Standard Operating Procedure for Gamma Spectroscopy Using the Canberra Genie 2000 Gamma Spectroscopy Counting System with Apex Software

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1.0 Identification of Test Method

1.1 The procedure described in this SOP has been developed by the LDEQ Environmental Radiation Laboratory in accordance with the requirements of the Louisiana Department of Environmental Quality. This SOP describes in detail the essential elements of the procedure for performing Gamma Spectroscopy analysis using the Canberra Genie 2000 Gamma Spectroscopy system with Apex software.

2.0 Applicable Matrices

2.1 This SOP is applicable to the following matrices: Air (Charcoal Cartridges, Air Particulate Filters), Fish, Milk (Whole Milk, Iodine Resin), NORM samples, Sediment, Vegetation, and Water.

3.0 Detection and Quantitation Limits

3.1 The Apex software calculates the Minimum Detectable Activity (MDA) for all radionuclides in the nuclide library. The calculation is based on the level of background radiation or noise in the region of interest where the characteristic peaks of the nuclide would be expected to appear. MDAs are calculated using the Currie algorithm, which is described more fully in the Genie 2000 Customization Tools Manual, Chapter 3, “Genie Algorithms,” pp 324-342. For nuclides that have been identified, the MDA is calculated using the calculated continuum under each peak that has been found and using the counts in the spectrum for each peak that has not been found. For nuclides that have not been identified, the MDA is calculated by summing the counts over an interval centered on the characteristic location of each of the nuclide’s lines. There is an inverse relationship between the MDA and the length of time for the count. A longer count gives a lower MDA. The MDAs of all nuclides of interest are listed on the instrument printout for each sample run.

3.2 The Limit of Quantitation (LOQ, reporting limit) for the nuclides of interest in each matrix are given Table 1 below. For samples whose activity is at or below the LOQ, the MDA is entered in the LIMS with the prefix “MDA” as the primary result.

Limits of Quantitation							
Matrix (Units)	**Air pCi/m^3**	**Fish pCi/kg**	**Milk pCi/L**	**Sediment pCi/kg**	**Vegetation pCi/Kg**	**Water pCi/L**	**NORM pCi/g**
Mn-54		**130**				**15**	
Co-58		**130**				**15**	
Fe-59		**260**				**30**	
Co-60		**130**				**15**	
Zn-65		**260**				**30**	
Nb-95						**15**	
Zr-95						**30**	

Limits of Quantitation							
Matrix (Units)	Air pCi/m^3	Fish pCi/kg	Milk pCi/L	Sediment pCi/kg	Vegetation pCi/Kg	Water pCi/L	NORM pCi/g
I-131	7.0E-02		1		60	2	
Cs-134	5.0E-02	130	15	150	60	15	
Cs-137	6.0E-02	150	18	180	80	18	
Ba-140			60			60	
La-140			15			15	
Ra-226							5

Table 1

4.0 Scope and Application

4.1 This SOP describes in detail the essential elements of the procedure for performing Gamma Spectroscopy analysis using the Canberra Genie 2000 Gamma Spectroscopy system by the LDEQ Laboratory.

5.0 Summary of Method

5.1 Gamma emissions are counted using the Canberra Genie 2000 Gamma Spectroscopy system. A sample is placed on a detector inside a lead shield, and emissions are counted for a specified length of time. The Apex software assigns the counts to channels according to the energy of the emissions, and produces a spectrum. Radionuclides are identified by the characteristic energies of their emissions, by reference to nuclide libraries supplied by the instrument manufacturer. The nuclide library used for characterization of samples is designated as “Library1.” The nuclide library used for standards calibration checks is designated as “Library5.” The nuclide libraries are listed in Appendix D.

5.2 The activity of samples is calculated based on energy and efficiency calibrations of the detectors to known standards.

5.3 The Apex software has been set up to calculate the Minimum Detectable Activity for selected isotopes based on the level of background noise in the region of the spectrum where the characteristic peaks the isotope would be expected to appear. In cases where the activity of a radionuclide of interest is statistically indistinguishable from the background noise, the MDA is entered into the LIMS system.

5.4 Environmental radiological samples are analyzed for 2000 to 60,000 second counts, depending on the desired MDA. NORM samples are analyzed for 2,000 second counts.

6.0 Definition of Terms

6.1 Activity – a measure of the number of emissions produced by a radioactive nuclide.

6.2 Duplicate Measurement – A second measurement made on the same (or identical) sample of material to assist in the evaluation of measurement variance.

6.3 ERL – LDEQ Environmental Radiation Laboratory

6.4 FWHM – Full-Width Half-Maximum, a measurement of the detector resolution.

6.5 Iodine Resin – Anion-Selective Dowex 1-X8 Ion Exchange Resin, used to extract iodide ion from milk samples. See ERL SOP 1023,

6.6 keV – Kilo electron-Volts, the symbol for one thousand electron-volts

6.7 Minimum Detectable Activity (MDA) – The minimum level of activity that can be measured (counted) with a defined level of confidence that the measurement is not the result of random fluctuations in the background count (i.e. “noise”).

6.7.1 The DEQ Environmental Radiation Laboratory defines the level of confidence for the MDA at 95%. This means that for an observed sample count that appears to indicate that the sample activity is equal to the MDA, there is only a 5% probability that the sample might actually be free of activity.

6.7.2 The MDA is also referred to as the **detection limit** or **lower limit of detection**. The counting rate from a sample at the MDA is called the **determination level.**

6.8 NORM – is an acronym for Naturally Occurring Radioactive Materials. It is associated with oil and gas exploration and refining processes.

6.9 See QA Manual, Appendix B for additional definitions.

7.0 Interferences and Pretreatments

7.1 Refer to current official copy of LDEQ Sop_1023 for sample preparation.

8.0 Safety

8.1 Laboratory personnel shall be trained in radiation safety procedures.

8.2 Always wear a lab coat and safety glasses, goggles or lab face shield when working in the lab.

8.3 Caution must be exercised as shield doors are very heavy. Please exercise care as to not cause a back injury opening or closing shields. The door must be opened all the way to allow easy access to the detector. Keep hands completely clear of the shield opening when closing the shield door.

8.4 The Canberra Genie 2000 Gamma Counting System uses Liquid Nitrogen to keep the detectors cold. Refer to the MSDS for the handling of Liquid Nitrogen.

8.5 Material safety data sheets (MSDS) of all chemicals used in this SOP are available at a web site maintained by Cornell University. The link is: http://hazard.com.msds/index.php.

9.0 Equipment and Supplies

9.1 Canberra Genie 2000 Gamma Counting System

9.2 Germanium Gamma Detectors.

9.3 Lead shields

9.4 50-L Dewar for Liquid Nitrogen transfer.

10.0 Reagents and Standards

10.1 All standard information shall be entered into an appropriate logbook. All standards are traceable to the National Institute of Standards and Technology (NIST).

10.2 Gamma Standards are supplied by Analytics, inc. of Atlanta, Georgia and are traceable to the National Institute of Standards and Technology (NIST). Standards are formulated to include the radionuclides listed Table 2 below:

Nuclide	Energy (keV)	Emission Rate (gps)
Co-57	88.034	1063 ± 5%
Co-60	122.061	2502 ± 5%
Co-60	165.853	2507 ± 5%
Y-88	279.196	5069 ± 5%
Y-88	391.688	5367 ± 5%
Cd-109	661.657	2022 ± 5%
Sn-113	898.042	2120 ± 5%
Cs-137	1173.240	1353 ± 5%
Ce-139	1332.500	1510 ± 5%
Hg-203	1836.060	3158 ± 5%

Table 2

10.3 Standard Geometries used are shown Table 3 below:

Standard Geometries		
Geometry Name	**Description**	**Sample Type(s)**
Geometry 01	1.0 L Solid Polyester Resin in 130G GA-MA Beaker	Water, Milk, Fish
Geometry 03	4.0 L Solid Polyester Resin in 430G GA-MA Beaker	Water, Milk
Geometry 04	500 mL Sand in 500-mL Marinelli Beaker	Sediment
Geometry 05	Vermiculite in 430G GA-MA Beaker	Vegetation, Sediment
Geometry 06	Face-Loaded BG-300 Charcoal Cartridge:	Charcoal Cartridge:
Geometry 07	Composite of 13 2-inch Glass Fiber Filters in Sealed Bag.	Air Particulate Filter Composite
Geometry 09	65 mL Solid Polyester Resin in 125 mL Taral Jar	Iodine Resin:
Geometry 10	500 mL Solid Polyester Resin in 500-mL Marinelli Beaker	Water, Fish
Geometry 11	65 mL Solid Polyester resin in 125 mL Taral Jar	Quality Control
Geometry 13	Sieved Griffin Soil in 120-mL Delta Jar.	NORM

Table 3

11.0 Sample Collection, Preservation, Shipment, Storage, and Sample Rejection Policy

11.1 Procedures for sample collection are described in Section 11 of the current official version of LDEQ SOP 1023, “Preparation of Samples for Gamma Spectroscopy and Gross Beta Analysis.”

11.2 Samples received by Laboratory Services Division must be entered into the LIMS. The procedure for logging in samples is described in Appendix A of the current official version of LDEQ SOP 1023, **“**Preparation of Samples for Gamma Spectroscopy and Gross Beta Analysis.”

11.3 In case of samples with incomplete chain of custody, contact the person(s) submitting the sample to obtain the missing information. Document the contact and how the information was obtained in the comment section of the chain of custody form.

11.4 For policy on chain of custody usage, see Section 11.5 of QAM.

12.0 Quality Control

12.1 A quality control program is required for this method. The requirements of this program consist of demonstration of laboratory capability, and the continuing analysis of a NIST-traceable standard of known activity as ongoing demonstration of performance. All Demonstrations of Capability (DOC's) must be documented using the appropriate Certification Statement Form. The analyst shall maintain performance records that define the quality of the data that are generated.

12.2 Demonstration of Capability

12.2.1 The demonstration of capability is performed by analyzing the Quality Control Standard four (4) times in each detector, and obtaining results that satisfy the established QC acceptance criteria. The procedure for analyzing the standard is the same as the Quality Control procedure performed prior to sample analysis. See Section 14.2.

12.3 System Background Count – A monthly System Background count is performed for each detector. The empty shield is counted for 60,000 seconds.

12.4 Pre-Analysis Quality Control Procedures

12.4.1 A full step-by-step description of how the Quality Control Procedures are performed is given in Section 14.3, "Quality Control Procedures."

12.4.2 For each detector, a QA Background Check and a QA Calibration Check shall be performed prior to sample analysis on every day that the detector is used. Acceptance criteria are listed in Appendix E, "Quality Control Limits for Gamma Spectroscopy." All acceptance criteria specified below and in Appendix E must be met before the sample is analyzed.

12.4.3 In the QA Background Check, the empty shield is counted for 1000 seconds, and the total count in picocuries is evaluated for channels in the low region (50-400) and the high region (400-4096) of the spectrum.

12.4.4 In the QA Calibration Check, the Quality Control Standard is counted for 1000 seconds, and the key energy lines and decay-corrected activities for Cd-109, Cs-137, and Co-60 are evaluated. The resolution of the Co-60 peak at 1332.501 keV is also evaluated.

12.4.5 During the QA Calibration Check, the Apex software performs the following statistical tests:

12.4.5.1 N-Sigma Test: Tests whether the values fall within defined confidence interval based on the standard deviation of previous measurements over a three-month period subsequent to the energy and efficiency calibrations for the current set of standards. Because of differences in detector response, the statistical control limits will always be slightly different for each detector. Measurements outside the warning limit (± 2σ) will be flagged with

"In" (Investigate). Measurements outside the action limit (± 3σ) will be flagged with "Ac" (Action).

12.4.5.2 Trend Test: The software evaluates the previous 20 samples tested and prints a warning message if the values appear to be moving persistently upward or downward.

12.4.5.3 When a new set of standards are acquired, the QC acceptance criteria must be recalculated. The number of data points used to calculate the acceptance criteria shall be not less than twenty, nor more than three months of accumulated data. Until a sufficient number of data points have been accumulated from the new standards, the standard deviations from the previous set of standards will be used to calculate control limits for the new standards, with a mean value specified to be the assay value of the standard.

12.4.6 Acceptance criteria for the Quality Control parameters have been established according to the rules. See Table 4:

Rules for Quality Control Acceptance Criteria			
Parameter	Boundary Test	N-Sigma Warning Limit (Investigate)	N-Sigma Action Limit
Peak Energy - 88.034	± 1.0 keV	± 2σ	± 3σ
Peak Energy - 661.657	± 1.0 keV	± 2σ	± 3σ
Peak Energy - 1332.501	± 1.0 keV	± 2σ	± 3σ
Peak FWHM - 1332.501	1.75-2.20	± 2σ	± 3σ
Decay-corrected Activity - Cd-109	± 6% of Assay	± 2σ	± 3σ
Decay-corrected Activity - Cs-137	± 6% of Assay	± 2σ	± 3σ
Decay-corrected Activity - Co-60	± 6% of Assay	± 2σ	± 3σ

Table 4

12.4.7 The following condition indicates a QC failure: An ""Ac" (Action) flag in any of the N-Sigma Tests.

12.4.8 An "In" (Investigate) flag in an N-Sigma test is a warning, but is not considered to be a QC failure. An "In" flag does not preclude the running of a sample, but the analyst must investigate and initiate action to correct the problem.

12.4.9 A warning message in the Trend Test must be investigated, but is not considered to be a QC failure so long as the N-Sigma test is passing.

12.5 Corrective Action

12.5.1 QC failures are an indicator of possible problems with the detector or instrument settings. Actions must be taken to correct any problem(s) before continuing with sample analysis.

12.5.2 Gamma detectors are sensitive to sudden changes in weather and temperature. In most cases, a QC failure is caused by a temporary change in ambient conditions. It is permitted to repeat the QC procedure at a later time to see if the condition that caused the failure has changed, but not more than three times in a 24-hour period. If the failure persists over several days, it may be necessary to recalibrate or service the detector.

12.5.3 Quality Control failures are often caused by not allowing sufficient time after filling the liquid nitrogen Dewars before performing the Quality Control procedure. On days when the Dewars are filled, a minimum of two hours must be allowed to elapse before performing the Quality Control Procedure. **Do not add liquid nitrogen to a Dewar during the time between the QC procedure and the sample analysis**.

12.5.4 Persistent QC failure in peak energy measurement may indicate a drift in the detector response. This may be correctable by performing a new energy calibration, or by adjusting the offset and/or the fine gain for the detector. This procedure should only be performed by an experienced operator or technician. Instructions for the procedure are found in the Apex Operations Manual.

12.5.5 Persistent QC failure in decay-corrected activity may be correctable by performing a new energy or efficiency calibration, as described in Section 13.0.

12.6 Control Charts.

12.6.1 The Apex software keeps a record of all QC measurements, and automatically generates error messages whenever established control limits are exceeded. The software allows the operator to generate a control chart to cover any period of time. Control charts shall be printed for the peak energies, resolution and decay-corrected activities evaluated in the Quality Control Procedure, on a quarterly basis and whenever a persistent sequence of QC failures is observed. The control charts shall be kept in the same binders as the individual Quality Control reports for each detector.

13.0 Calibration

13.1 A new set of calibration reference standards shall be purchased annually. The reference standard shall have the same general characteristics (i.e., geometry, homogeneity, density, etc.) as the associated samples.

13.2 Information on the calibration standards is stored in Certificate Files. There is a separate certificate file for each calibration standard geometry. The certificate

file includes the calibration date and time, and the measured activity and %uncertainty for each radionuclide in the standard. Whenever a new set of calibration standards is received, a new Certificate File must be created for each geometry before the new standards can be used.

13.3 After the new certificate files have been prepared, a Full Energy and Shape Calibration must be performed for each detector, using one of the new standards.

13.4 After the annual Full Energy and Shape Calibration have been performed, an Efficiency Calibration for each geometry and each detector must be performed using the new standards.

13.5 A preliminary evaluation of all Energy and Efficiency Calibrations shall be performed for each detector prior to the first time the detector is used after the calibration. Acceptance criteria for Energy Calibrations are given in Section 16.3. Acceptance criteria for Efficiency Calibrations are given in Section 16.4.

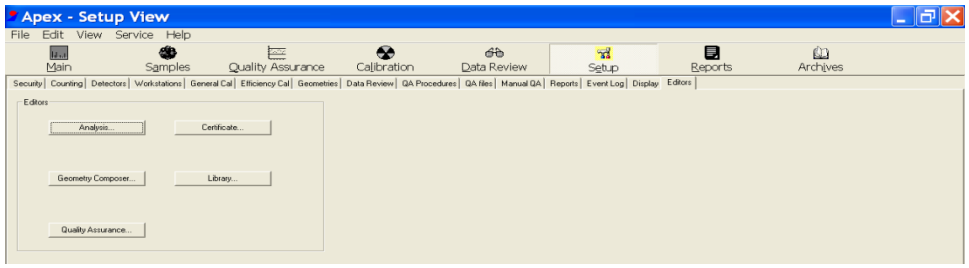
13.6 Instrument Calibration will be verified on each day of use, prior to sample testing, by performing the Quality Control procedure described in Section 12.4 of this SOP.

13.7 Certificate Files

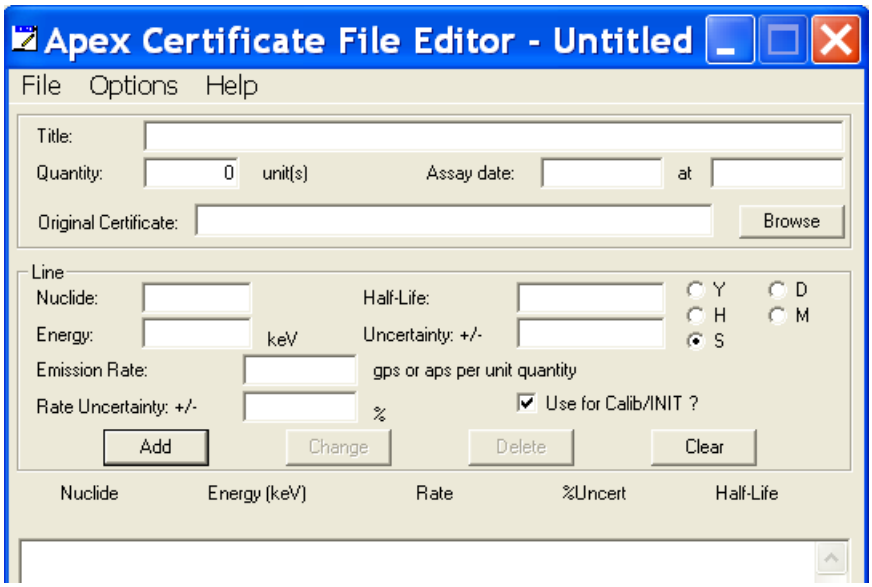
13.7.1 Information on the calibration standards is stored in Certificate Files. There is a separate certificate file for each calibration standard geometry. The certificate file includes the calibration date and time, and the measured activity and %uncertainty for each radionuclide in the standard. Whenever a new set of calibration standards is received, a new Certificate File must be created for each geometry before the new standards can be used. A new certificate file is created by editing the old certificate file for the same geometry and saving with a new file name. The information to be entered is found on the SRS (Standard Reference Source) calibration certificate that comes with the new standard.

