using the **calibration** program. The command used is **CALIB /INIT /cer=<standard certificate> <configuration>**. This configuration becomes the file containing the background subtraction information. He copies it to the system disk and renames it with a name in the form: **xx_background.cnf** where **xx** is the first two characters of the detector name. The **move** command accomplishes this.

The Energy and FWHM Calibration

The initial energy and full width at half maximum calibration occurs by issuing a **CALIBRATE /INITIAL <detector name>** command at the VAX keyboard. The program asks for the positions of the peaks flagged in the certificate file as those to be used in an initial calibration. As a check, a peak search occurs next by issuing the **PEAK /LIST=\$PRINTER** command. The peak energy values obtained are compared with the correct energies for those peaks. See Appendix E for an example.

The Efficiency Calibration

After any adjustment of the peak energies, an update calibration is next performed. The **do_calibrate.com** DCL command procedure is used to calculate efficiencies with a polynomial fit. If a spline fit is desired, the **do_calibrate_noemp.com** DCL command procedure is used to complete the update calibration. (See appendix D) An example of the calibration report is found at appendix F. The peak positions are checked by calculating again with the **PEAK /LIST=\$PRINTER** command. If the peaks have not shifted, the efficiency plot is displayed with the **EFF /PLOT /LOG** command. The curve should be a smooth bell shaped curve skewed to the low energy side. The final step is to run the identification routine, **NID /LIST=\$PRINTER**. If the calculated activities are within the acceptable error, usually plus or minus five percent of the certificate value, the **move** command is used to copy the standard configuration file to the system disk with a name in the form of: **XX-F-TYPE.cnf**. The **XX** is the first two letters of the detector name, the **F** is a designator indicating the amount of sample material in the in the geometry (for

example, F for full, H for half full), and TYPE is a description of the standard matrix (for example, water, soil, potato or coconut).

Comparison of the Results from the Rest of the Standard Set

The remainder of the standard set spectra are calculated using the newly calculated efficiency parameters. The use of the `new_calc.com` DCL command procedure with the standard library and the normal background file makes this task easier. (see appendix D)

Tabulate the results and compare the activities sorted with respect to standard number with the amounts listed on the standard certificate. Files containing the calculated activities are produced and have names in the form `XX_#####A.txt`. The XX is the user code, the ##### is the spectrum ID number and the A is an alphanumeric indicating the recalculation position. A FORTRAN code located in appendix G is used to change the format of the activity data produced by the NID program to one that can be used with a data base program. The structure listing of the data base is also found in appendix G. If the values are in satisfactory agreement with the certificate values (usually plus or minus five percent), the calibration is complete. See appendix G for examples of the printouts from the various steps.

Record Keeping

The term calibration also implies traceability. The records and printouts generated in the calibration process are retained in permanent storage. The calibration is not considered complete until a hard copy of the data is stored in binders and the calibration files are stored in the electronic archives.

Notes on Quality Control

Quality Control (QC) is the process undertaken to provide confidence in a particular result. The Quality Control program in use at the gamma counting 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 determination. Each part is the responsibility of separate group of individuals.

A prudently designed experimental program will 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 test the facility's capabilities. The standards contain well-known amounts of certain isotopes chosen for their properties which test channel - energy shifts, efficiency changes and detector contamination of the counting 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.

The other part of the QC program is performed at the counting facility. Special attention is paid to the calibration process making sure that a counting 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 done as part of the routine counting program. The purpose of this portion is to monitor the performance of the counting systems and make any needed adjustments to the software parameters or electronics as to produce the correct answer for particular standards. Background counts are performed once a week to keep the systems under surveillance to make sure that the detectors and caves are not contaminated by leaky samples. Also as part of their part of the Quality Control program, changes made during software development and maintenance are recorded to keep records of the algorithms in use and noting changes in coding or logic. (Canberra, 1989)

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. Interested laboratories receive aliquants 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.

References

Allen, Michael J., Private communication (1994).

American National Standards Institute and the Institute of Electrical and Electronic Engineers, *IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors*, ANSI/IEEE 325-1986 (August 13, 1986).

American National Standards Institute, *American National Standard Calibration and Use of Germanium Spectrometers for the Measurement of Gamma-Ray Emission Rates of Radionuclides*, N42.14-1991 (July 2, 1991).

American Society for Testing and Materials, *Standard Practices for the Measurement of Radioactivity*, D3648-78 (January 27, 1978; Re approval, October 1987).

American Society for Testing and Materials, *Standard Methods for Detector Calibration and Analysis of Radionuclides*, E181-93 (April 15, 1993).

Brunk, James L., *Diode Calibration Manual*, Lawrence Livermore National Laboratory, Livermore, CA, M-262 (1989).

Canberra Industries, *Ge(Li) Detector Test Procedure and Troubleshooting Guide*, Informal Document (July 1, 1976).

Canberra Nuclear Products Group, *Spectroscopy Applications Algorithms and Software Verification and Validation Manual*, 07-0386 (December, 1989).

Canberra Nuclear Products Group, *VAX/VMS Spectroscopy Applications User's and Display Manuals*, Vol. 1, 07-0196 (November, 1990).

Gunnink, R., J. B. Niday, *Computerized Quantitative Analysis by Gamma-ray Spectroscopy*, UCRL-51061, Vol. 1-3 (March 1, 1972).

Isotope Products Laboratory, Catalog, (1993).

Kehl, Steven R., private communications (1995).