13.7.2 The example shows how a new certificate file is created. The example shows Geometry 11 (Quality Control), but the same procedure is performed for each geometry.

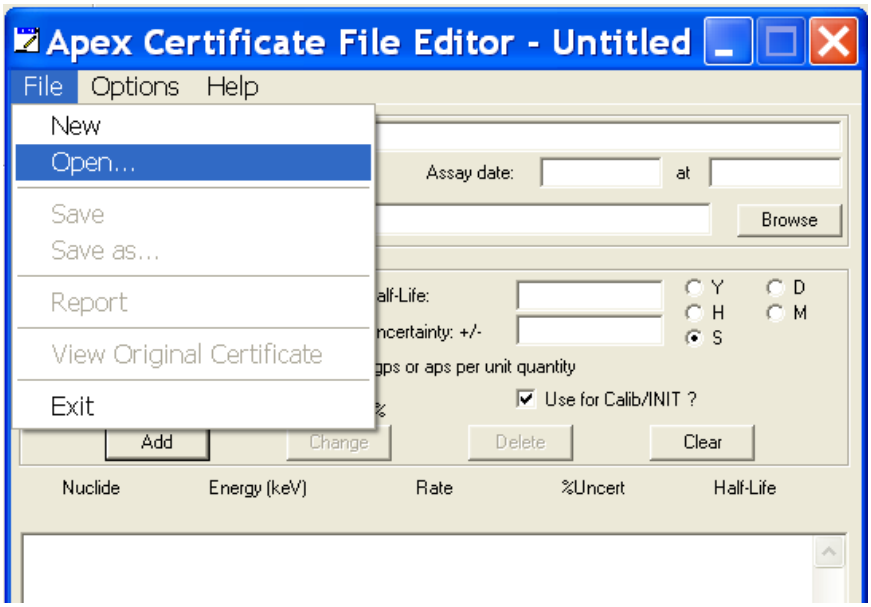
13.7.2.1 In the **Apex – Setup View** screen**,** select the “Editors” tab. Click the “Certificate” button to open the Certificate File Editor.

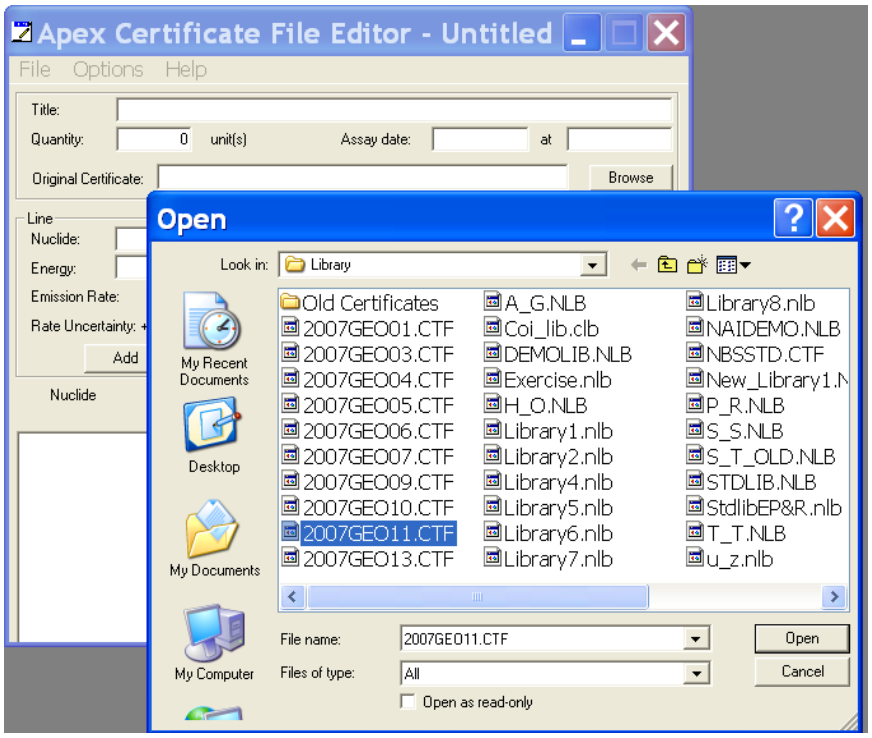


13.7.2.2 The Certificate File Editor screen will open initially with all the fields blank.

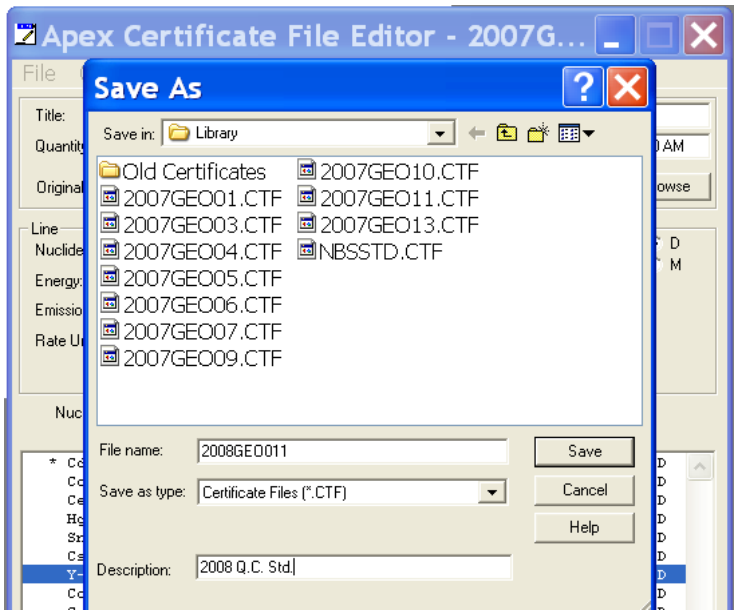


13.7.2.3 Go to **File** and Open the old certificate file for the geometry. The file name will be in the format YYYYGEOnn.CTF where “YYYY” is the current year, and “nn” is a number assigned to the geometry. For example, 2007GEO11.CTF is the name of the certificate file for Geometry 11 (Quality Control) for 2007.

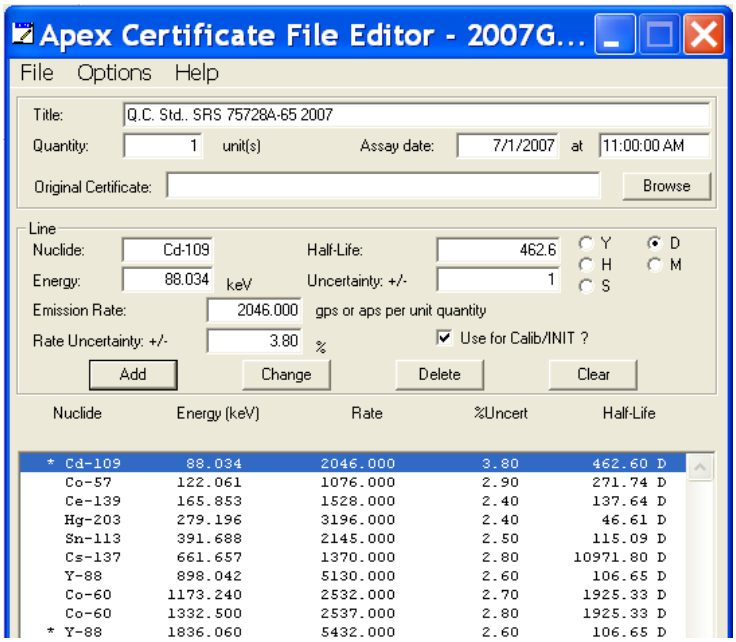




13.7.2.4 When you open the old certificate file, the old certificate data will appear in the fields. Go to **File** and **Save as** current certificate file, changing the year in the filename to the current year.



13.7.2.5 In the **Certificate File Editor** Screen, change the Title, Assay date and time to match the information on the calibration data sheet for the new standard. Make sure that you enter the correct time for the Central Time Zone (E.g., 12:00 PM ET = 11:00 AM CT).



13.7.2.6 Highlight the first nuclide on the list. Enter the Emission Rate (GPS) and Rate Uncertainty from the calibration data sheet into the fields above the list, then click the **Change** button to save the changes made. Repeat this for each nuclide on the list. DO NOT change the energy or half-life.

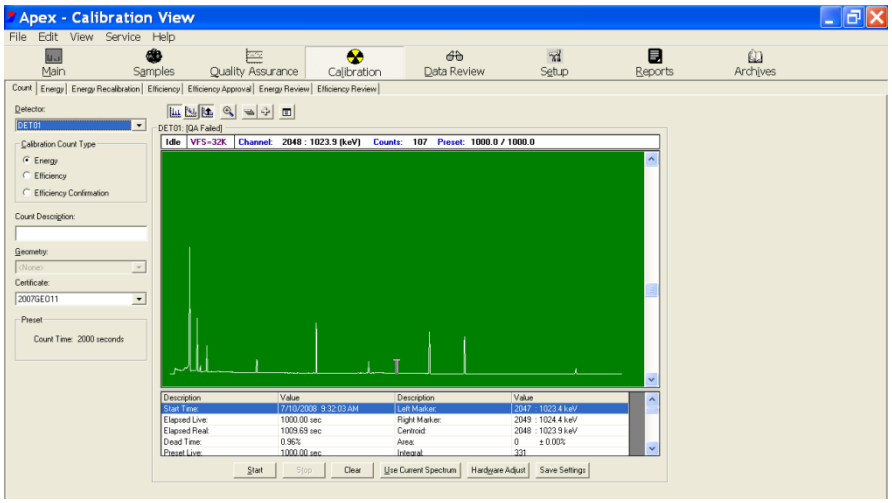
13.7.2.7 After all of the Emission Rates and Uncertainties have been changed to match the certificate for the new standard, **Save** the file and **Exit**.

13.7.3 Count a Calibration Spectrum

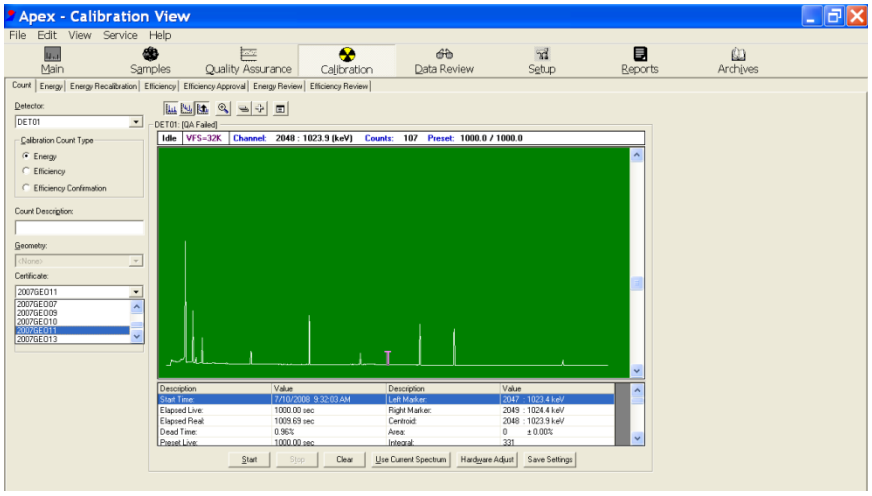
13.7.3.1 Before an energy or efficiency calibration can be performed, a calibration spectrum must be counted. The count time shall be at least 2000 seconds.

13.7.3.2 Put a calibration standard onto a detector. If you are doing an energy calibration, any of the standards can be used. If you are doing an efficiency calibration, use the standard for which you wish to calibrate the efficiency.

13.7.3.3 On the **Apex – Calibration View** screen**,** select the “Count” tab. Select the detector to be used from the pull-down menu. Select the Calibration Count Type. If you have chosen either of the efficiency calibrations, select the geometry that corresponds to the standard being used.



13.7.3.4 Choose a certificate from the pull-down menu that corresponds to the standard being used.



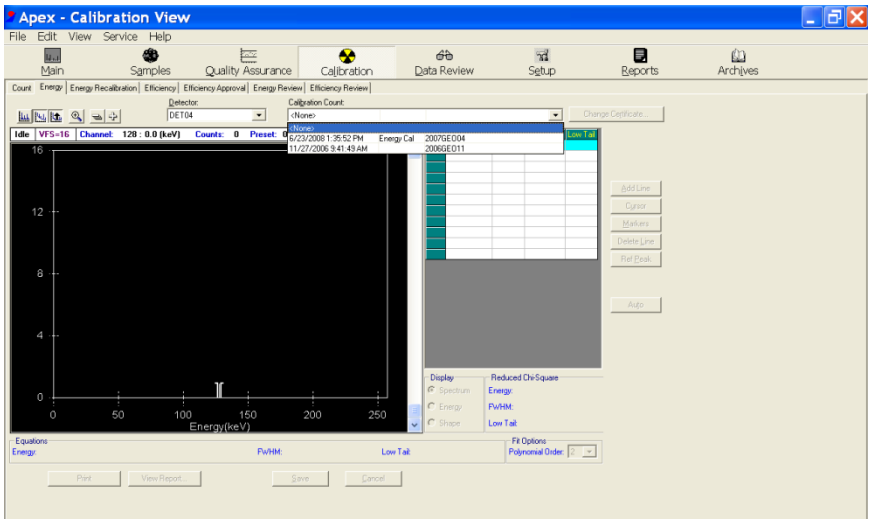
13.7.3.5 Click on the “Clear” button to clear out any existing data

13.7.3.6 Click on the Start button. The count will be performed automatically, and a spectrum will appear in the display window.

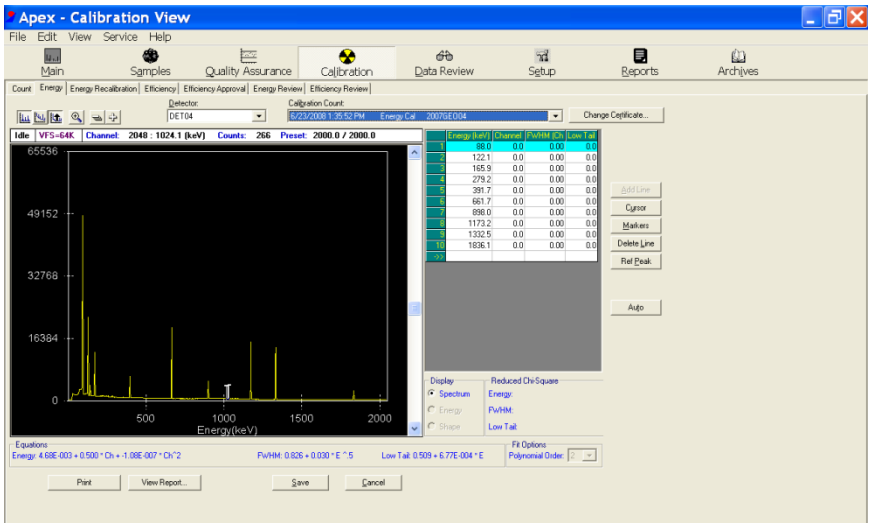
13.7.4 Energy Calibration

13.7.4.1 After the calibration count is complete, perform the following steps.

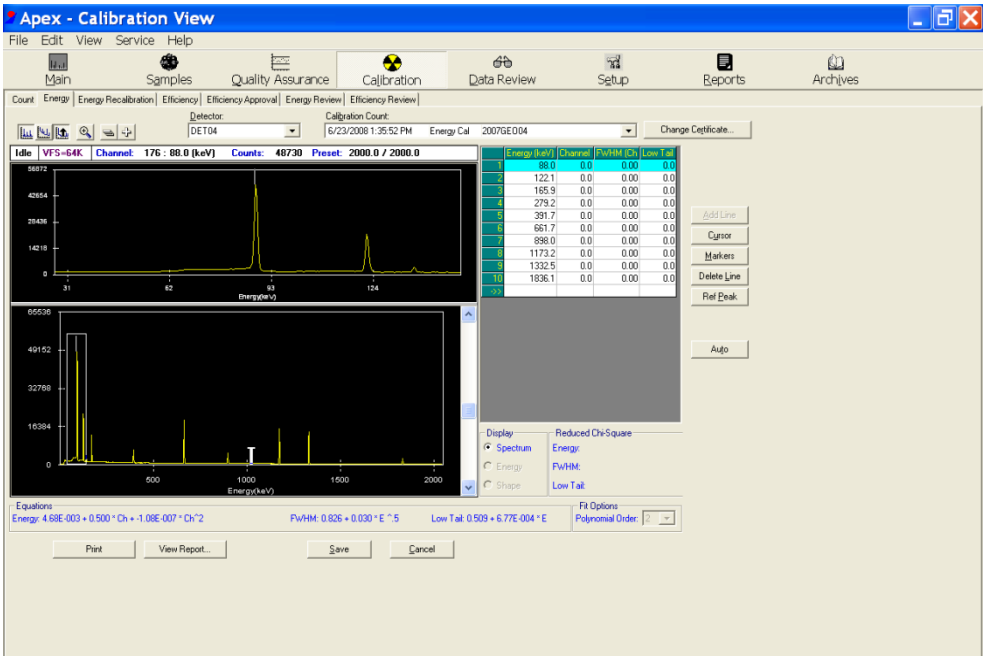
13.7.4.2 On the **Apex – Calibration View** screen**,** select the “Energy” tab. Select the Detector and Calibration Count that you want to create an energy calibration for, using the pull-down menus at the top of the screen.



13.7.4.3 To the right of the spectrum, you’ll see a list of energies with data: channels, FWHM, and Low Tail. This list corresponds to nuclide energies in the Geometry Certificate File. Click the cursor on the list entry for 88.0 keV to highlight the entry.



13.7.4.4 Immediately above the spectrum display is a row of little boxes. One of the boxes has a picture of a magnifying glass with a plus sign (+) in it. Click on that box to activate the “Expand On” function.

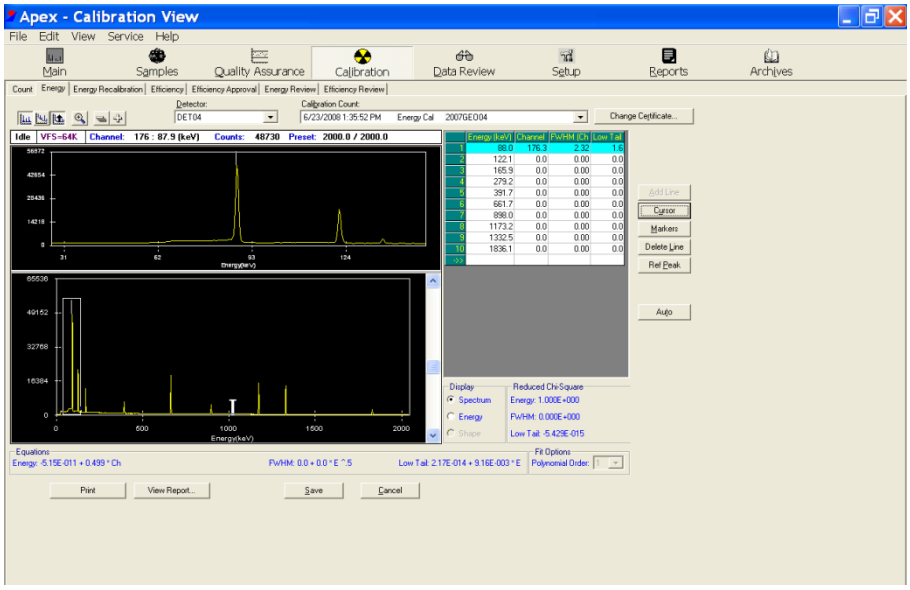


13.7.4.5 The spectrum display will split horizontally into a dual display of the same spectrum. The lower window will show the entire spectrum, with a small box and two channel markers. The small box can be moved along the spectrum to select the region of the spectrum that appears in the upper window. As you use the cursor to drag the small box or move its boundaries, the upper window will show a magnified view of the region of the spectrum that falls inside the box.

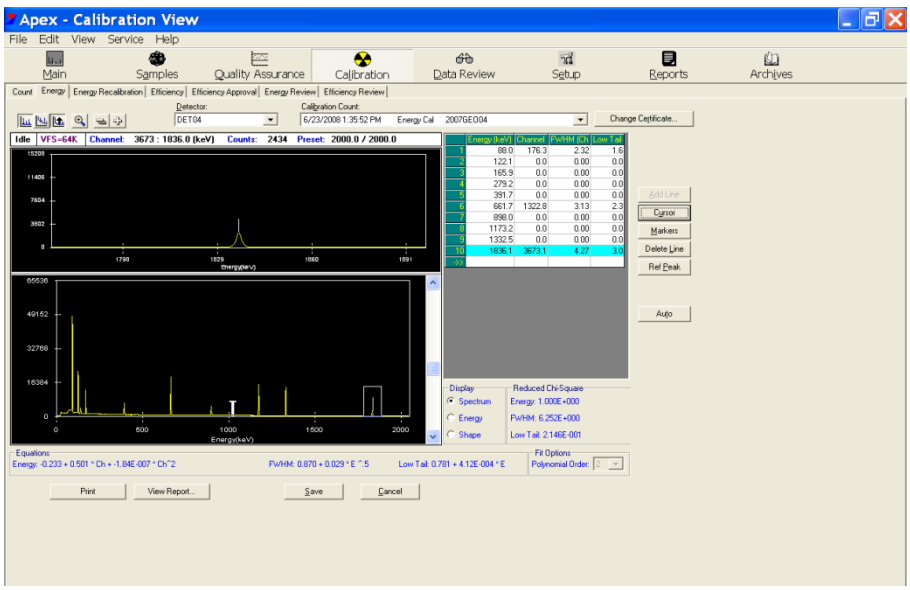
13.7.4.6 Position the cursor on the top of the peak that corresponds to the energy level (keV) that you have highlighted on the peak list. The channel, energy level (keV), and number of counts are shown in the bar immediately above the spectrum. Fine movement of the cursor can be performed using the side-to-side arrow keys on the computer keyboard.

13.7.4.7 The top of the peak is the cursor position that shows the highest count in the vicinity. The channel number will be approximate 2 times the energy level (keV).

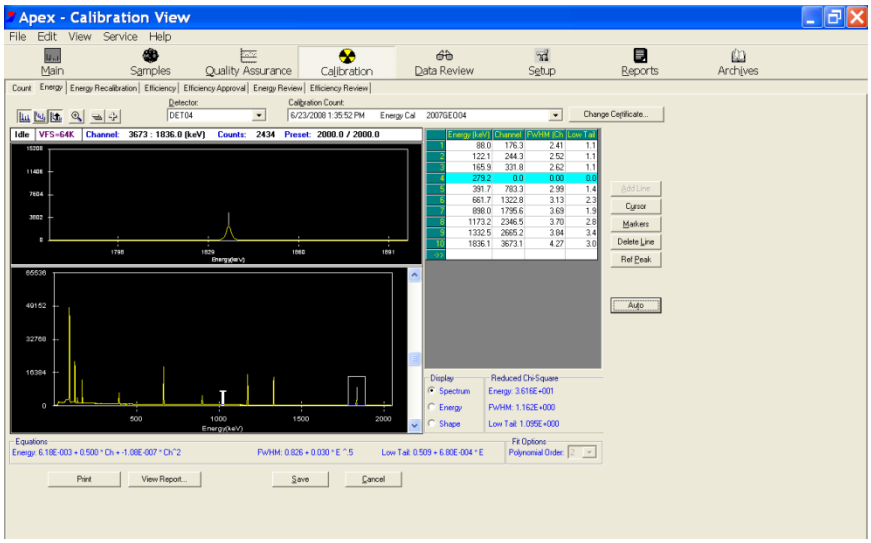
13.7.4.8 With the cursor on the top of the peak that corresponds to the energy level that you have highlighted on the peak list, click the “Cursor” button to the right of the list. The Channel number, FWHM, and low tail will be filled in on the list.



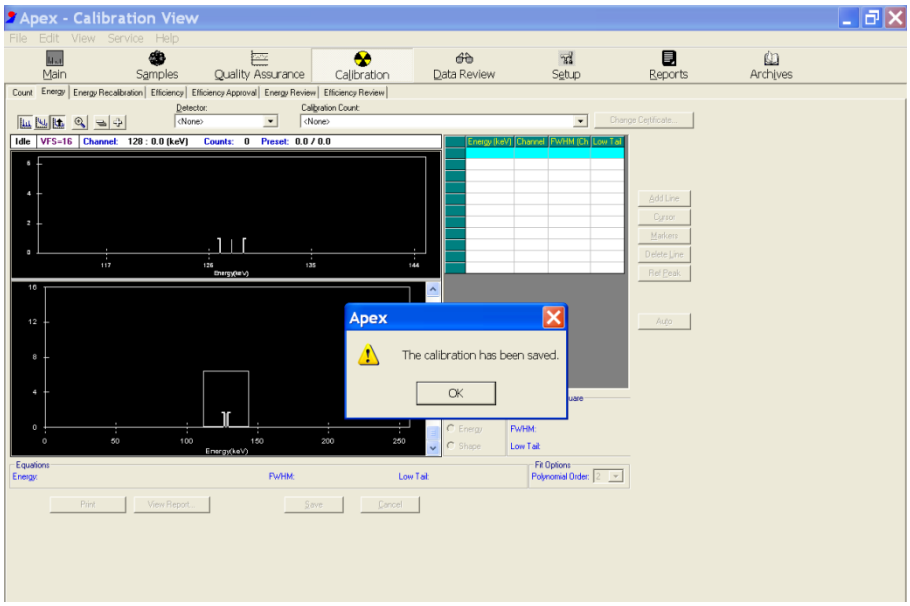
13.7.4.9 Repeat steps No. 13.6.4.6 through No. 13.6.4.8 on the energy peak at 661.7, and again for the energy peak at 1836.1.



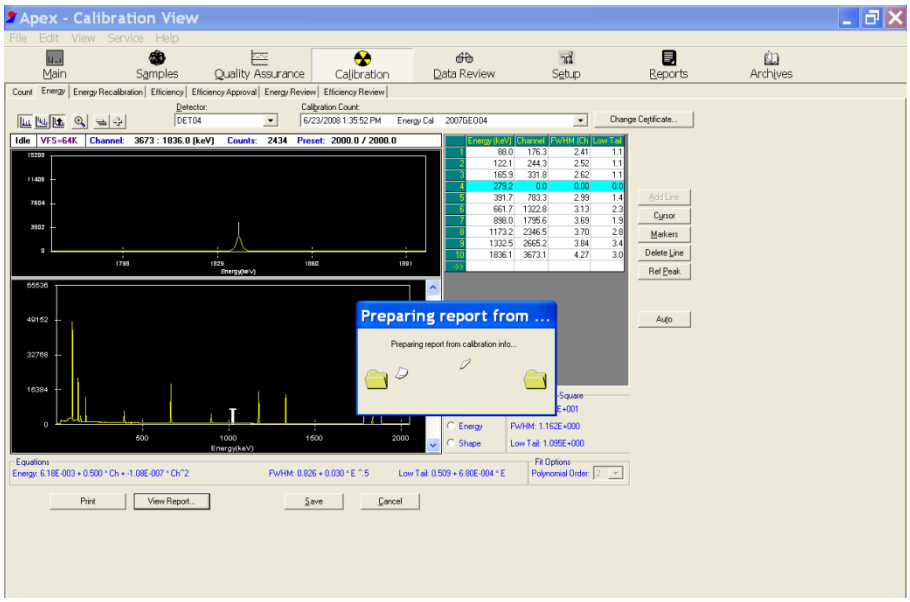
13.7.4.10 After the three peaks have been set, click the “Auto” button. The remaining values will be calculated automatically and entered into the list.



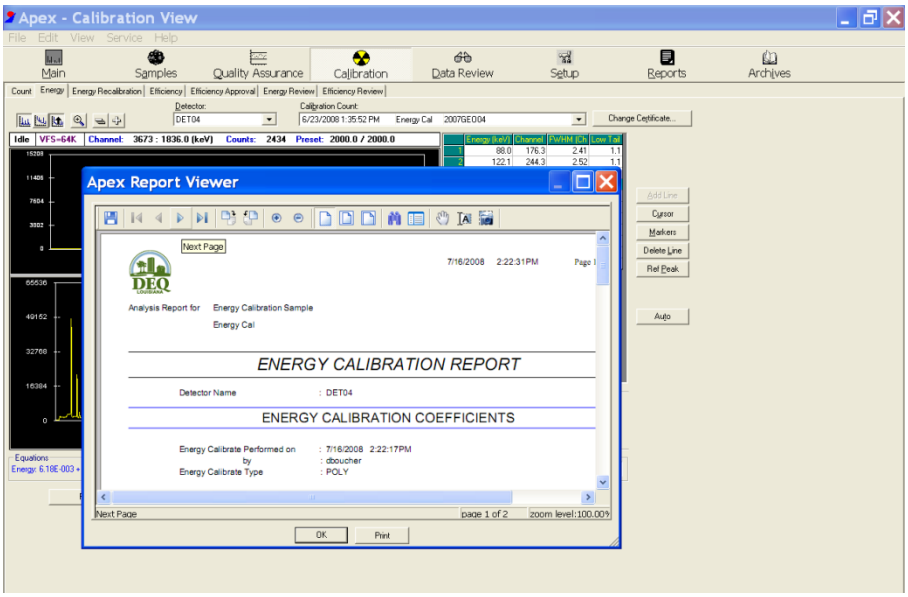
13.7.4.11 Click the “Save” button immediately below the spectrum to save the spectrum.



13.7.4.12 To view and print the calibration report, Click the “View Report” button immediately below the spectrum. The program will begin preparing the report.



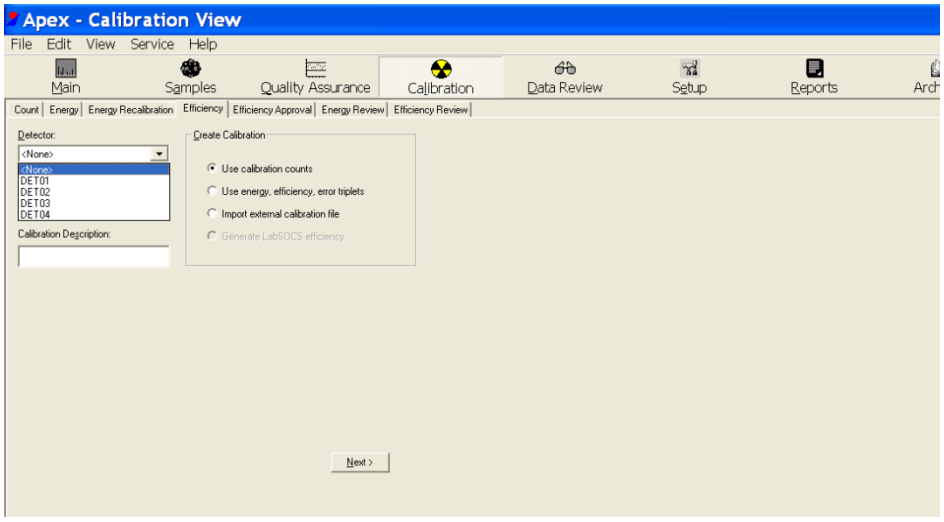
13.7.4.13 When the Energy Calibration Report appears, click the “Print” button to print the report.



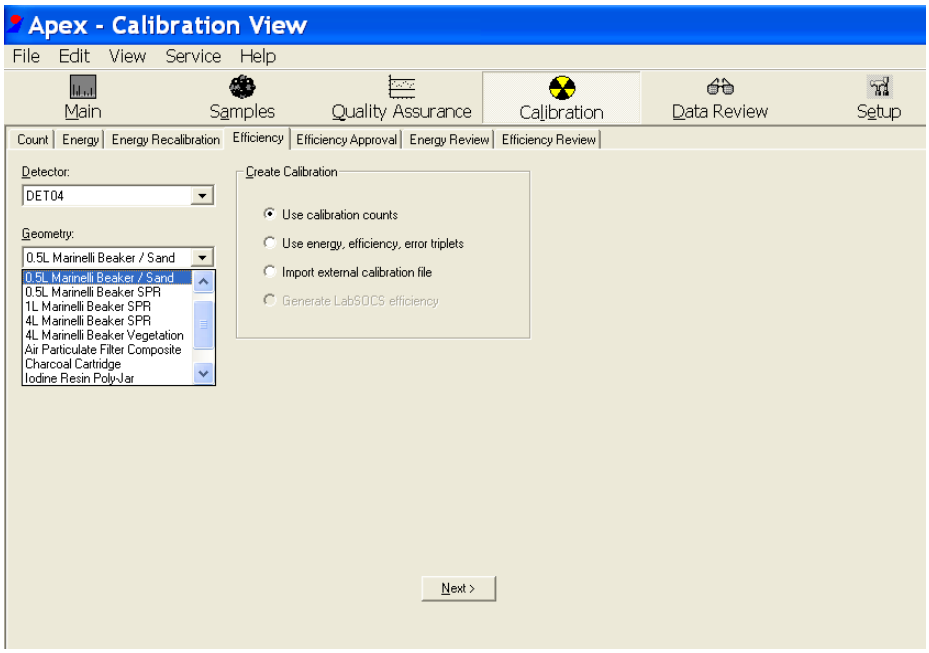
13.8 Efficiency Calibration

13.8.1 Take the standard with the Geometry for which you wish to calibrate the efficiency, place it on a detector, and perform a calibration count as described in Section 13.7.3.

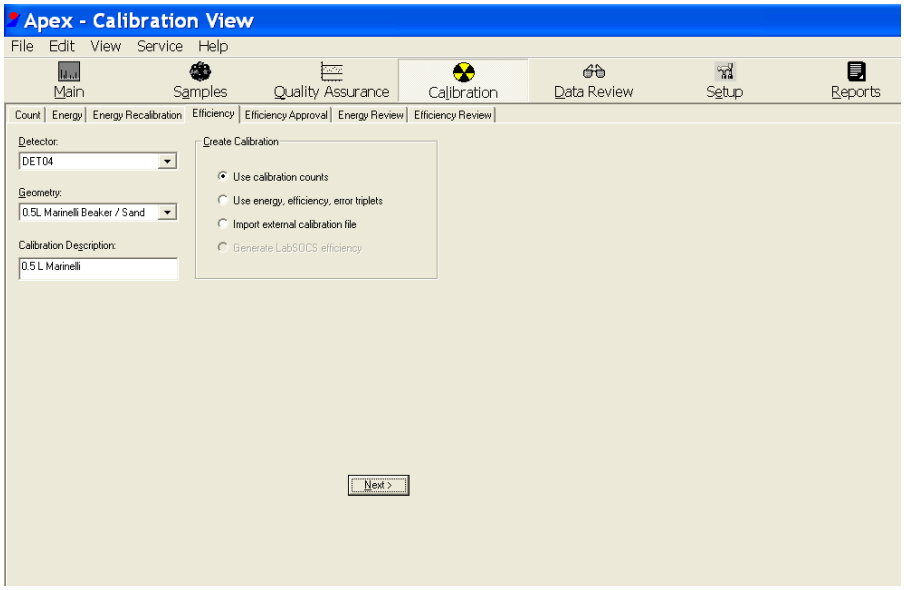
13.8.2 On the **Apex – Calibration View** screen**,** select the “Efficiency” tab. Select the Detector from the pull-down menu. Use the checkbox to select “Use Calibration Count.”



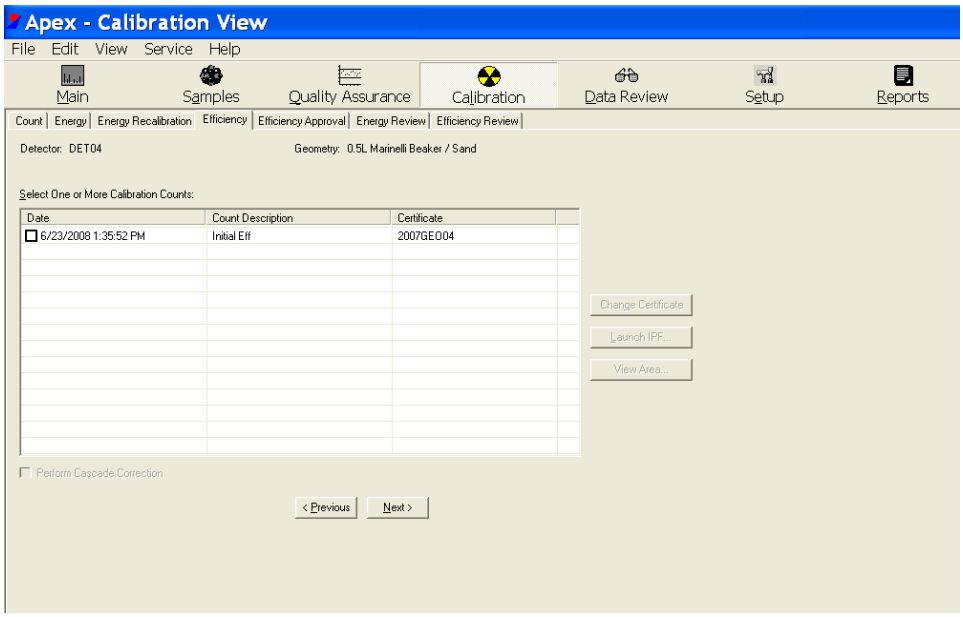
13.8.3 Select the Geometry from the pull-down menu.