National Council on Radiation Protection and Measurements, *A Handbook of Radioactivity Measurements Procedures*, NCRP Report No. 58 (February 1, 1985).

US NIM Committee, *Standard NIM Instrumentation System*, DOE/ER-0457T, (May 1990). [Formerly TID 20893 (Rev) and NIM/GPIB].

Appendix A --Required Files for the Standardization Procedure

Creating Certificate Files

The calibration software requires a file describing the physical and radiological characteristics for each standard. The software vendor refers to these as certificate files and they contain all the necessary information about the properties of that particular standard. The software vendor supplies the certificate file editor (CFE) program to create and maintain these files.

The certificate file contains two broad categories of information. The first category contains data that applies to the radioactive standard in general. These items are the certificate file name, title, date and quantity. Due to the limitations of the program, the units of the quantity are not specified. This shortcoming is somewhat unfortunate, with the potential of causing unneeded confusion. To overcome this, copies of the certificate of traceability and related construction notes are filed with the output of the CFE program. This way, the units can be seen from the original paperwork. The other category of data contains data that applies to an individual gamma ray emitted by a radionuclide. These data are stored in one data record per gamma ray. These items are the nuclide's name, half-life, gamma ray energy and abundance. Other data in an individual record are whether to use that particular line in an initial calibration, the number of gammas emitted per second and the activity of the nuclide. The limitations of the program prevent the display of the units of energy and emission rate. Once again, the related paper work must be referred to in order to find this information.

CFE Program Output Example

Print Time : 13-DEC-1994 15:10:09.62
Certificate file name : SYSSYSDEVICE:[GAMMA]F-414-46-2-001.CER;1
Certificate title : F-414-46-2-01 full coral soil
Certificate date : 15-FEB-1993 00:00:00.00
Certificate quantity : 3.05900E+02

Rcd	Nuclide	Halflife	CAL/ INIT	Energy	Rate	%Abun	Activity (uCi)
1	AM-241	432.70Y	Yes	59.54	1.5492E+01	35.70	1.1728E-03
2	CD-109	1.27Y	No	88.03	4.4600E+00	3.61	3.3391E-03
3	CO-57	271.77D	No	122.06	7.9900E+00	85.50	2.5257E-04
4	CO-57	271.77D	No	136.47	1.0000E+00	10.69	2.5283E-04
5	TE-123M	119.70D	No	158.99	5.5960E+00	84.00	1.8005E-04
6	CR-51	27.70D	No	320.08	1.6227E+01	9.83	4.4615E-03
7	SN-113	115.09D	No	391.69	1.7839E+01	64.00	7.5334E-04
8	SR-85	64.84D	No	514.00	2.8312E+01	99.27	7.7082E-04
9	CS-137	30.00Y	Yes	661.66	1.6971E+01	85.21	5.3829E-04
10	CO-60	5.27Y	No	1173.24	2.5019E+01	99.90	6.7687E-04
11	CO-60	5.27Y	No	1332.50	2.5056E+01	99.98	6.7731E-04
12	Y-88	106.61D	No	898.07	4.6336E+01	92.70	1.3509E-03
13	Y-88	106.61D	Yes	1836.08	4.9667E+01	99.35	1.3511E-03

Library Files

A nuclide library file contains information that allows the identification software to identify and calculate the activity of a particular nuclide. As with the certificate files, there are two categories of information stored in the library. The first category contains common data. These data are the library name, file name, number of nuclides and number of lines. The second category contains the nuclide name, half-life, type (which is a field used to describe the source of a particular nuclide), an indication of key line status (whether the particular line is the line used to calculate the activity or minimum detectable activity (MDA) of a nuclide), gamma ray energies and abundance associated with the isotope. The nuclide library editor (NLE) program prints out all these entries in the form shown below.

The information needed for calibration consists of the name, energy, half life and branching for each nuclide. Nuclide type is not needed since field is used to describe the source of the nuclide. Since some of the nuclides in the standards emit more than one gamma ray, each gamma ray is assigned a unique name. This is why there are unusual isotope names like CO-601.

NLE Program Output Example

```
Library Title       : Isotope Products Standard Mixture
Library file name   : SYSSYSDEVICE:[GAMMA]ISOTOPE_PRODUCTS.NLB;1
Date printed        : 13-DEC-1994 15:11:29.09
Number of nuclides  : 13
Number of lines     : 13
```

Nuclide Name	Half-Life	Nuclide Type	Key Line	Energy	Abundance
CR-51	27.70D		*	320.08 keV	9.83 %
SR-85	64.84D		*	514.00 keV	99.27 %
CD-109	1.27Y		*	88.03 keV	3.61 %
SN-113	115.09D		*	391.69 keV	64.00 %
TE-123M	119.70D		*	158.99 keV	84.00 %
CS-137	30.00Y		*	661.66 keV	85.21 %
AM-241	432.70Y		*	59.54 keV	35.70 %
CO-571	271.77D		*	122.06 keV	85.50 %
CO-572	271.77D		*	136.47 keV	10.69 %
CO-601	5.27Y		*	1173.24 keV	99.90 %
CO-602	5.27Y		*	1332.50 keV	99.98 %
Y-881	106.61D		*	898.07 keV	92.70 %
Y-882	106.61D		*	1836.08 keV	99.35 %