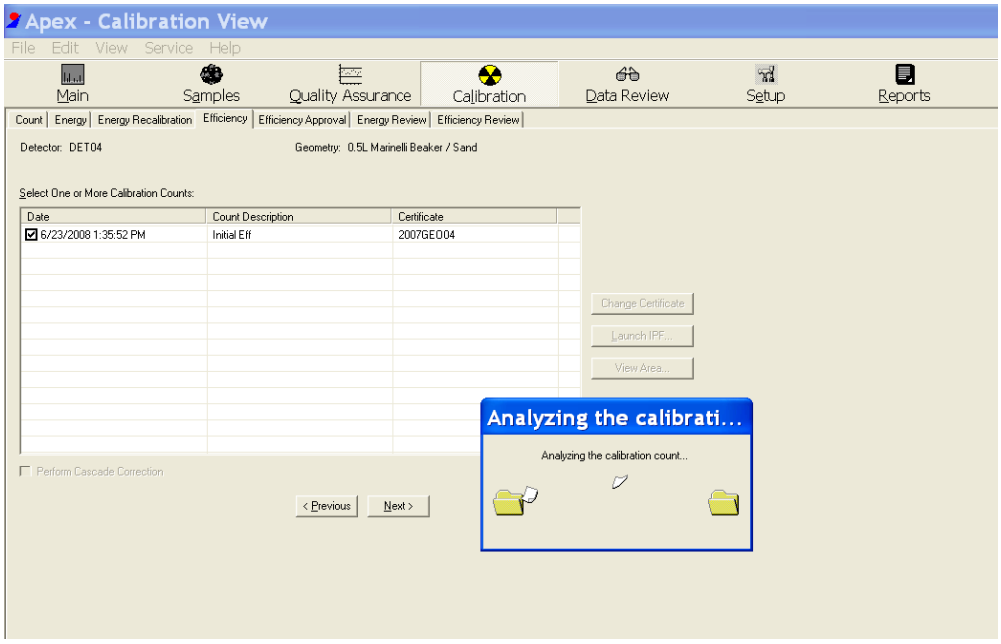
13.8.4 Enter a Description for the Calibration in the designated field and click the “Next” button.



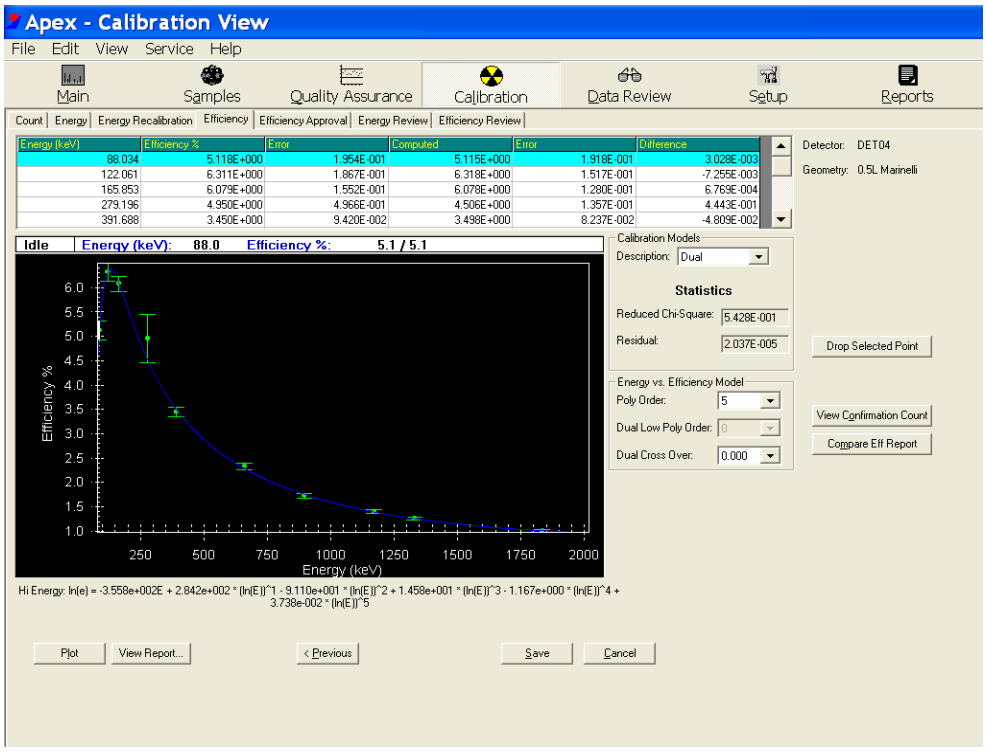
13.8.5 A list of calibration counts will appear. Select a calibration count to use by clicking the check-box next to the count.



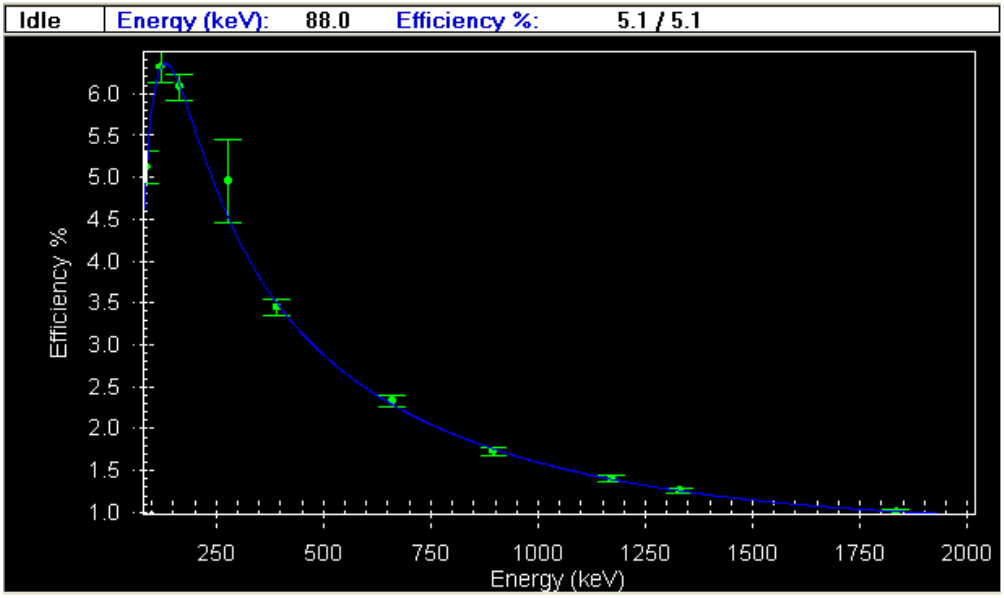
13.8.6 After you have selected the calibration count to be used, click on the "Next" button. The program will analyze the count.



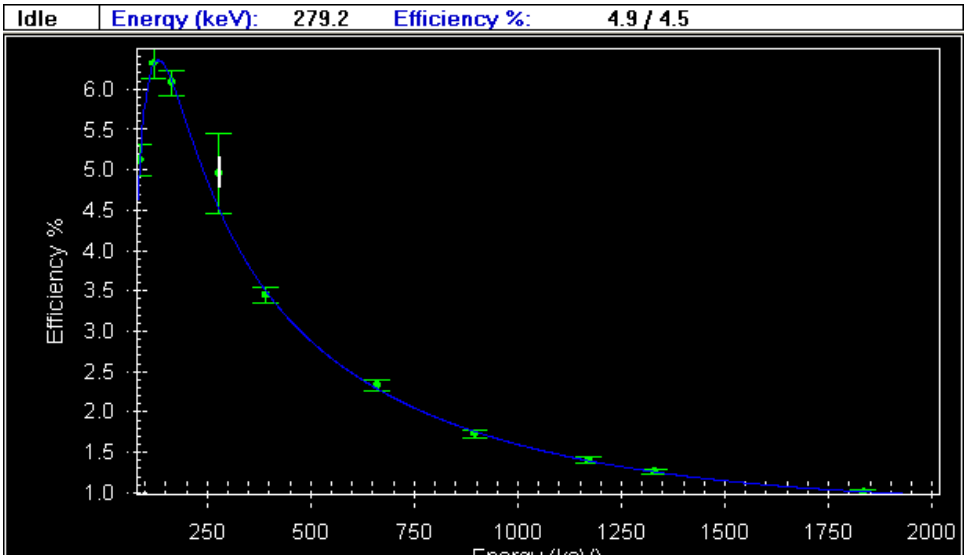
13.8.7 The Efficiency Curve will appear on the screen, with error bars indicating the uncertainty in the fit for each data point.



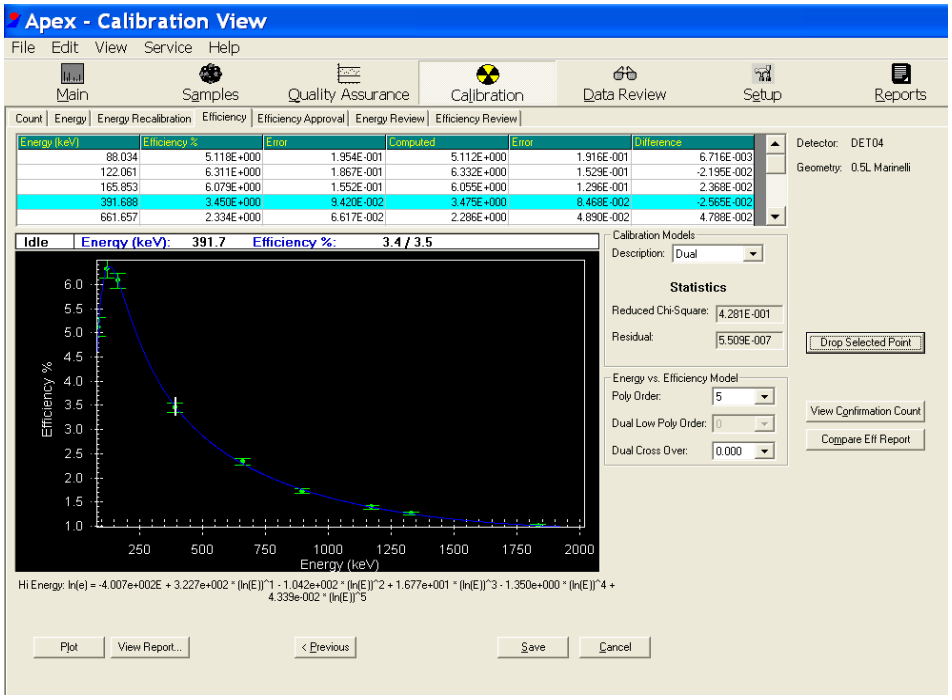
13.8.8 In the example shown, note that the error bars for the point at 279 keV are much larger than the error bars for any other data point**.** This point represents a peak for Hg-203, which has the shortest half-life (46.61 days) of all the nuclides in the standards. As the standard ages, the Hg-203 peak eventually becomes too weak to measure accurately. If this condition is observed, a better calibration curve may be obtained by dropping the Hg-203 data point. **NOTE:** This is NOT analogous to dropping a data point from a standard response curve – rather, it is analogous to running a response curve using nine standards instead of ten to span the same range.



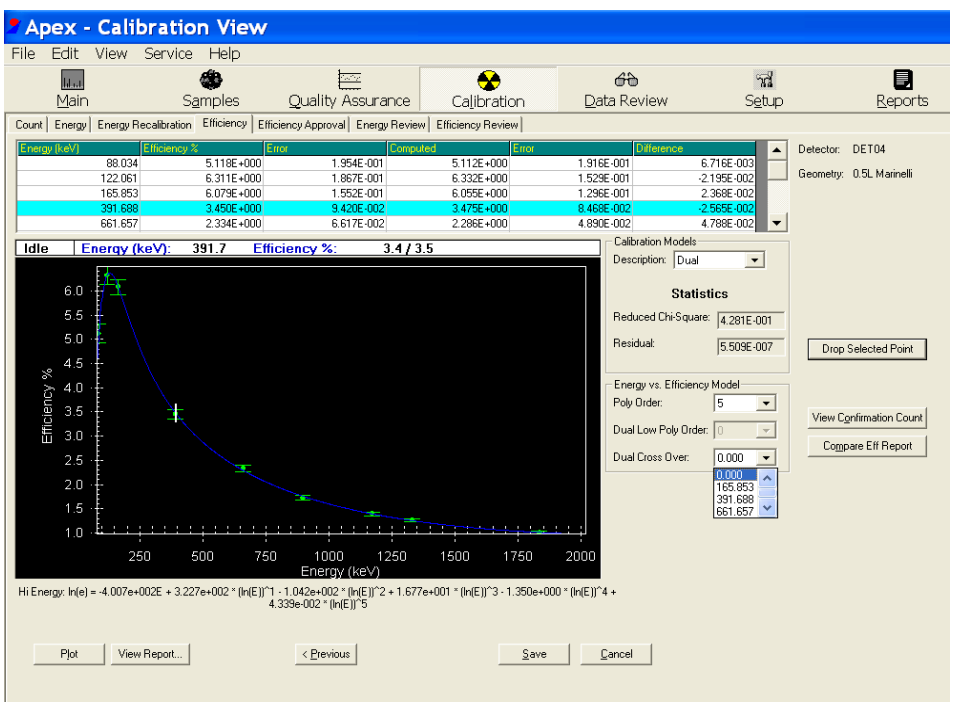
13.8.9 To delete a data point from the curve, first click on the data point to select it, then click the “Drop Selected Point” button to remove the point from the curve.



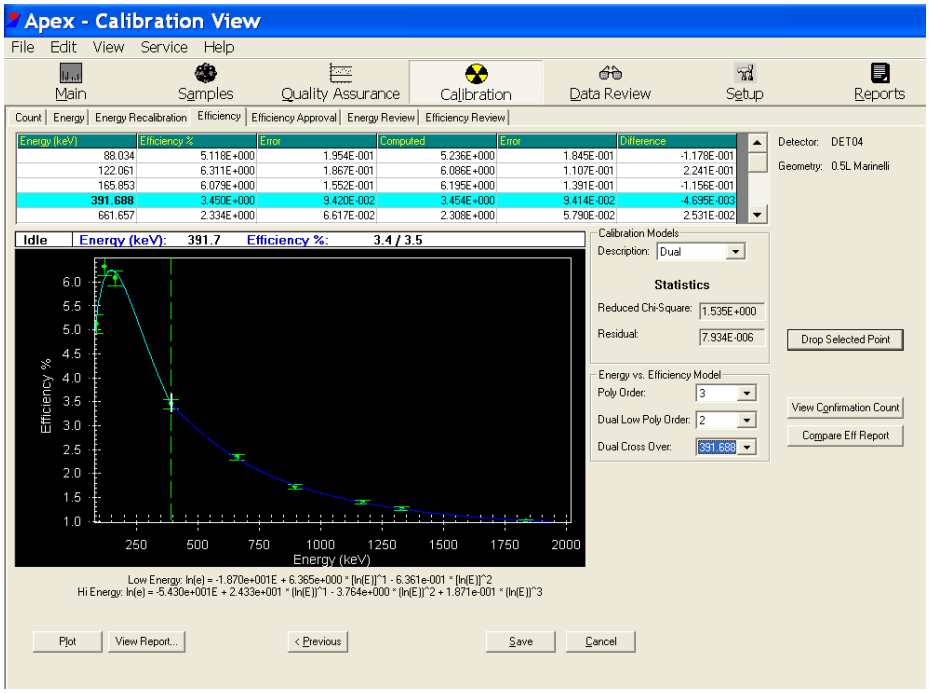
13.8.10 In the “Calibration Models” box immediately to the right of the spectrum, confirm that “Dual” is selected from the “Description” pull-down menu.



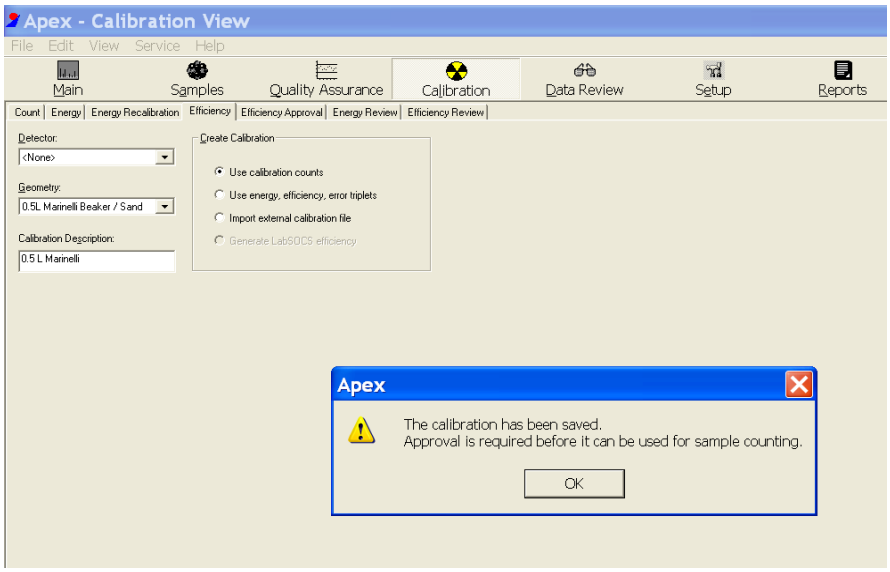
13.8.11 In the “Energy vs. Efficiency Model” box, select the “391.688” peak from the “Dual Cross Over” pull-down menu.



13.8.12 The Dual Cross Over improves the accuracy of the calibration by using one equation to fit the upper portion of the curve, and a different equation to fit the lower portion. If the two portions of the curve do not intersect smoothly at the cross over point, select a different cross over point. If the curve is smooth, click the “View Report” button to view and print the report, as shown in Sections 13.7.4.12 and 13.7.4.13, then click the “Save” button to save the Efficiency Calibration.

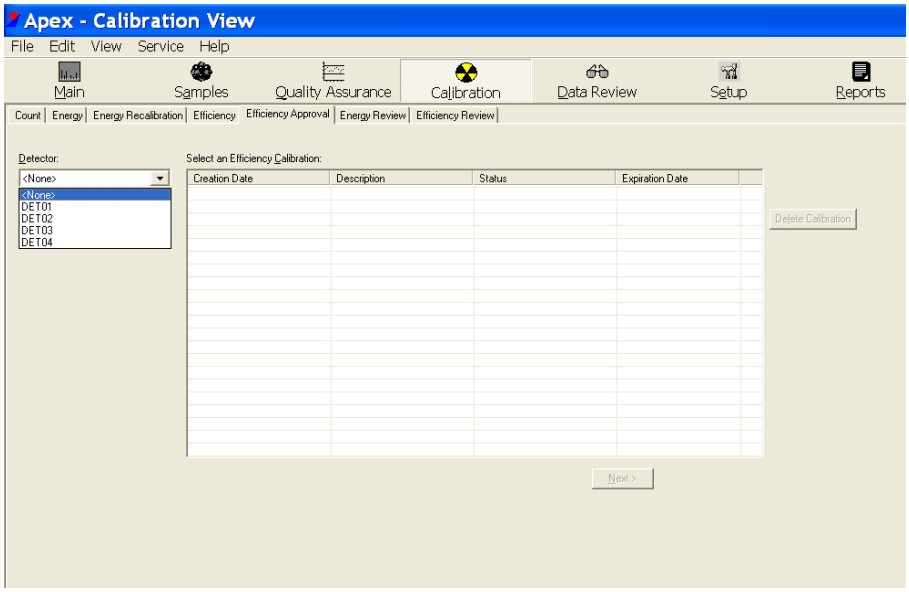


13.8.13 After the Efficiency Calibration has been saved, it will need to be approved before the Calibration can be used for sample counts.

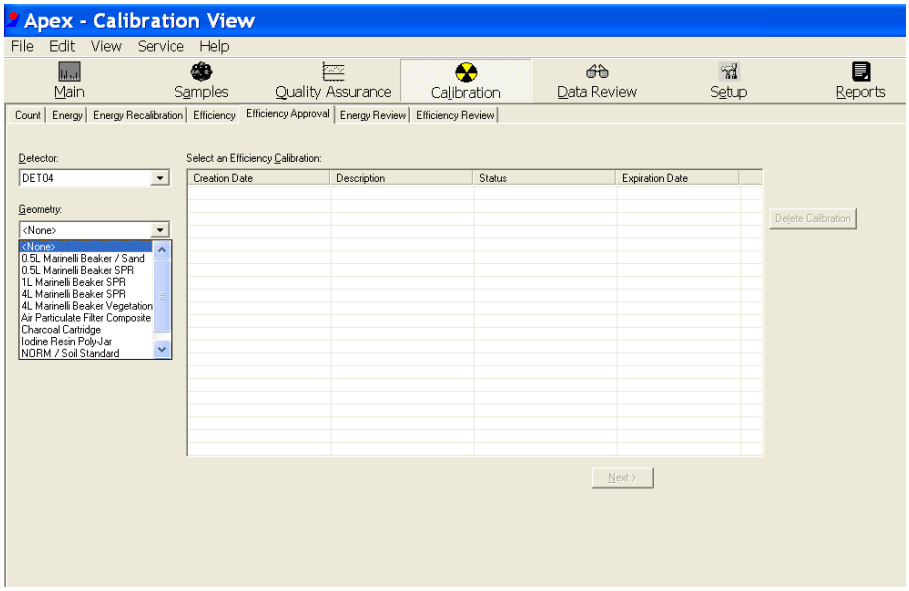


13.9 Approval of Efficiency Calibration

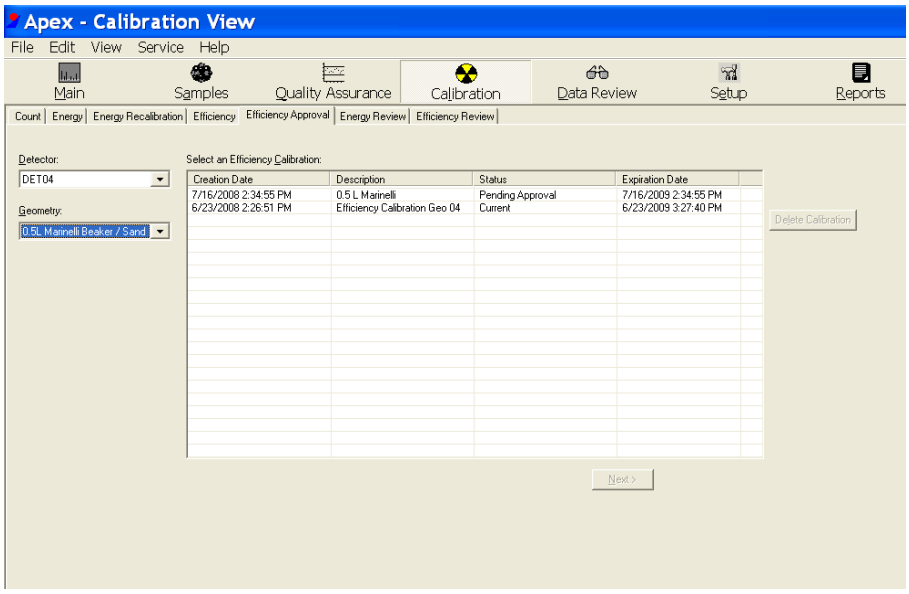
13.9.1 On the **Apex – Calibration View** screen, select the "Efficiency Approval" Tab. Select a detector from the pull-down menu.



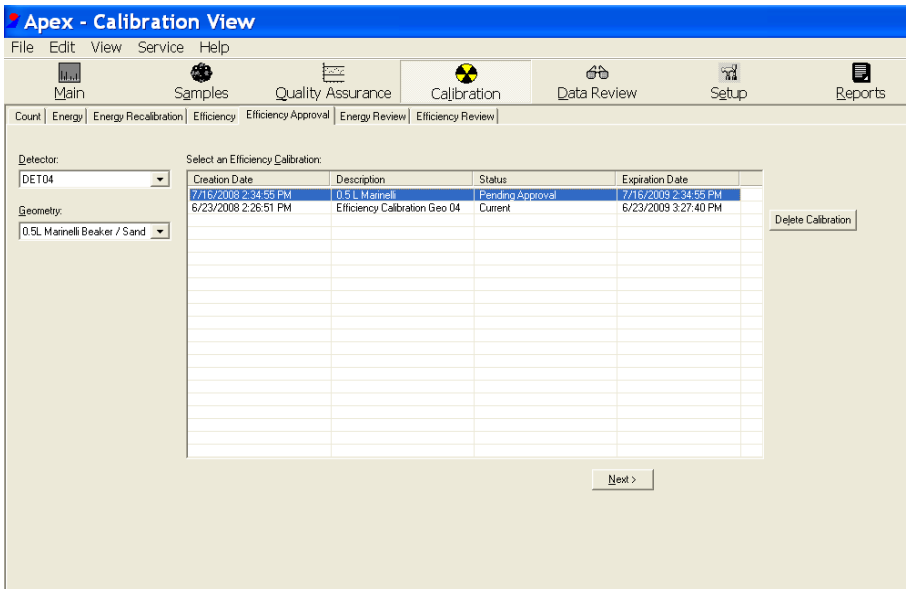
13.9.2 Select a Geometry from the pull-down menu.



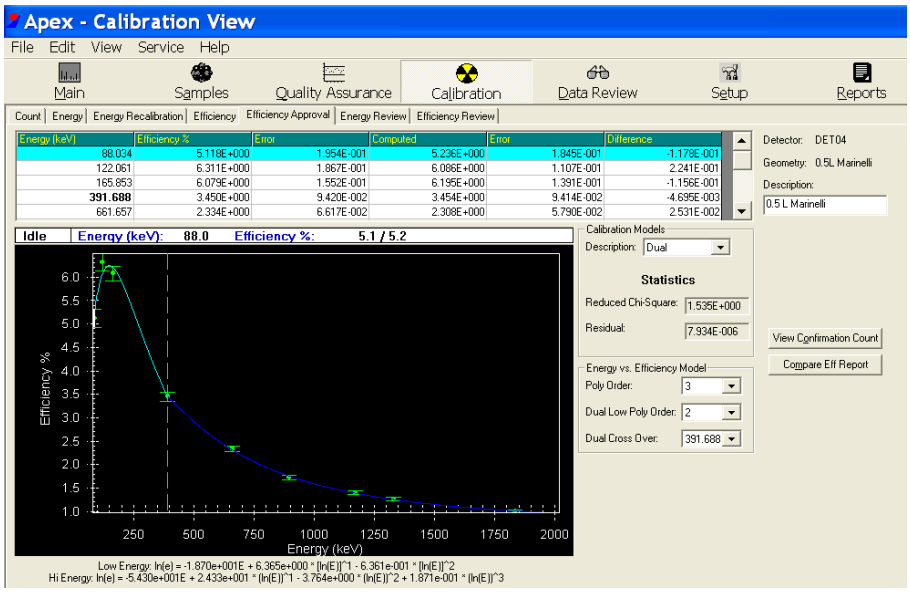
13.9.3 A list of the Efficiency Calibrations that have been performed for the selected detector and geometry will appear. The list will indicate the status of the calibrations, as either “Current”, “Old”, or “Pending Approval.”



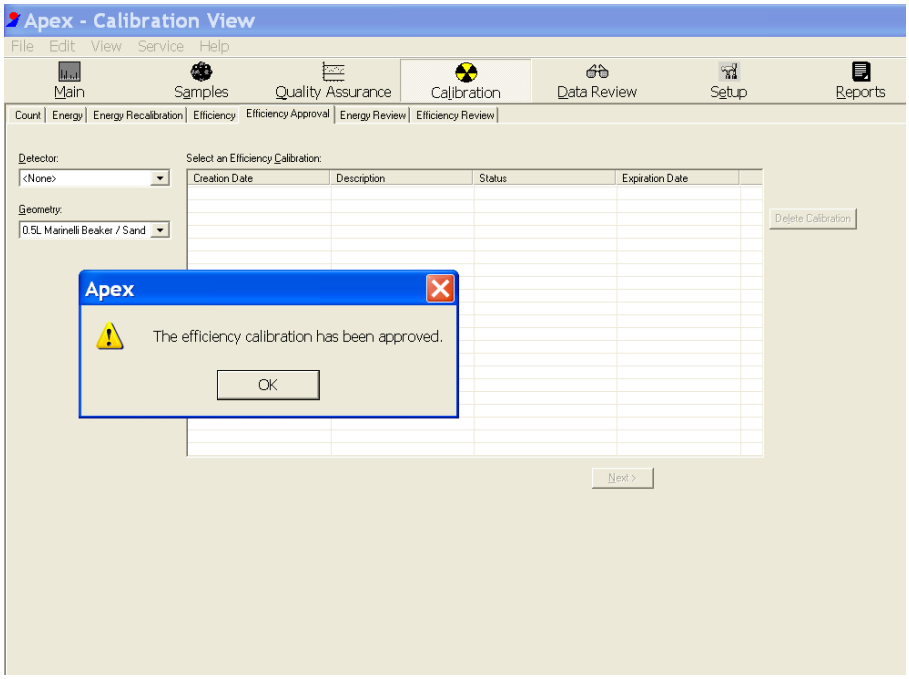
13.9.4 Select the Efficiency Calibration that you wish to review for approval, and click the “Next” button.



13.9.5 The selected Efficiency Calibration Curve will appear on your screen. If you wish to select a different curve, click the “Previous” button below the curve to return to the previous screen. If this is the curve you wish to approve, click the “Approve” button below the spectrum.



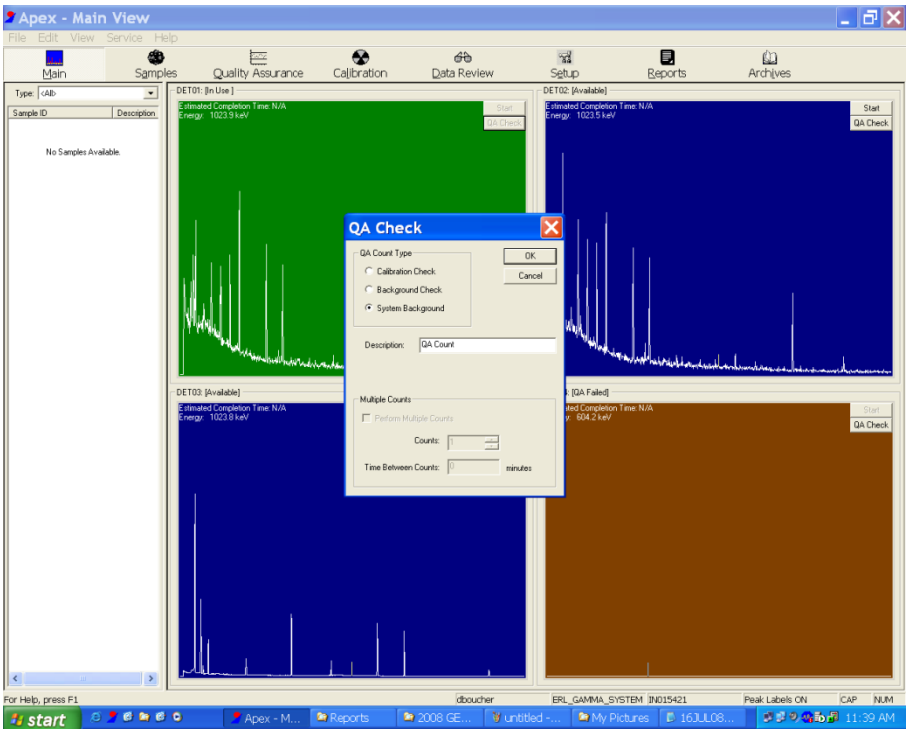
13.9.6 Click “OK” on the dialog box to complete the approval process.



13.10 Monthly System Background Count

13.10.1 A monthly System Background count is performed for each detector. Begin by examining the detector to ensure that the shield is empty and closed.

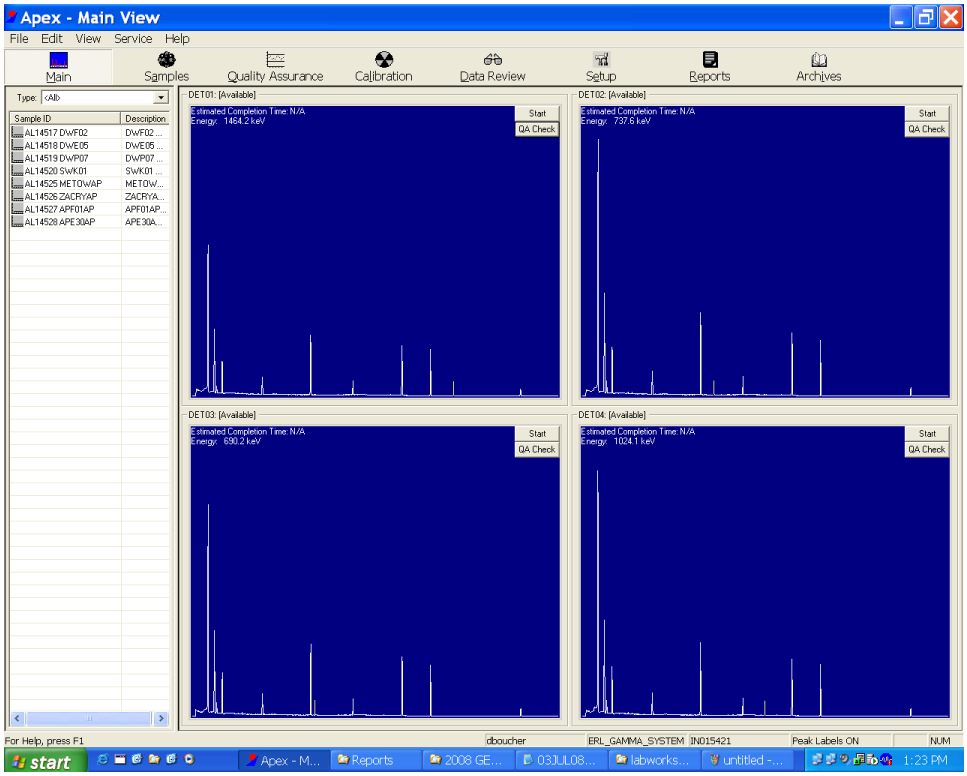
13.10.2 On "**Apex - Main View**" Screen, Click the "QA Check" button in the upper right corner of the detector window. Select "System Background" and click "OK". The window color will change from blue to green for the duration of the count.



13.10.3 The System Background count will run for 60,000 seconds. When the count is complete, a two-page Gamma Spectrum Analysis and Peak Locate Report will print out automatically. The Q.A. Report shows the evaluation of the background Q.A. control limits. Staple the Gamma Analysis/Peak Locate and Q.A. Reports together, initial and date, and place in the designated binder.

14.0 Procedure

14.1 The **Apex – Main View** screen shows four windows, one for each detector. The color of the window indicates the state of the detector. At the left-hand side of the screen is a list of samples that have been entered but have not yet been run.



14.2 Each detector is equipped with a 30-L Dewar, which must be filled with liquid nitrogen at a minimum once per week. The analyst shall log-in time of filling, initial the log sheet and store these records in the appropriate binder.

14.2.1 If for any reason the detectors are not filled according to the prescribed schedule, the analyst must first fill the detector, and then look inside the detector shield to confirm that the detector is at the proper operating temperature. This is indicated by a small light on the side of the detector. If the light is green, it means that the detector is cold enough to operate. If the light is red, it means that the liquid nitrogen has run out and the detector cannot be used. If the detector has warmed to room temperature, it requires a minimum of four hours for the detector to cool down to the proper operating temperature. Operating the detector with the red light on may result in damage to the detector.

14.2.2 Quality Control failures are often caused by not allowing sufficient time after filling the liquid nitrogen Dewars before performing the Quality Control procedure. On days when the Dewars are filled, a minimum of two hours must be allowed to elapse before performing the Quality

Control Procedure. **Do not add liquid nitrogen to a Dewar during the time between the QC procedure and the sample analysis**.

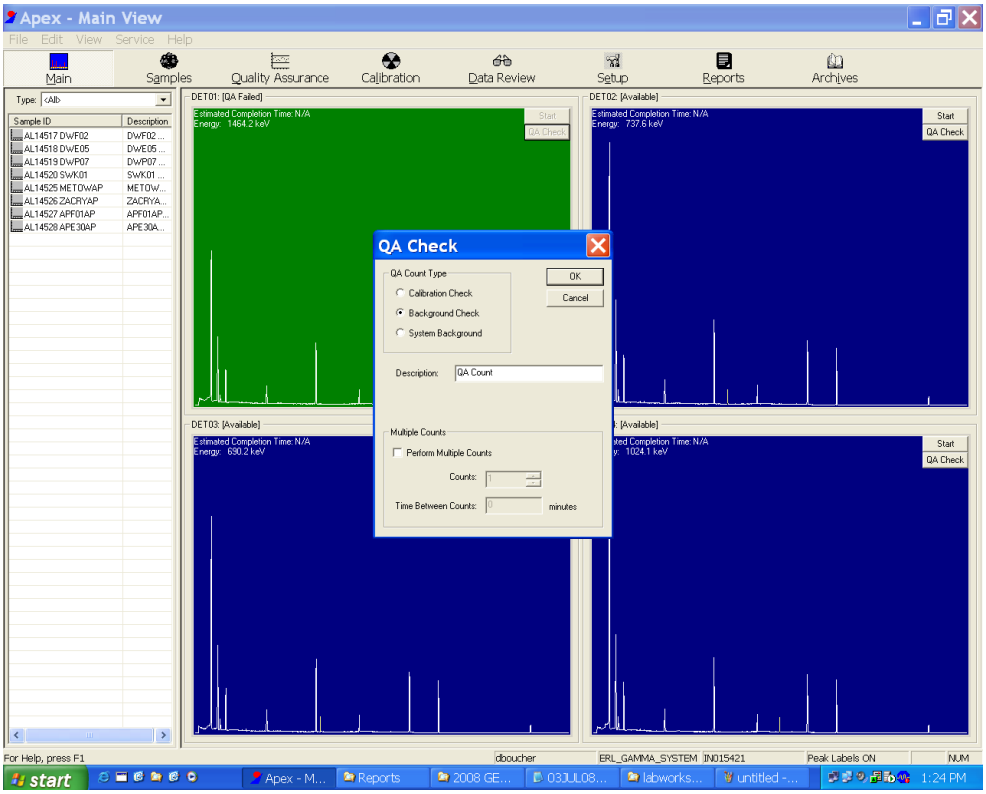
14.3 Quality Control Procedures

14.3.1 The Quality Control procedures described in this section must be performed on each day of use, prior to the analysis of samples.