Appendix B -- Calibration Check List and Commands

Calibration Check List

1. Set up Detector and be sure it is working properly.
2. Fill in Detector Information Sheet.
3. Count the Standards and Background.
4. Organize the configurations for ease of use. Double check that the sample description data recorded in the configurations are correct. Pay attention to the zero time, detector names, sample weights and the count times. These data affect the calculated activities and description of the results.
5. Do an initial channel - energy calibration. Perform a peak search operation and adjust the peak to channel relationship for each standard.
(CALIB/INIT /Cer=<Certificate File Name> <Configuration File Name>)
6. Do the update Calibration.
(@DO_CALIBRATE_NOEMP <Configuration File Name> <Certificate File Name> <Library File Name>)
7. Inspect the results to insure a reasonable calibration.
8. Copy the configuration to the system disk with the **move** command. Use **pars/screen** to make sure that the geometry name, detector name, configuration title and sample geometry fields are correct. An example of the final file name is 0P-F-FULL-SOIL.CNF. The letters "0P" are the first two letters of the detector name, the "-F" signifies the F steel bean dip can geometry, the "-FULL-" indicates that this is for a full can and "SOIL" is the material in the can.
9. Calculate the balance of the standards in the normal way. (**new_calc.com**) Having the command file ordered with respect to detector and standard number will help a great deal later when having to deal with storing the printouts.
10. Check for obvious inconsistencies such as missing activities, values that are grossly out of line with the rest of the activities or counting errors that are sufficiently different from those associated with the other activities.
11. Tabulate the data and check the accuracy of the activities in each of the standards. Compare the calculated activities with the certificate values. The activities should be within $\pm 5\%$ of the certificate value.
12. Verify that the calculated activity for each isotope is within the desired precision range. This range is typically $\pm 5\%$ of the mean activity.
13. Store the results in binders and in the computer archive.

Calibration Commands

Initial Calibration

The initial calibration is usually performed from the keyboard due to its interactive behavior. The CALIB program asks for the channel numbers of the peaks marked for initial calibration use in the certificate file. This is the form of the command:

CALIB /INIT/CER=<certificate file name> <Detector Name or Configuration Name>

Update Calibration

The update calibration is less interactive. A command procedure is constructed with the following commands:

PEAK /LIST=\$PRINTER/CER= <certificate file name> <Detector Name or Configuration Name>
CALIB/UPDATE/EMPIRICAL/LIST=\$PRINTER/EFF/LIB=<Library Name> <Detector or Configuration Name>
PEAK /LIST=\$PRINTER/CER=<Certificate Name> <Detector Name or Configuration Name>
NID/LIST=\$PRINTER/LIB=<Library Name> <Detector Name or Configuration Name>

The second line controls the actual efficiency calculation. The /empirical switch indicates that the least squares method is being specified. If the spline method is desired, the appropriate switch is /nonempirical

Note that the calculation software uses the DCL operating system symbol capability to store information such as configuration name, certificate file names and library file names. The software reads these symbols and uses the information stored there as the default information for a particular operation. The explicitly supplied information takes precedence over the symbols and in fact over writes the information associated with the symbol. Be aware of this characteristic to avoid incorrect calculations due to the wrong data being used. On the other hand, this feature can simplify the use of sequential operations by allowing a much shortened command structure.

Appendix C -- Detector Installation and Counter Information Sheet

Detector Installation

The first task to accomplish is to set up a new detector and check it for proper operation. Internationally and nationally recognized standard methods are followed to set up the counting systems. (ANSI, 1991; Canberra, 1976; US NIM, 1990) The detector is unpacked from the shipping container and is checked for visible damage that might have occurred in transportation. The detector is placed in a cave and is connected the liquid nitrogen lines. The exhaust tubing directs the nitrogen vapor away from the working areas and locations of the cables. The detector assembly is placed on an acoustic insulating pad to decouple the detector from the floor. A piece of plywood distributes the detector weight evenly over the pad. The detector is then topped off with liquid nitrogen and in the case of HPGe detectors are allowed to cool for at least the amount of time specified by the manufacturer.

Power cables are prepared and tested to see if they are delivering the correct voltages. The five conductor preamp power cables terminate with nine pin female subminiature D connectors (typically, AMP part number 205203-1). These preamp cable connectors have positive 12 volts on pin 4, negative 12 volts on pin 6, positive 24 volts on pin 8 and negative 24 volts on pin 9. Pin 1 is the reference ground pin. Fifty ohm coaxial cable is used to deliver the high voltage. These cables have high voltage connectors (typically Kings part number 1704-1). The cables are tested for continuity and shorts using an ohmmeter and then tested for proper performance by connecting a high voltage power supply to a 1000:1 voltage divider with the it. The signal cable is a 93 Ω coaxial cable of the RG-62 type. The continuity and short tests are performed in the same way as the high voltage cable tests. After determining that the cables operate properly, they are connected to the detector and the support electronics. The time constant control on the spectroscopy amplifier is set to the appropriate setting as indicated on the detector's information sheet. A ^{60}Co point source standard is placed 25 cm from the detector's window and a spectrum is collected. The amplifier's gain controls are adjusted until the centroid of the 1332 keV peak is in channel number 2665. The detector's performance is evaluated with respect to the specifications provided by the manufacturer. The usual specifications are full width at half maximum for the 1332 keV peak, relative efficiency, resolution and peak to Compton ratio. The FWHM is also calculated for the 122 keV peak of ^{57}Co . If the specifications are not met, the support electronics are adjusted to attempt to improve the performance. The counts are repeated. If the specifications are still not met, the detector is sent back to the manufacturer for repair. (Canberra, 1976, ANSI/IEEE, 1986). An arbitrarily chosen calibration standard is counted several times per day for approximately a week to see if there are any other problems such as long term drift in the system. After installation, the electronic configuration portion of the Counter Information Sheet is completed. See below.