14.3.2 Daily QA Background Check

14.3.2.1 The background check is performed simultaneously on all detectors. Begin by examining the detectors to ensure that all of the shields are empty and closed.

14.3.2.2 On "**Apex - Main View**" Screen, Click the "QA Check" button in the upper right corner of the detector window. Select "Background Check" and click "OK". The window color will change from blue to green for the duration of the count.



14.3.3 The background count will run for 1000 seconds. When the count is complete, a two-page Gamma Spectrum Analysis and Peak Locate Report will print out automatically, followed by a one-page Last Measurement Q.A. Report. The Q.A. Report shows the evaluation of the background Q.A. control limits. Staple the Gamma Analysis/Peak Locate and Q.A. Reports together, initial and date, and place in the designated binder.

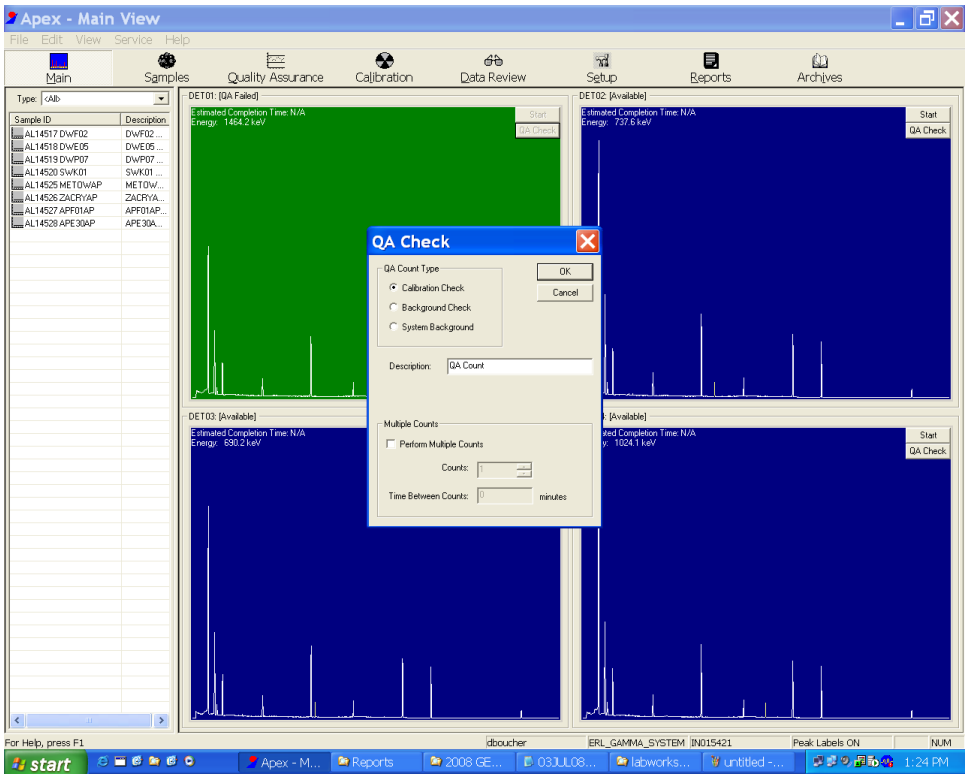
14.3.4 Calibration QA Check.

14.3.4.1 Carefully open the shield door. The top of the lead shield open by means of a lever mechanism on the left side of the shield. To open, grasp the lever with the left hand and lower to the shield table. This will raise the top of the shield just enough to allow it to swing to the left, opening the shield.

14.3.4.2 Place the holder for the Quality Control Standard onto the detector. The holder is a half-liter Marinelli beaker with a foam insert to hold the Quality Control Standard poly-jar.

14.3.4.3 Place the Quality Control Standard onto the detector, and close the lid to the shield. You are now ready to begin the count.

14.3.4.4 On **Apex Main View** screen, click the "QA Check" button in the upper right corner of the detector window. Select "Calibration Check" and click "OK". The window color will change from blue to green for the duration of the count.



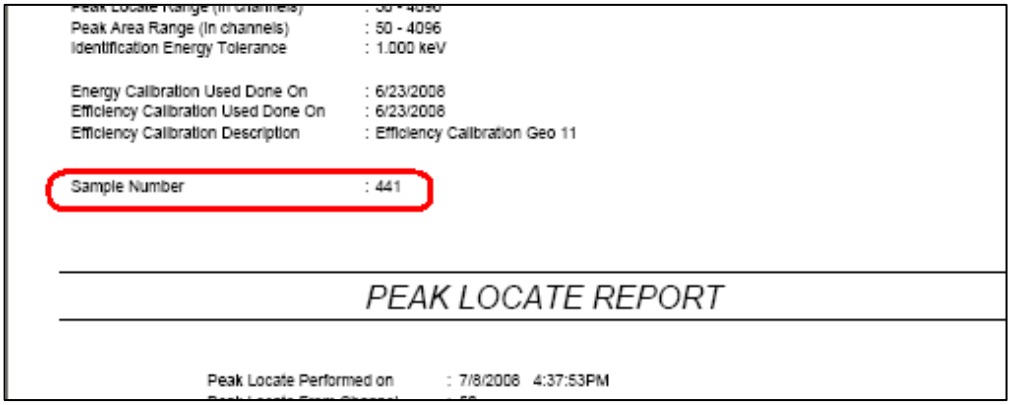
14.3.4.5 The count will run for 1000 seconds. When the count is complete, a two-page Gamma Spectrum Analysis and Peak Locate Report will print out automatically, followed by a one-page Last Measurement Q.A. Report. The Q.A. Report shows the evaluation of the calibration Q.A. control limits. Staple the Gamma Analysis/Peak Locate and Q.A. Reports together, initial and date, and place in the designated binder.

14.3.4.6 Repeat the Calibration QA check procedure for all 4 detectors, beginning at Section 14.3.4 of this SOP.

14.3.4.7 After the Quality Control procedure has been performed for all four detectors, remove the Quality Control standard and holder from the last detector and store the standard in the designated location.

14.3.5 For each detector, copy the Last Measurement Q.A. Reports for the background check and calibration check into text files, using the procedure described in Section 14.4.2 of this SOP. These text files are used to link the QC data to the analytical data in the LIMS. See Sections A3.10-A3.16 of Appendix A of this SOP for more information on how these files are linked to sample results in the LIMS.

14.3.6 On the first page of each Gamma Spectrum Analysis Report, right above the Peak Locate Report, is an entry labeled "Sample Number." This number is a unique sequential number generated by the Apex software each time a count is performed. It should not be confused with the LIMS Sample ID.


Peak Area Range (in channels) : 50 - 4096
Identification Energy Tolerance : 1.000 keV

Energy Calibration Used Done On : 6/23/2008
Efficiency Calibration Used Done On : 6/23/2008
Efficiency Calibration Description : Efficiency Calibration Geo 11

Sample Number : 441

PEAK LOCATE REPORT

Peak Locate Performed on : 7/8/2008 4:37:53PM

14.3.7 Whenever a test sample is run, the Sample Number for the associated QA background and calibration check reports shall be entered into the Gamma Spectroscopy Sample Run Log along with appropriate sample information. The Gamma Spectroscopy Sample Run Log is shown in Appendix C of this SOP.

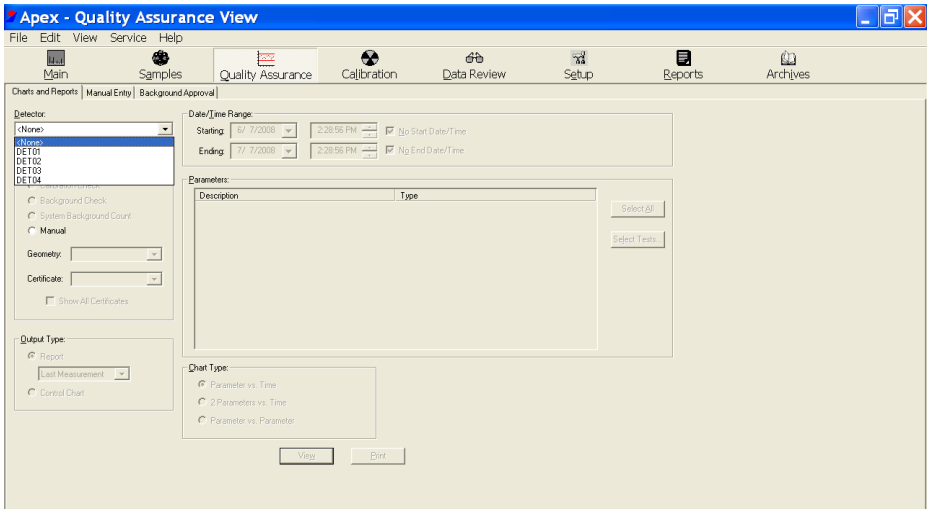
14.3.8 Every Analysis Report is automatically stored in a PDF file on the Apex Computer. The filename for the Analysis Report PDF file is the Apex Sample Number preceded by zeros to expand the number to ten characters. E.g., Apex Sample Number 549 would have a filename of 0000000549.pdf.

14.3.9 Procedure for Storing the Last Measurement Q.A. Reports as text files.

14.3.9.1 The Apex Software generates two Last Measurement Q.A. Reports, one for the Background QA Check and one for the Calibration QA Check. These reports are overwritten each time

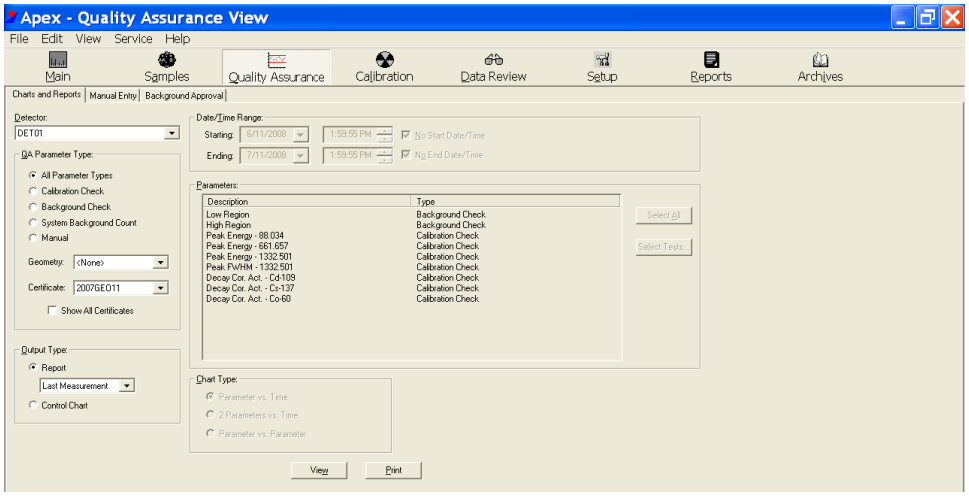
the QA Checks are performed, and so the reports must be copied into text files in order to preserve them in electronic form. This section describes how to copy both reports into a single text file.

14.3.9.2 In the "**Apex – Quality Assurance View"** Screen, select a detector from the pull-down menu near the upper left-hand of the screen.

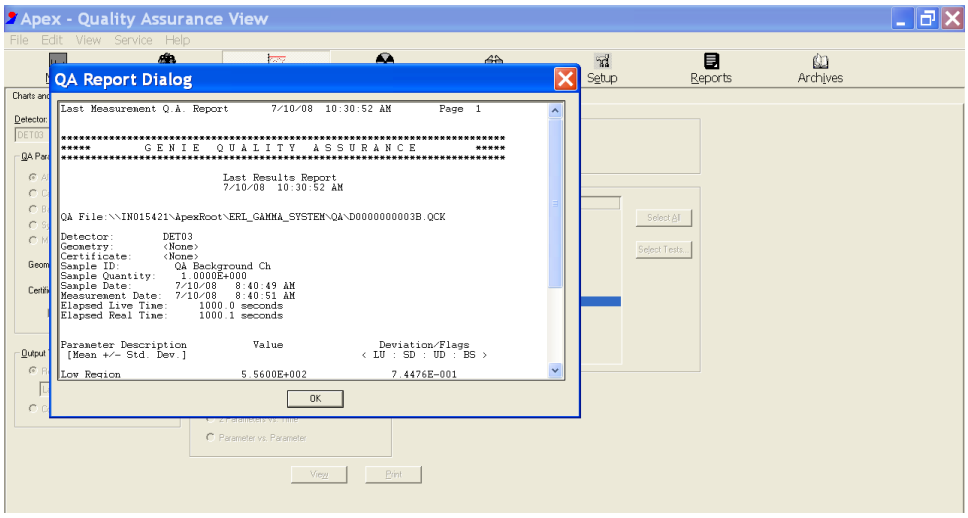


14.3.9.3 In the box labeled "QA Parameter Type" on the left-hand side of the page, select "All Parameter Types." On the pull-down menu labeled "Certificate", select the Certificate for Geometry 11 ("2007GEO11").

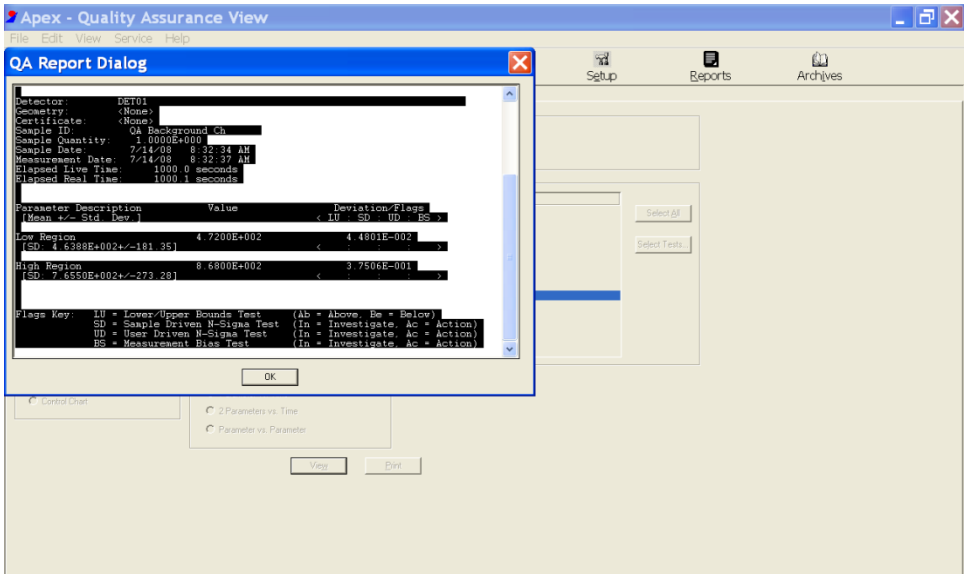
14.3.9.4 In the box labeled "Output Type" on the left-hand side of the page, select "Report", and select "Last Measurement" on the pull-down menu.



14.3.9.5 After all the selections have been made, click the button for "View." The "QA Report Dialog" window will appear with the Last Measurement Q.A. Report for the background.

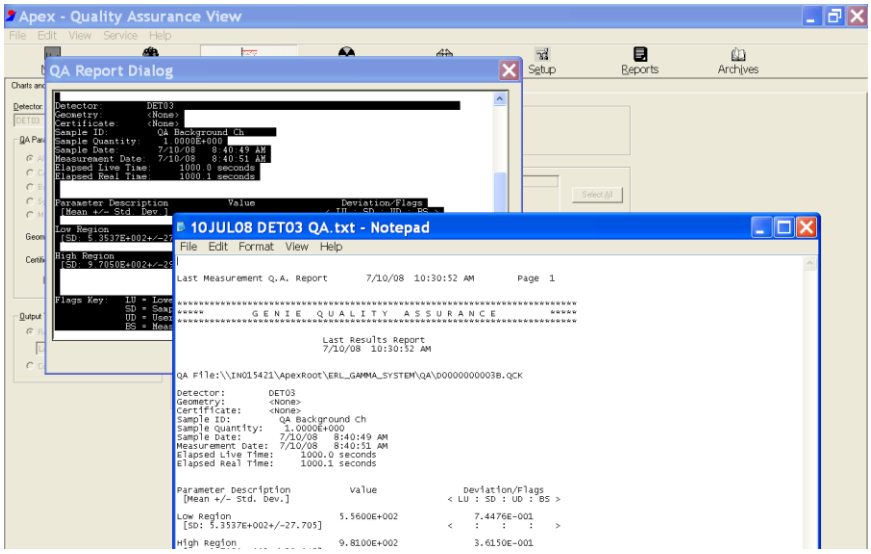


14.3.9.6 Set the cursor in the upper left corner of the Last Measurement Q.A. Report in "QA Report Dialog" window, then hold the left mouse button down and drag to the bottom of the window to highlight the text of the report.

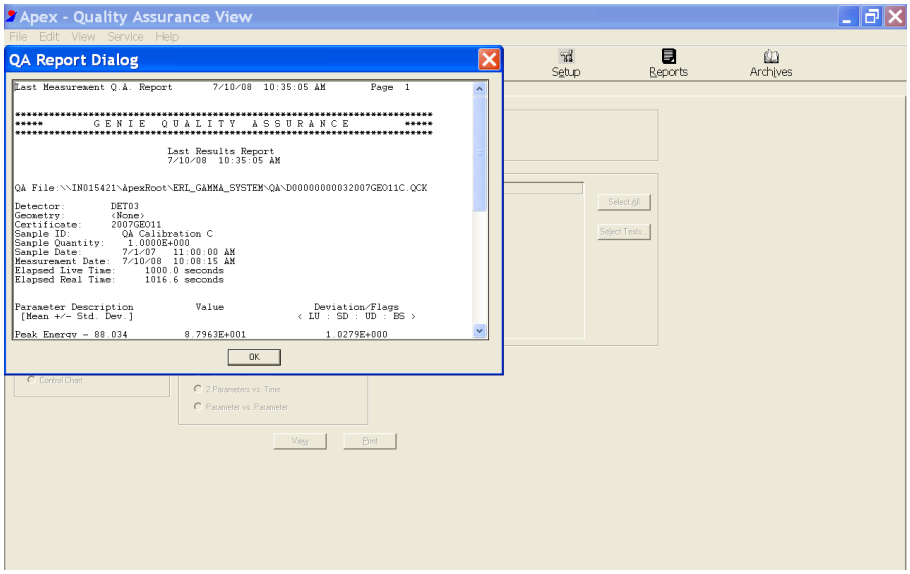


14.3.9.7 Press Control-C to copy the text from the Last Measurement Q.A. Report for the background.

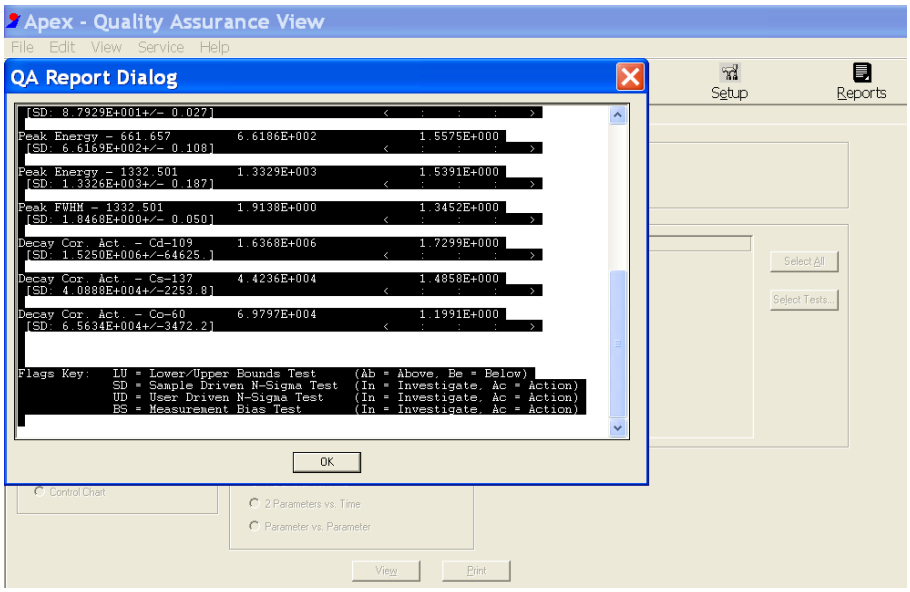
14.3.9.8 Open a WordPad document and Press Control-V to paste the text from the Last Measurement Q.A. Report, then save the file in the gamma QC folder for the current year. Save report using the name for the current date and detector name. The format for QA report filenames (as shown below) is: “ddMMMyy DETnn QA.txt” For example, the QA report file for Detector 03 for July 10, 2008 would be “10JUL08 DET03 QA.txt”



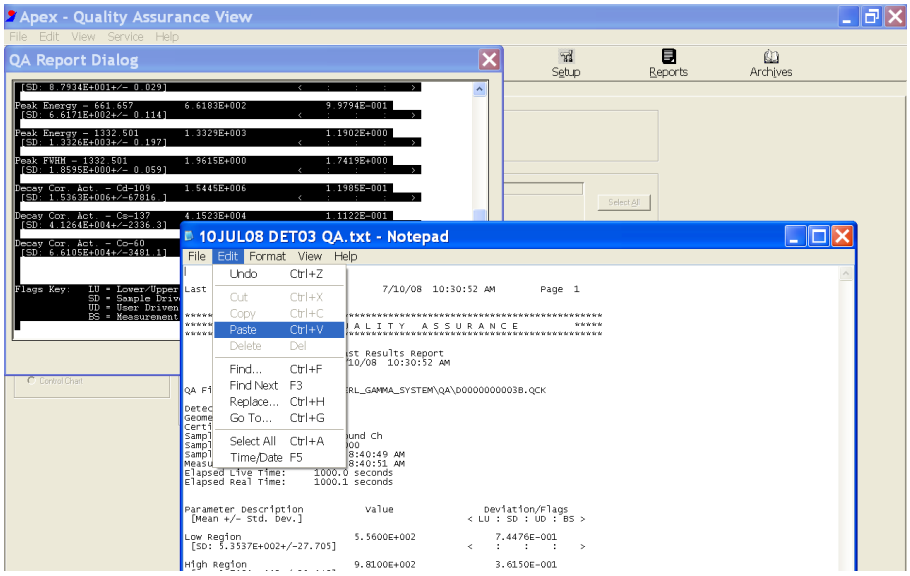
14.3.9.9 After saving the report, minimize the report and click “OK” on the “QA Report Dialog” window. The “QA Report Dialog” window will close, and then immediately reopen with the Last Measurement Q.A. Report for the calibration check.



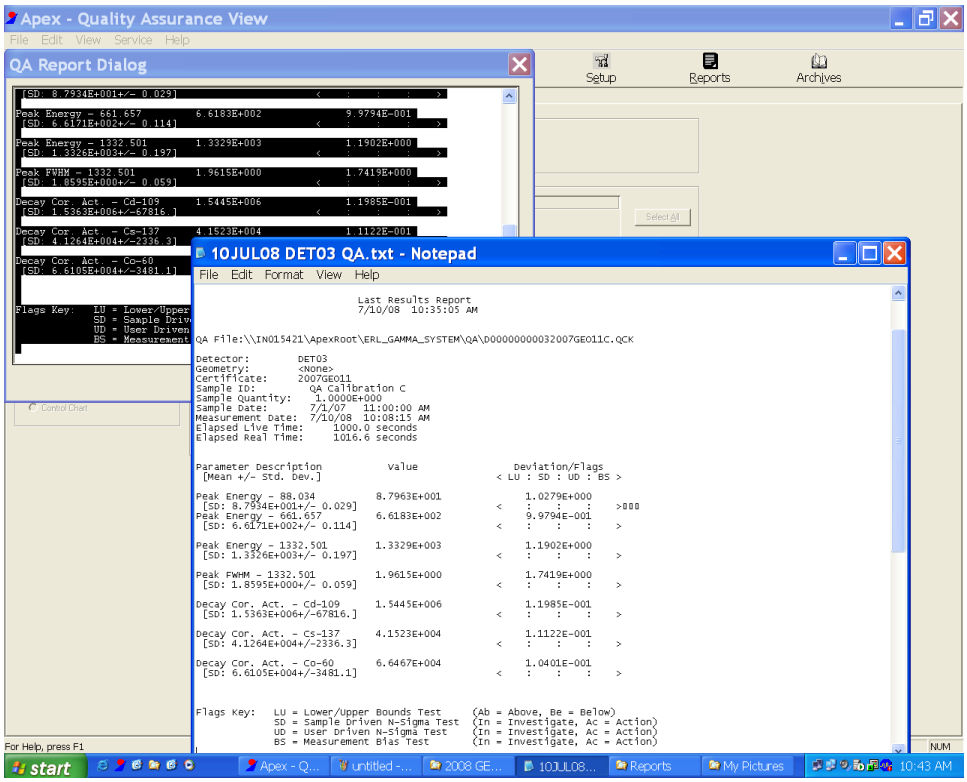
14.3.9.10 Set the cursor in the upper left corner of the Last Measurement Q.A. Report in “QA Report Dialog” window, then hold the left mouse button down and drag to the bottom of the window to highlight the text of the report. Press Control-C to copy the text of the Last Measurement Q.A. Report.



14.3.9.11 Reopen the window for the WordPad file that contains the text previously from the background report. Place the cursor in the upper left-hand corner at the top of the document, and paste the text from the calibration check report.



14.3.9.12 The WordPad file will now contain the text for both the background check and the calibration check. Save the file and minimize it. Click OK on the QA Report Dialog window to close it.



14.3.9.13 Repeat these steps to create and store the QA Report text files for all detectors in use.

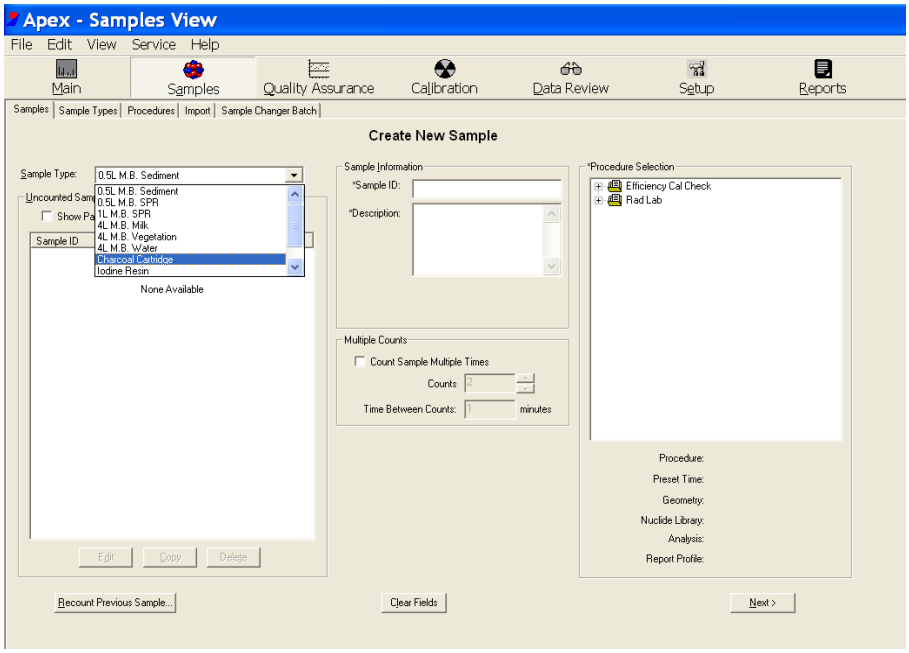
14.3.10 Copy the QA Report text files to the designated network folder for files to be linked to the LIMS entries for the associated sample results. The path for the designated network folder for Gamma is: \\labshares\Radfiles\Gamma\YYYY\MMMyy, where YYYY is the year, MMM is the three-letter abbreviation for the month, and yy is a two-digit abbreviation for the year. E.g., the dewsignated folder for July 2008 would be \\labshares\Radfiles\Gamma\2008\JUL08.

14.3.11 Copy the Analysis Report PDF files to the same folder. These files will be linked to the sample results when you enter them into the LIMS.

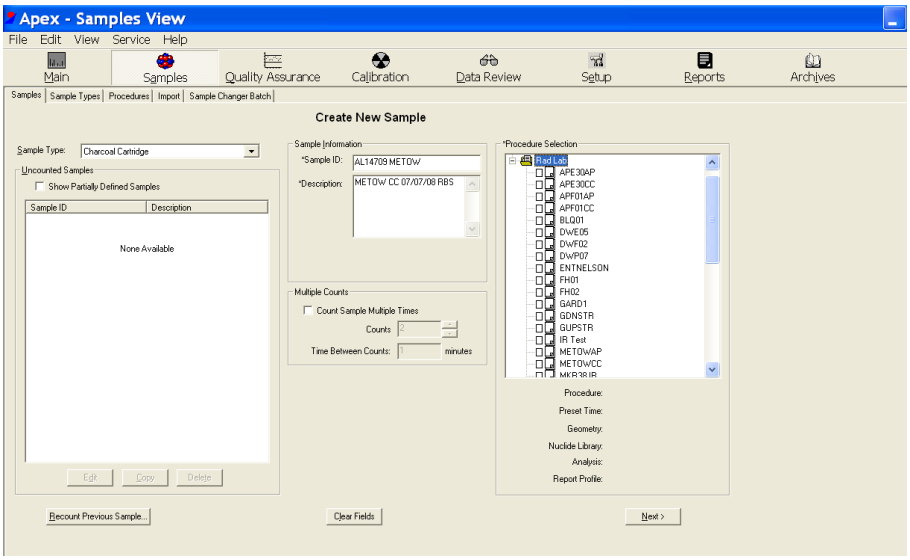
14.4 Sample Scheduling

14.4.1 Before a sample can be run, it must be entered into the list of scheduled samples. The list appears on the left-hand side of the **Apex – Main View** screen. The section describes how to enter samples and sample information into the list.

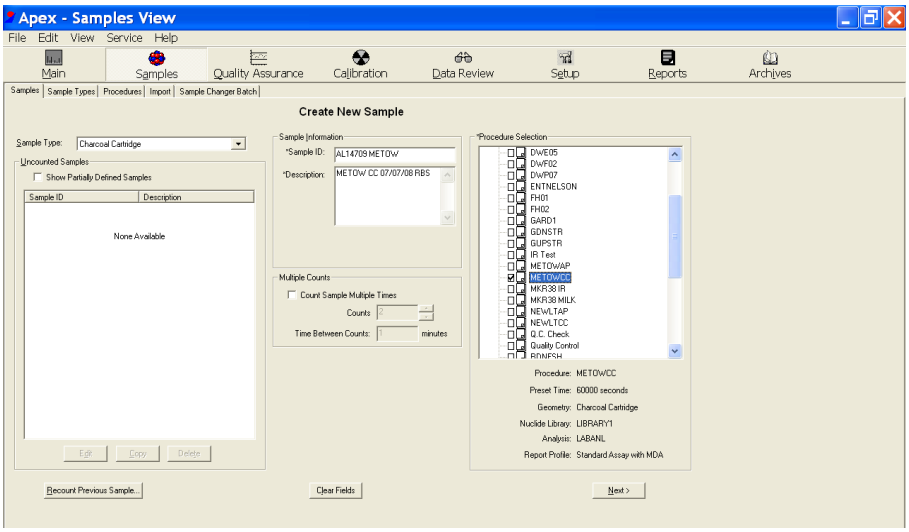
14.4.2 On the **Apex – Samples View** screen, select the “Samples” tab. You will see a “Create New Sample” header on the tab. Select the Sample Type from the pull-down menu in the upper left-hand of the screen.



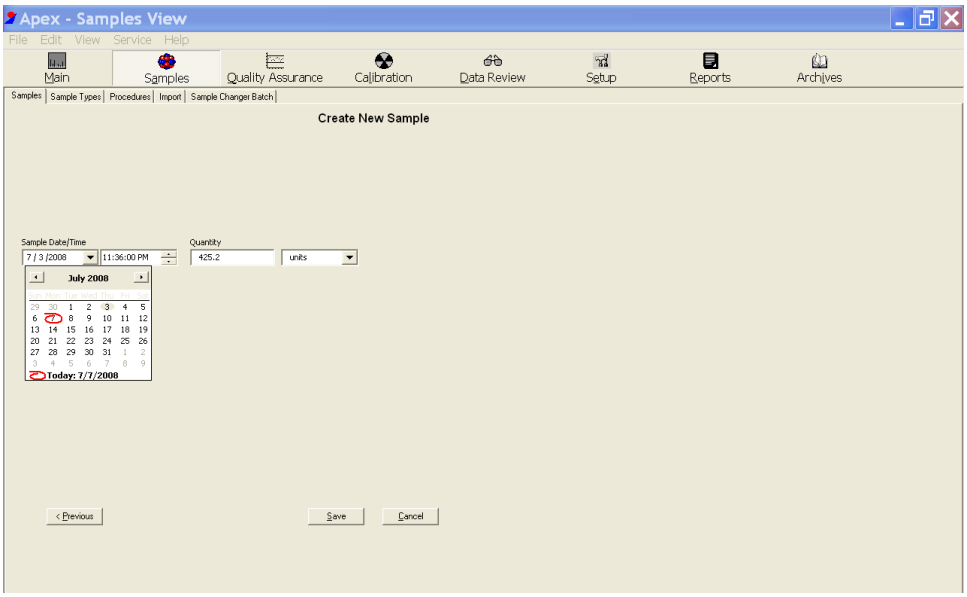
14.4.3 In the field labeled “Sample ID,” enter the LIMS Sample ID and the designation for the Sample Location. In the field labeled “Description,” enter descriptive information on the sample, including the location and date of sample collection.



14.4.4 In the field labeled “Procedure Selection,” there are two folders: One folder is labeled “Efficiency Cal Check.” The other folder is labeled “Rad Lab.” Click on the + sign next to “Rad Lab” to expand the folder, then scroll down to find the procedure that corresponds to the sample location and type. Use the cursor to put a check mark in the box next to the desired procedure, then click the “**Next**” button immediately below...

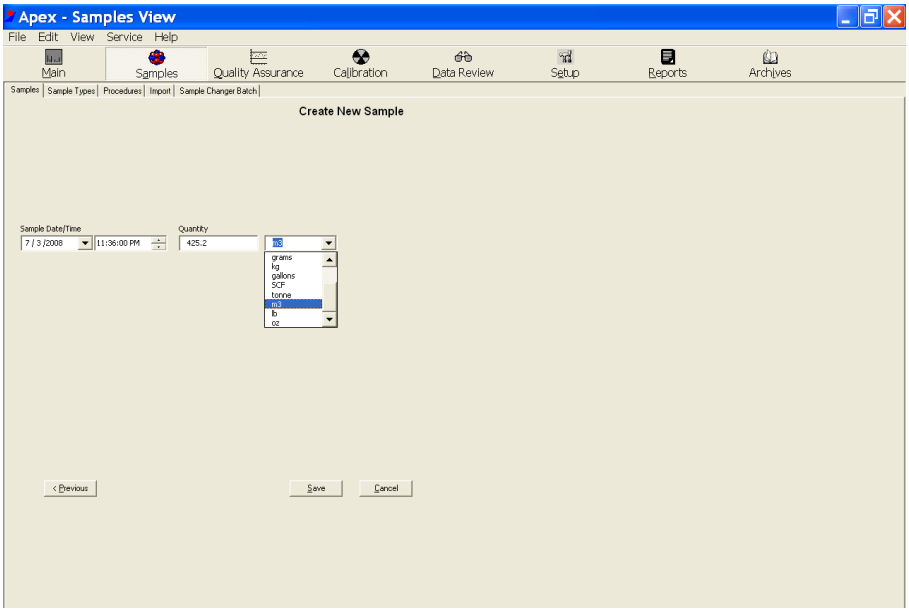


14.4.5 After you have clicked the “Next” button, a screen will appear for entering the sample date/time and quantity. Use the pull-down menu to select the sample date. Enter the time in hours and minutes, and enter AM or PM for the time. Set the “seconds” portion of the time field to zero.