Detector Specifications

After installation and check out but before a detector is placed into service, the appropriate information about it and its supporting electronics is recorded on an information form. This form will be the first page in a file folder that describes the

specific detector system. The folder also contains other documents that describe or refer to that detector. This includes items such as instruction books, specification sheets, calibration reports and the like.

There is also a place to record the dates of calibration for various geometries. Each geometries are given a letter designation. The following table describes the material and dimensions of these geometries.

Geometry Designations		
Designation	Container material	Dimensions
F	steel	8.4 cm diameter x 4.2 cm high
K	aluminum	8.1 cm diameter x 5.1 cm high
S	aluminum	6.0 cm diameter x 3.8 cm high
P	plastic	3.7 cm diameter x 4.4 cm high
C	plastic	2.4 cm diameter x 1.4 cm high

Example Information Sheet

Detector System --

	Manufacturer	Model Number	Serial Number
Detector			
Preamp			
Amplifier			
MUX			
ADC			
HV Power Supply			

MUX Address	
MUX Port Number	

Diode Bias Voltage	
--------------------	--

Date Installed	
Date Put in Service	

	Full Can Date	Half Can Date
F Soils Calibration		
F Vegetation Calibration		
K Soils Calibration		
K Vegetation Calibration		
S Calibration		
P Calibration		
C Calibration		
Other Calibration		
Other Calibration		
Other Calibration		
Other Calibration		
Other Calibration		
Other Calibration		
Other Calibration		

Appendix D -- Supplemental Command Procedures and Programs

MAKE_INFO.COM

```

options /g_floating/extend_source
program make_info

c
c      A program to generate a command file to make listing files
c
c      The page numbers refer to VAX/VMS Spectroscopy Applications
c      Package Programmer's Guide, ND# 07-0225, April 1990

c      Jim Brunk
c      Started:   16-Sep-1993
c      Last edit: 17-Sep-1993

implicit integer*4 (a-z)

character*64
1      name,                      ! Configuration name
2      directory                  ! Directory Name

open(1,file='dir.dir',defaultfile='.dir',status='old',      ! Open it
1      access='sequential',form='formatted',
2      recordtype='variable',carriagecontrol='list',
3      dispose='keep')

open(2,file='info.com',defaultfile='.com',status='new',      ! Open it
1      access='sequential',form='formatted',
2      recordtype='variable',carriagecontrol='list',
3      dispose='keep')

write(2,2001)

51      read(1,101,end=2000)name
      if(index(name,'Directory ').gt.0) then
          directory=name(index(name,' '):len(name))
      else
          semi=index(name,';')
          if (semi.eq.0) goto 51
          write(2,201)directory(:index(directory,']')), name(:index(name,' '))
      endif
      goto 51

c
c      That's all!
c
2000      close(1)
          write(2,203)directory(:index(directory,']')),directory(:index(directory,']'))
          close(2)
          call exit

c      Formats

101      format(a64)
2001      format('$!set verify')
201      format('$assign ',a,a,' work'
1          /'$run what_is_it')
203      format('$copy/concat ',a,'*.inf info.all'
1          /'$delete ',a,'*.inf;*'
1          /'$exit')
end

```


INFOREC.FOR

```
Snottruncate
  program InfoRec

c   By Jim Brunk
c   Started : 14 Dec 1993
c   Last edit: 21 Jul 1994

c   Modifications:
c   21 July 1994 - Added T-tube support

c   InfoRec expects to find the Geometry in col 1
c                       Sample Name in Col 2
c                       Spec ID in Col 18
c                       Detector in Col 25
c   of file INFO.IN ...
c   The code produces:
c   INFO.COM - a DCL command file that does the calculations
c   and
c   PEAK.PK2 - a DCL command file that prints out the peak shaping.

      character*1 Geometry
      character*2 usercode, detector
      character*6 specid
      character*13 library
      character*15 Sample_Name

      open(1,file='Info.in')
      open(2,file='Info.com')
      open(3,file='peak.pk2')

      write(*,201)
      read(*,202)usercode

100   read(1,101,end=9999)geometry,sample_name,Specid,detector
      library='-full-Potato'

      if(index(sample_name,'spr').gt.0) library='-full-Soil'
      if(index(sample_name,'SPR').gt.0) library='-full-Soil'

      if(index(sample_name,'ssr').gt.0) library='-full-Soil'
      if(index(sample_name,'SSR').gt.0) library='-full-Soil'

      if(index(sample_name,'pfa').gt.0) library='-full-Coconut'
      if(index(sample_name,'PFA').gt.0) library='-full-Coconut'

      if(index(sample_name,'pfd').gt.0) library='-full-Coconut'
      if(index(sample_name,'PFD').gt.0) library='-full-Coconut'

      if(Geometry.eq.'T') library='-3g-amp'
      if(Geometry.eq.'t') library='-3g-amp'

      write(2,102)usercode,
1         usercode,
1         specid,
1         detector,
1         detector,
1         geometry,
1         library
      write(3,103)usercode,
1         usercode,
1         specid
      goto 100
9999  close(1)
      write(2,199)
      close(2)
      write(3,199)
      close(3)
      stop
101   format(a1,a15,t18,a6,t25,a2)
```

```

102  format('$@new_calc disk$data:[gamma.',a2,
      1      ']',a2,
      1      ' ',a6,
      1      ' etakalpha ',a2,
      1      ' _background ',a2,
      1      ' ',a1,
      1      ' ',a13)
103  format('$peak/start=40/list=$printer disk$data:[gamma.',a2,
      1      ']',a2,
      1      ' ',a6)
199  format('$exit')
201  format(1x,'Enter the User code. ',%)
202  format(a2)
      end

```

DO_CALIBRATE.COM

```
$ ! Calibration command file
$ ! by Jim Brunk  2 Feb 1993
$ ! Last edit    8 Sep 1992
$ !
$ ! does a complete calibration
$ ! p1 is the detector configuration
$ ! p2 is the certificate file
$ ! p3 is the library file
$ !
$ if p1 .eqs. "" then inquire p1 "Enter the Detector name"      ! Get the name
$ if p2 .eqs. "" then inquire p2 "Enter the Certificate file name" ! get the name
$ if p3 .eqs. "" then inquire p3 "Enter the Library file name"  ! Get the name
$ !
$ ! calibrate/initial 'p1'                                     ! do an initial calibration
$ peak/list=$printer 'p1'                                     ! print out the data for inspection
$ calibrate/update/efficiency/list=$printer/empirical/certificate='p2'/new ! Do an update
calibration
$ efficiency/plot/log/long/list=$printer                      ! Look at the plot
$ nid/report=all/list=$printer/library='p3'/clear             ! Do a calculation
$ exit                                                         ! Bye Bye
```

DO_CALIBRATE_NOEMP.COM

```
$ ! Calibration command file
$ ! by Jim Brunk  2 Feb 1993
$ ! Last edit    16 Nov 1995
$!
$!      16 Nov 1995    Changed $printer to tta2: (laser que) jb
$ !
$ ! does a complete calibration
$ ! p1 is the detector configuration
$ ! p2 is the certificate file
$ ! p3 is the library file
$ !
$ if p1 .eqs. "" then inquire p1 "Enter the Detector name"          ! Get the name
$ if p2 .eqs. "" then inquire p2 "Enter the Certificate file name"    ! get the name
$ if p3 .eqs. "" then inquire p3 "Enter the Library file name"      ! Get the name
$ !
$ ! calibrate/initial 'p1                      ! do an initial calibration
$ peak/list=tta2: 'p1'                      ! print out the data for inspection
$ calibrate/update/efficiency/list=tta2:/noempirical/certificate='p2'/new ! Do an update
calibration
$ efficiency/plot/log/long/list=tta2:                      ! Look at the plot
$ nid/report=all/list=tta2:/library='p3'/clear            ! Do a calculation
$ exit                                                    ! Bye Bye
```

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="dpm" activmult=2.22e6 ! 2.22e6 dpm/uCi
$! call do_it 'p1' 'p2' 'p3' 'p4' dpm
$!
$! pars 'p1' activunits="pCi" activmult=1e6 ! 1e6 pCi/uCi
$! call do_it 'p1' 'p2' 'p3' 'p4' pci
$!
$! pars 'p1' activunits="Bq" activmult=37000 ! 37000 Bq/uCi
$! call do_it 'p1' 'p2' 'p3' 'p4' bq
$! report 'p1' ! Print out the rest of the reports
$! /nid=unknowns -
$! /header=bq -
$! /list=tta2:
$! write sys$output "Printing the rest of the reports for 'p1'"
$ 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
$!set veri !
$ 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
```

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 endlist      ! Exit the Loop
$   goto detector_loop
$
$ endlist:
$   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

```


Appendix E -- Results an Initial Calibration

The peak search printout has the following header items:

Configuration	This is the name of the configuration.
Analyses by	This is the list of programs that have acted on this configuration. The version numbers are also indicated.
Sample title	This is the field for the Spectrum ID number assigned by the computer as the spectrum is dumped to a disk file. While the spectrum is in being acquired, the entry is: Not_Finished!
Sample date	This is the reference zero date and time of the sample.
Acquisition date	This is the date and time that the data collection was started.
Sample ID	This field contains the sample identifier.
Sample quantity	The quantity and units of the samples are in this field.
Sample type	An indication of the category of the sample is placed here. This field is primarily used to indicate spectra from standards and backgrounds.
Sample geometry	This field contains the letter that represents the container that the sample is in. Appendix C has a table listing these letters.
Elapsed live time	The amount of live time that the spectrum counted. Live time is the amount of time that the electronics are able to process counts.
Elapsed real time	The amount of time that the sample counted. The percentage dead time is also indicated on this line.
Start energy	The energy of the first channel processed. This setting can be modified by adding a processing flag on the program execution line.
End energy	The energy of the last channel processed. This setting can be modified by adding a processing flag on the program execution line.
Sensitivity	This parameter is roughly the minimum number of standard deviations above the average background that a background subtracted peak must be in order to be accepted as a peak. (Canberra, 1990)
Gaussian	This field contains the number that determines how close to a Gaussian curve a peak must be. If the deviation exceeds this percentage, the peak is flagged as a multiplet.
Critical level	This field indicates if the critical level test is in effect. This test specifies that a peak will be rejected if the area is smaller than 2.33 times the square root of the background.
The following items are the header labels on the listing portion of the print out.	
Pk	The number of the peak assigned by the program.
It	The number iterations performed to resolve the particular peak.
Energy	The energy of the centroid of the peak.

Area The area under the peak with the background and compton subtracted.

Bkgnd The amount of compton and background below the peak.

FWHM The full width at half maximum of the peak. This is an indication of peak shape.

Channel This is the channel that the peak centroid is in.

Left This is the left limit channel of the peak.

Pw This is how wide the peak is in channels.

Cts/Sec This is the peak area divided by the live time.

%Err This is the percentage error in the area.

Fit This is the reduced chi-square if a Gaussian fit was performed.

Example of the Output From a Peak Search

VAX/VMS Peak Search Report V1.8 Generated 2-FEB-1993 14:38:03

Configuration : MCA0:[GAMMA]6H93A07S1
 Analyses by : PEAK V16.1
 Sample title : Not_Finished!
 Sample date : 1-FEB-1993 00:00:00 Acquisition date : 2-FEB-1993 12:44:40
 Sample ID : P-414-45-HALF Sample quantity : 1.0000 SAMPLE
 Sample type : STANDARD Sample geometry : P
 Elapsed live time: 0 01:15:03.00 Elapsed real time: 0 01:50:56.00 32%
 Start energy : 2.80 keV End energy : 2040.31 keV
 Sensitivity : 5.00 Gaussian : 10.00
 Critical level : No

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	7	12.05	261742	63357	1.80	19.60	15	32	5.81E+01	0.4	2.09E+03
2	7	14.13	324187	261217	3.28	23.77	15	32	7.20E+01	0.5	
3	7	16.74	131216	360439	2.58	29.01	15	32	2.91E+01	1.2	
4	7	18.58	72868	343792	2.05	32.71	15	32	1.62E+01	1.7	
5	7	20.11	54060	354214	1.89	35.80	15	32	1.20E+01	2.1	
6	7	21.65	40965	399329	1.88	38.88	15	32	9.10E+00	2.8	
7	7	23.35	21431	374317	1.75	42.31	15	32	4.76E+00	4.5	
8	3	49.94	35552	581921	2.41	35.75	89	38	7.90E+00	4.6	5.58E+02
9	3	52.16	31157	572068	2.41	190.22	89	38	6.92E+00	5.3	
10	3	54.59	42421	559515	2.41	105.11	89	38	9.42E+00	3.9	
11	3	59.60	830789	274681	1.32	115.17	89	38	1.84E+02	0.2	
12	0	88.07	627825	501062	1.31	172.40	165	15	1.39E+02	0.3	
13	0	122.07	606913	411150	1.32	240.75	235	13	1.35E+02	0.3	
14	0	136.44	70943	318520	1.31	269.62	265	11	1.58E+01	1.6	
15	0	158.99	753356	523548	1.38	314.96	307	16	1.67E+02	0.2	
16	0	255.06	41486	206205	1.46	508.06	504	10	9.21E+00	2.1	
17	0	320.03	1050118	286895	1.47	638.66	632	15	2.33E+02	0.1	
18	0	368.56	1105	61364	1.27	736.21	734	5	2.45E-01	33.8	
19	0	391.66	845854	200574	1.52	782.63	776	16	1.88E+02	0.2	
20	0	513.95	1223935	188737	1.58	1028.43	1020	17	2.72E+02	0.1	
21	0	661.63	611640	172213	1.67	1325.26	1316	18	1.36E+02	0.2	
22	0	814.02	20213	56952	1.74	1631.55	1626	12	4.49E+00	2.5	
23	0	898.08	1085392	121708	1.82	1800.50	1792	19	2.41E+02	0.1	
24	0	1173.32	463470	67037	1.99	2353.68	2345	20	1.03E+02	0.2	
25	5	1325.07	22993	41612	3.11	2658.65	2648	46	5.11E+00	2.3	1.35E+02
26	5	1332.51	406909	29865	2.08	2673.62	2648	46	9.04E+01	0.2	
27	0	1836.04	610796	29414	2.32	3685.52	3673	26	1.36E+02	0.1	

Appendix F -- Results of an Update Calibration

The peak search printout has the following header items:

Configuration	This is the name of the configuration.
Analyses by	This is the list of programs that have acted on this configuration. The version numbers are also indicated.
Detector Name	This is the designator of the detector the sample was counted on.
Energy Calib Time	This is the date and time that the energy calibration used for the calculation was performed.
Efficiency type	This field indicates the type of calibration. The two possible types are empirical or non-empirical.
Effncy Calib Time	This is the date and time that the efficiency calibration used for the calculation was performed
Detector Geometry	This field describes the calibration in abbreviated notation.
Shelf	This field is not used. Its purpose is to indicate the distance the sample is with respect to the detector window.

The *Energy Calibration Report* section contains the following:

An equation describing the energy - channel relationship.

Nbr	The number of the standard peak.
Centroid Channel	The channel that the centroid of the peak resides in.
True Energy	The energy of the peak centroid as indicated in the certificate file
Computed Energy	The energy the program computed from the calculated equation.
Difference	The result from subtracting the computed energy from the certificate energy.

The *Efficiency Calibration Report* portion of the report contains:

The equation that describes the efficiency curve, if an empirical calibration is being calculated, followed by the calculated coefficients.

Average Deviation = This is a measure of uncertainty in the calculated fit.

Reduced Chi-Square = This is a measure of uncertainty in the calculated fit.

The following items are reported for each peak described in the certificate file.

Nbr	This is the number of the Standard peak.
Energy	This is the energy measured in keV of the peak as recorded in the certificate file.
Measured Efficiency	This is the efficiency for the particular peak calculated from the spectra.
Efficiency Error	This is the calculated error in the efficiency.

Computed Efficiency This is the efficiency for the particular peak calculated from the fit.

Diff/ Error This is the measured efficiency subtracted from the calculated efficiency and then divided by the efficiency error.

% Diff The is the percentage difference between the measured efficiency and the calculated efficiency.

Typical Calibration Report

VAX/VMS Calibration Report V1.3 Generated 2-FEB-1993 14:38:57

Configuration : MCAO:[GAMMA]6H93A07S1
 Analyses by : CALIBRATE V1.5,PEAK V16.1
 Detector Name : Energy Calib Time: 2-FEB-1993 14:38:56
 Efficiency type : Empirical Effncy Calib Time: 2-FEB-1993 14:38:56
 Detector Geometry: Shelf :

Energy Calibration Report

$$\text{Energy} = 2.304 + 0.4975 \cdot \text{Channel} + 1.9454\text{E-}08 \cdot (\text{Channel}^2)$$

Nbr	Centroid Channel	True Energy	Computed Energy	Difference
1	115.17	59.54	59.60	-0.063
2	172.40	88.03	88.07	-0.034
3	240.75	122.06	122.07	-0.013
4	269.62	136.47	136.44	0.035
5	314.96	158.99	158.99	-0.002
6	638.66	320.08	320.03	0.049
7	782.63	391.69	391.66	0.029
8	1028.43	514.00	513.95	0.048
9	1325.26	661.66	661.63	0.030
10	1800.50	898.07	898.08	-0.017
11	2353.68	1173.24	1173.32	-0.084
12	2673.62	1332.50	1332.52	-0.014
13	3685.52	1836.08	1836.04	0.036

FWHM Calibration Report

$$\text{FWHM} = 0.9950 + 2.8934\text{E-}02 \cdot (\text{Energy}^{1/2})$$

Nbr	Energy	True FWHM	Computed FWHM	Difference
1	59.54	1.32	1.22	0.101
2	88.03	1.31	1.27	0.043
3	122.06	1.32	1.31	0.006
4	136.47	1.31	1.33	-0.023
5	158.99	1.38	1.36	0.019
6	320.08	1.47	1.51	-0.045
7	391.69	1.52	1.57	-0.051
8	514.00	1.58	1.65	-0.067
9	661.66	1.67	1.74	-0.065
10	898.07	1.82	1.86	-0.037
11	1173.24	1.99	1.99	0.009
12	1332.50	2.08	2.05	0.024
13	1836.08	2.32	2.23	0.087

Efficiency Calibration Report

Eff = exp(a2 + a3*x + a4*x**2 + a5*x**3 + a6*x**4 + a7*x**5), x=ln(a1/energy)

a1	a2	a3	a4	a5	a6	a7
947.8	-4.808	0.9499	0.1012	5.4950E-02	-5.7214E-02	0.0000E+00

Average Deviation = 2.15 % Reduced Chi-Square = 1.34

Nbr	Energy (keV)	Measured Efficiency	Efficiency Error	Computed Efficiency	Diff/ Error	% Diff
1	59.54	2.72E-02	5.45E-04	2.74E-02	-0.47	-0.93

Efficiency Calibration Report (continued)

Page : 2

Sample ID : P-414-45-HALF

Acquisition date : 2-FEB-1993 12:44:40

Nbr	Energy (keV)	Measured Efficiency	Efficiency Error	Computed Efficiency	Diff/ Error	% Diff
2	88.03	4.93E-02	1.53E-03	4.66E-02	1.75	5.46
3	122.06	5.17E-02	1.56E-03	5.12E-02	0.32	0.98
4	136.47	4.83E-02	1.64E-03	5.01E-02	-1.08	-3.65
5	158.99	4.60E-02	1.39E-03	4.70E-02	-0.67	-2.01
6	320.08	2.50E-02	7.75E-04	2.56E-02	-0.75	-2.31
7	391.69	2.06E-02	6.41E-04	2.05E-02	0.20	0.62
8	514.00	1.53E-02	4.58E-04	1.52E-02	0.07	0.22
9	661.66	1.22E-02	3.67E-04	1.17E-02	1.50	4.53
10	898.07	8.73E-03	2.80E-04	8.59E-03	0.50	1.59
11	1173.24	6.67E-03	1.14E-04	6.69E-03	-0.23	-0.39
12	1332.50	5.85E-03	1.00E-04	5.96E-03	-1.11	-1.90
13	1836.08	4.59E-03	1.47E-04	4.43E-03	1.04	3.34

Approved by: _____

Approval Date: __ / __ / __

Appendix G -- Data Handling Codes and Databases

FORTRAN Code To Convert The Data File To A One Line Format

```

$nottruncate
  program std_fix

c      started:   16 Aug 1993
c      last edit: 14 Dec 1994
c      by   Jim Brunk
c      14 Dec 94  added multiple lines, rearrange energy order

  character*16 isotope, units, id, detector, geometry, date
  character*20 infile, outfile
  character*64 spec_id
  character*200 line

  integer*2 dot, space
  integer*4 status

  real*4 answer      ,error,
1      AM_241_answer ,AM_241_pct_err,
1      CD_109_answer ,CD_109_pct_err,
1      CO_571_answer ,CO_571_pct_err,
1      CO_572_answer ,CO_572_pct_err,
1      TE_123M_answer,TE_123M_pct_err,
1      CR_51_answer  ,CR_51_pct_err,
1      SN_113_answer ,SN_113_pct_err,
1      SR_85_answer  ,SR_85_pct_err,
1      CS_137_answer ,CS_137_pct_err,
1      Y_881_answer  ,Y_881_pct_err,
1      CO_601_answer ,CO_601_pct_err,
1      CO_602_answer ,CO_602_pct_err,
1      Y_882_answer  ,Y_882_pct_err

  numarg=nargs()
  if (numarg.gt.1) then
    call getarg(1,infile,status)
  else
    write(*,11)
    read(*,21)infile
  endif

  dot=index(infile, '.')
  if (dot.gt.0) then
    outfile=infile(1:dot)//'fix'
  else
    outfile=infile//'fix'
  endif

  open(27,file=infile)
  open(28,file=outfile)

1  read(27,12,end=999)isotope,
1      answer,
1      error

  backspace(27)
  read(27,13)line

  line(:)=line(44:)
  space=index(line, ' ')
  units=line(:space-1)

  line(:)=line(space+1:)
  space=index(line, ' ')
  id=line(:space-1)

  line(:)=line(space+1:)
  space=index(line, ' ')
  spec_id=line(:space-1)

```

```

line(:)=line(space+1:)
space=index(line,' ')
detector=line(:space-1)

line(:)=line(space+1:)
space=index(line,' ')
geometry=line(:space-1)

line(:)=line(space+1:)
space=index(line,' ')
date=line(:space-1)

if(isotope(1:len_trim(isotope)).eq.'CR-51') then
    cr_51_answer=answer
    cr_51_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'CO-571') then
    co_571_answer=answer
    co_571_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'CO-572') then
    co_572_answer=answer
    co_572_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'CO-601') then
    co_601_answer=answer
    co_601_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'CO-602') then
    co_602_answer=answer
    co_602_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'SR-85') then
    sr_85_answer=answer
    sr_85_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'Y-881') then
    y_881_answer=answer
    y_881_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'Y-882') then
    y_882_answer=answer
    y_882_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'CD-109') then
    cd_109_answer=answer
    cd_109_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'SN-113') then
    sn_113_answer=answer
    sn_113_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'TE-123M') then
    te_123m_answer=answer
    te_123m_pct_err=(error/answer)*100.
endif

if(isotope(1:len_trim(isotope)).eq.'CS-137') then
    cs_137_answer=answer
    cs_137_pct_err=(error/answer)*100.
endif

```

```

        if(isotope(1:len_trim(isotope)).eq.'AM-241') then
            am_241_answer=answer
            am_241_pct_err=(error/answer)*100.
        endif

        goto 1

999    write(28,22)id, spec_id, units, geometry, date, detector,
1      AM_241_answer ,AM_241_pct_err,
1      CD_109_answer ,CD_109_pct_err,
1      CO_571_answer ,CO_571_pct_err,
1      CO_572_answer ,CO_572_pct_err,
1      TE_123M_answer ,TE_123M_pct_err,
1      CR_51_answer  ,CR_51_pct_err,
1      SN_113_answer ,SN_113_pct_err,
1      SR_85_answer  ,SR_85_pct_err,
1      CS_137_answer ,CS_137_pct_err,
1      Y_881_answer  ,Y_881_pct_err,
1      CO_601_answer ,CO_601_pct_err,
1      CO_602_answer ,CO_602_pct_err,
1      Y_882_answer  ,Y_882_pct_err

        close(27)
        close(28)
        stop
11     format(1x,'Enter the input file name ==> ',%)
12     format(a16 ,1x,
1         e12.4,1x,
1         e12.4,1x)
13     format(a200)
21     format(a20)
22     format(1x,a16,1x,a64,1x,a16,1x,a16,1x,a16,1x,a16,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x,
1         e13.5,1x,e13.5,1x)
        end
end

```

dBase Data Base Structure Used To Store The Standards Data

Structure for database: H:\B379\STDS\FSOIL\FSOIL.DBF

Number of data records: 434

Date of last update : 12/14/94

Field	Field Name	Type	Width	Dec	Index
1	ID	Character	16		N
2	SPEC_ID	Character	10		N
3	UNITS	Character	16		N
4	GEOMETRY	Character	16		N
5	DATE	Date	8		N
6	DETECTOR	Character	16		N
7	AM_241	Float	13	5	N
8	AM_241_ERR	Float	13	5	N
9	CD_109	Float	13	5	N
10	CD_109_ERR	Float	13	5	N
11	CO_571	Float	13	5	N
12	CO_571_ERR	Float	13	5	N
13	CO_572	Float	13	5	N
14	CO_572_ERR	Float	13	5	N
15	TE_123M	Float	13	5	N
16	TE_123M_ER	Float	13	5	N
17	CR_51	Float	13	5	N
18	CR_51_ERR	Float	13	5	N
19	SN_113	Float	13	5	N
20	SN_113_ERR	Float	13	5	N
21	SR_85	Float	13	5	N
22	SR_85_ERR	Float	13	5	N
23	CS_137	Float	13	5	N
24	CS_137_ERR	Float	13	5	N
25	Y_881	Float	13	5	N
26	Y_881_ERR	Float	13	5	N
27	CO_601	Float	13	5	N
28	CO_601_ERR	Float	13	5	N
29	CO_602	Float	13	5	N
30	CO_602_ERR	Float	13	5	N
31	Y_882	Float	13	5	N
32	Y_882_ERR	Float	13	5	N
** Total **			421		