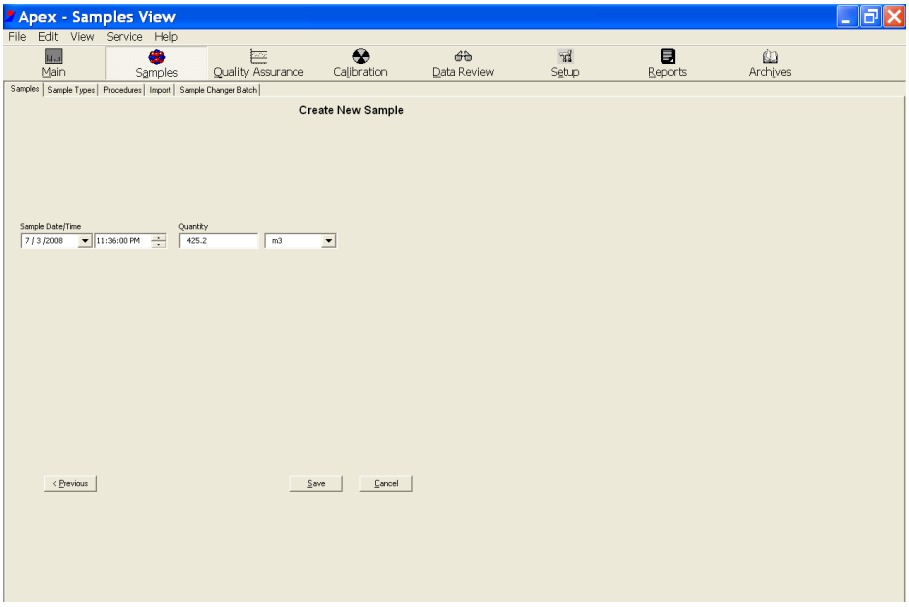


14.4.6 NOTE: The sample date and time for most samples is the collection date/time, except for charcoal cartridges and air particulate filters, for which the sample date/time is the mid-point time for sample collection

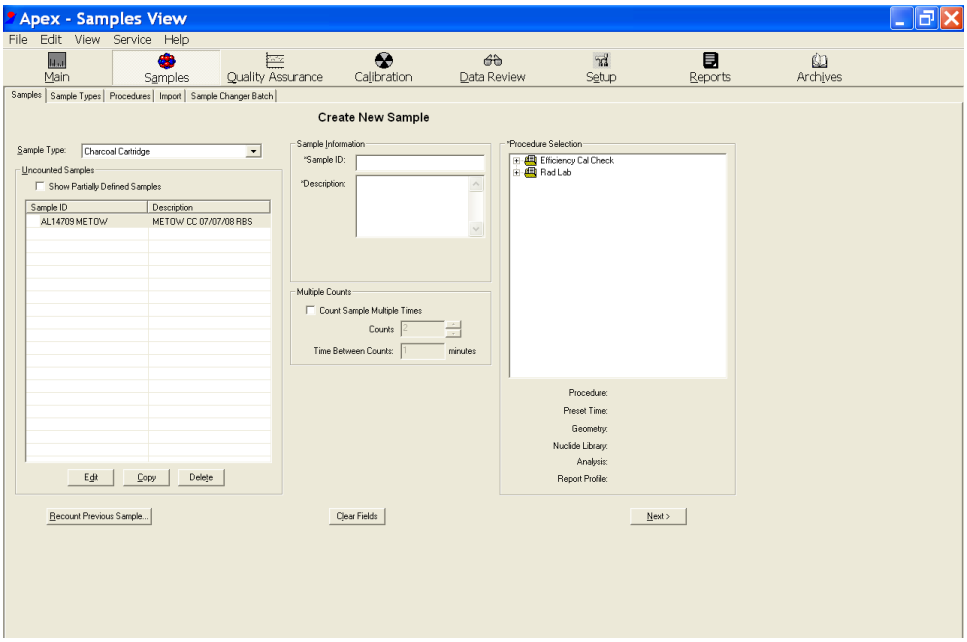
14.4.7 Enter the sample quantity in the designated field, and select the sample units from the pull-down list.



14.4.8 After all of the sample information has been entered, click the “Save” button.



14.4.9 After the sample information has been saved, you will be returned to the previous screen. The sample you just entered will be shown in the list of samples on the left-hand side of the screen. At this point you may enter additional samples, or return to the **Main View** screen.



14.5 Procedure for counting samples.

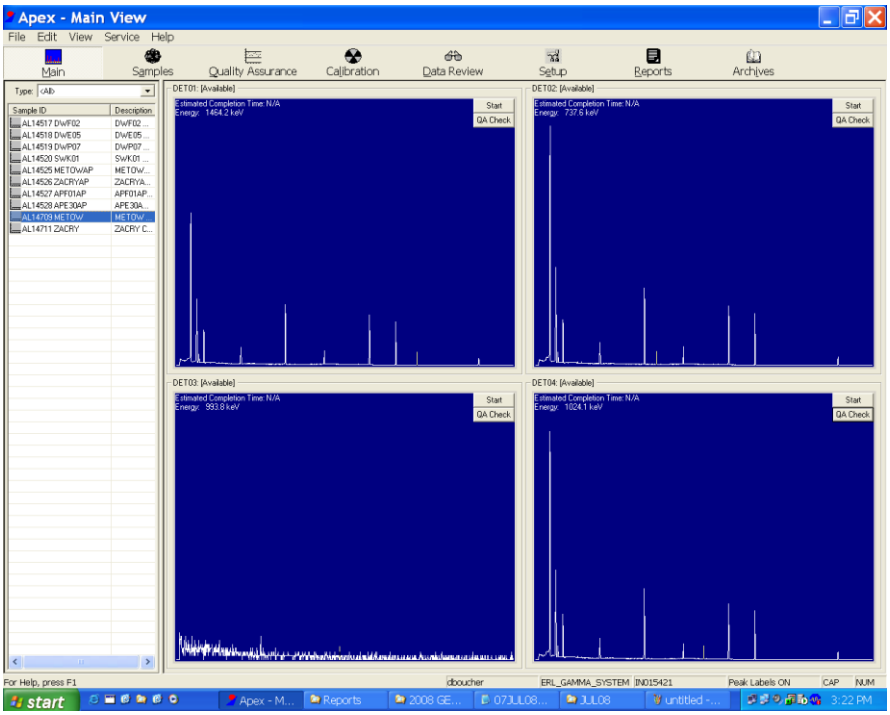
14.5.1 Prepare samples according to the current official Sample Preparation SOP (LDEQ SOP #1023).

14.5.2 Enter the sample information into Apex as described in the previous section.

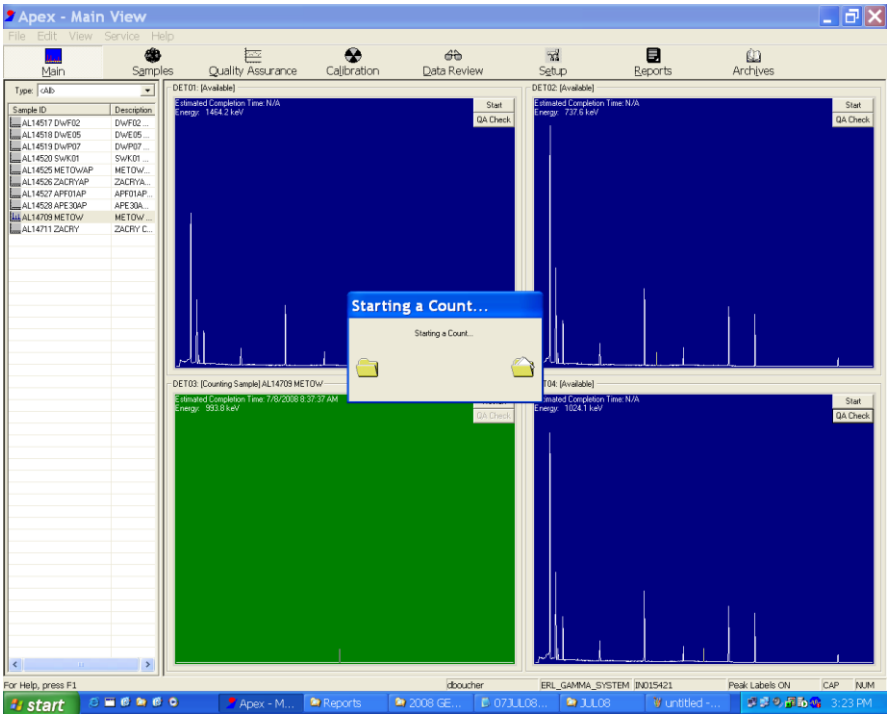
14.5.3 Place each sample to be run on one of the detectors inside the lead shield. To open the shield, grasp the lever with the left hand and lower it to the shield table. This will raise the top up just enough to allow it to swing to the left, opening the shield.

14.5.4 On the “Gamma Run Log.xlsx” spreadsheet, record the run date, detector number, LIMS Sample ID, and the Report Numbers (“Sample Number” from the Gamma Spectrum Analysis reports) for the Background QA Check and the Calibration QA check for each detector that is to be used.

14.5.5 On the **Apex – Main View** screen, a list of samples to be run is shown on the left-hand side of the screen.



14.5.6 Left-click on the sample in the list and, holding the mouse button down, drag the sample onto the screen that corresponds to the detector to be used to count the sample. The screen will turn from blue to green as the count begins.



14.5.7 The count time has been preset to 60,000 seconds for most types of samples. NORM samples are counted for 2000 seconds.

14.5.8 After the sample run has completed, a Sample Analysis report will print out automatically. On the first page of the report is an entry labeled "Sample Number." Open the Gamma Spectroscopy Sample Run Log spreadsheet (See Appendix C) and enter the Sample Number in the column labeled "Sample Report No."

14.5.9 Once sample data is has been entered and verified correct, save and exit the spreadsheet.

14.5.10 Copy the Analysis Report PDF file to the designated folder on the \\labshares|Radfiles\ drive.

15.0 Evaluation of Data, Reporting Results and Calculations

15.1 All data must be evaluated before reporting. All quality control samples must be within designated control limits.

15.1.1 Reports generated by the Quality Control procedure are set up to flag failures of quality control. Flags and acceptance criteria are described in Section 12.4 of this SOP, and in Appendix E. A table of flag definitions is printed at the bottom of the Last Measurement Q.A. Report, as shown in Appendix B. If a flag appears on the report, the analyst needs to examine the cause of the flags to determine whether the detector is ready for sample counting.

15.2 The ambient peaks detected during the background count are automatically subtracted from the sample spectrum.

15.3 Numerical results shall be reported to two decimal places.

15.4 The Apex software calculates the uncertainty for each result.

15.5 Data will be entered into LIMS. See Appendix A.

15.1 Decay-corrected activity is calculated by the following formula:

$$A = A_0 e^{-\lambda t}$$

Where: A : Decay-corrected activity

A_0 : Activity of the target nuclide at the time of calibration (Assay Date)

$$\lambda = \frac{\ln 2}{T_{1/2}}$$

$T_{1/2}$: Half life of the target nuclide

t: time from the calibration date to the date of activity calculation.

16.0 Method Performance

16.1 Demonstrations of Capability (DOC) must be performed at least annually or whenever there is a significant change in background or instrument response or when a new operator begins work.

16.2 Determination of Accuracy and Precision

16.2.1 Accuracy is determined by measuring the decay-corrected activity of representative nuclides (Cd-109, Cs-137, and Co-60) in the Quality Control Standard, as described in Section 12.4. Decay-corrected activities must satisfy the acceptance criteria described in Section 12.4 and in Appendix E, "Quality Control Limits for Gamma Spectroscopy."

16.2.2 Precision is measured as the standard deviation of repeated measurements of the Quality Control Standard. Decay-corrected activities must fall within ±5% of the assay value, and the selected peak energies must fall within ± 1.0 keV of the known energies. Additionally, all QC measures must satisfy the statistical acceptance criteria described in Section 12.4 and in Appendix E, "Quality Control Limits for Gamma Spectroscopy."

16.3 Energy Calibrations shall be evaluated by performing a 2000-second count of a calibration standard. This shall be done for each detector prior to the first time the detector is used after the calibration.

16.3.1 All key energy lines must be within ± 1.0 keV of the accepted values of those energies as defined in the nuclide library.

16.3.2 The difference between the measured key energy lines and the accepted values cannot be greater than the acceptance limits defined by the previous calibration.

16.3.3 The FWHM of the line at 1332.501 keV must be less than 2.20.

16.4 Efficiency Calibrations shall be evaluated for each geometry by performing a 2000-second count of the calibration standard for that geometry, for each detector. This shall be done for each detector prior to the first time the detector is used after the calibration.

16.4.1 The decay-corrected activity of the standard must fall within ± 5% of the original activity for Cd-109, Cs-137 and Co-60 as measured on the Assay Date. The decay-corrected activity of the standard must fall within ± 5% of the assayed activity for all other nuclides present.

16.5 Continuing Demonstration of Capability

16.5.1 Once initial laboratory and analyst capability are verified and established, a program of continued verification of data quality must be maintained. This requires:

16.5.1.1 Performance of the Quality Control procedure as described in Section 12.4.

16.5.1.2 Regular calibration and maintenance of laboratory instrumentation.

16.5.1.3 Maintenance of quality control records.

16.5.2 Annual performance of at least one of the following is required:

16.5.2.1 Performance of four consecutive Quality Control procedures with acceptable recovery and precision, or

16.5.2.2 An initial DOC study.

16.5.3 Documentation of Demonstrations of Capability must be kept in the analyst's training file. Training files are kept by the section supervisor.

17.0 Pollution Prevention

17.1 Pollution prevention encompasses any technique that reduces or eliminates the quantity or toxicity of waste at the point of generation.

17.2 The quantity of chemicals purchased is based on expected usage during its shelf life and disposal cost of unused material.

18.0 Data Assessment and Acceptance Criteria

18.1 All data collected in the quality control procedures is assessed for accuracy and precision as per Section 16.2 of this SOP. Quality Control parameters are described in Section 12.4.

18.2 Statistical acceptance criteria for Quality Control parameters were derived from results obtained from the analysis of the Quality Control Standard over a period from 06/23/08 through 08/06/08. Acceptance criteria shall be re-evaluated and updated at a minimum annually, whenever a new set of gamma standards is put into use, or if the detector is repaired. Current acceptance criteria are listed in Appendix E, "Quality Control Limits for Gamma Spectroscopy."

18.3 Data generated by the Quality Control procedure will determine QC pass or failure via any flag or deviation. If reports don't have any flag or deviation, QC is passed and ready for sample measurements. If flags or deviations are on the report, the analyst must investigate, perform any necessary corrective action, and ascertain that the problem has been corrected before the detector can be used for sample counting.

19.0 Corrective Action for Out of Control Data

19.1 Corrective Action procedures are described in Section 12.5.

19.2 If the procedures listed in Section 12.5 are not effective in correcting the problem, the detector must not be used until diagnostics have been completed and the problem resolved. The assistance of Canberra System Service Engineer(s) shall be utilized to determine the cause of out of control data.

20.0 Contingencies for Handling Unacceptable Data

20.1 Unacceptable QC data will result in the detector being unavailable for use until corrective action has been taken and the data from the system has been returned to acceptable conditions, i.e., at or near factory specifications.

21.0 Waste Management

21.1 Samples with an exposure rate less than or equal to 200 µR/h, or that upon analysis are shown to have activity equivalent to background or control samples can be disposed of in the same manner as ordinary waste. After a sample has been analyzed, if it is determined that the total sample activity is lower than 200 pCi, the sample+ can be handled and disposed of as non-radioactive material.

21.1.1 Solid samples and leftovers are put into a trash can that has been lined with a plastic bag. If necessary, put the sample in a plastic bag and then secure the bag before discarding.

21.1.2 Liquid samples must be drained into the double black sink in R01 with plenty of running water.

21.2 Samples that are determined to have radioactive levels unsuitable for regular disposal will be disposed in a safe way and by an NRC approved method.

22.0 Data and Records Management

22.1 Procedures for data and records management must adhere to the Quality Manual and subordinate documents covering record keeping and the document control plan. Records documenting all laboratory activities shall be retained permanently. All records shall be stored in such a way as to be secure and accessible.

22.2 All printed records must be initialed and dated by the analyst.

22.3 Certificates of analysis for standards used are kept in the designated binder by the analyst.

22.4 All Quality Control printouts must be kept in the designated binders for each detector to document the performance of the instrument. There is a separate binder for each detector assembly, and a common binder for temporary storage. At the end of the month, Quality Control data will be moved from the temporary binder to the permanent binder of each detector.

22.5 There is a bound maintenance logbook for each detector assembly, as well as a separate bound logbook for the Genie 2000 hardware. All ongoing maintenance and preventive maintenance must be documented in the designated logbook.

22.6 Electronic records are kept stored on the computer hard drive and are backed up on compact disks.

22.7 Printouts of test results shall be initialed and dated, and kept in reverse chronological order in designated folders in the file cabinet for a minimum of one year. There is a designated file draw for each of the three reactor sites, with a separate folder for each sample location and matrix.

22.8 Older documents shall be moved to storage folders, and kept in document storage boxes by year. Boxed documents shall be placed in the data storage room.

22.9 Data generated during Gamma analysis will be reviewed by the laboratory. When the data are approved as acceptable, the analysis data will then be filed in the designated location. Data generated on the nuclear power plants will be included in the laboratory's report data file for the respective power plant.

23.0 Tables, Diagrams, Flowcharts, and Validation Data

23.1 N/A

24.0 References

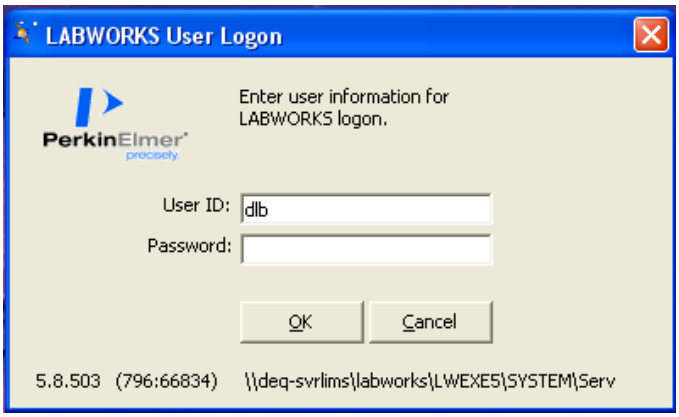
24.1 Apex 1.2 Lab Productivity Suite User's Manual.

24.2 Canberra Genie 2000 Gamma Spectroscopy System Manual

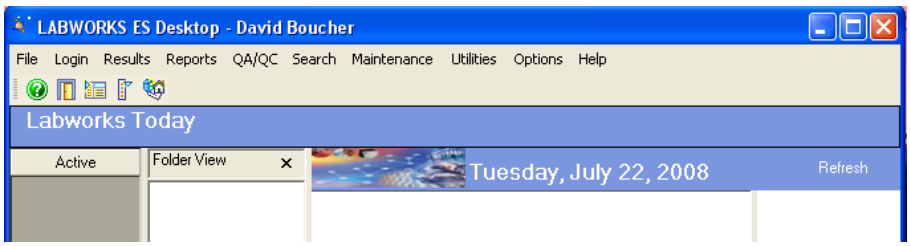
Appendix A. Logging into LIMS and Entering Data.

A1.0 Logging on to the LIMS System

A1.1 Click on the **LabWorks** icon on the desktop, enter your username and password in the designated fields, and click the "**OK**" button.



A1.2 The **LabWorks ES Desktop** screen will appear.

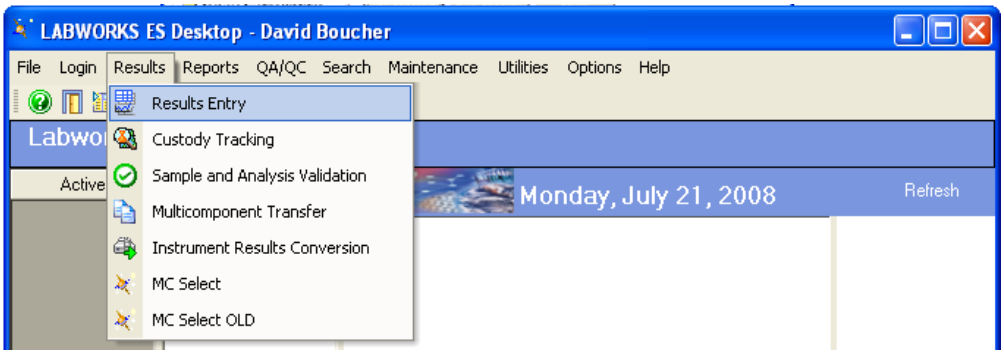


A2.0 Sample Log-In

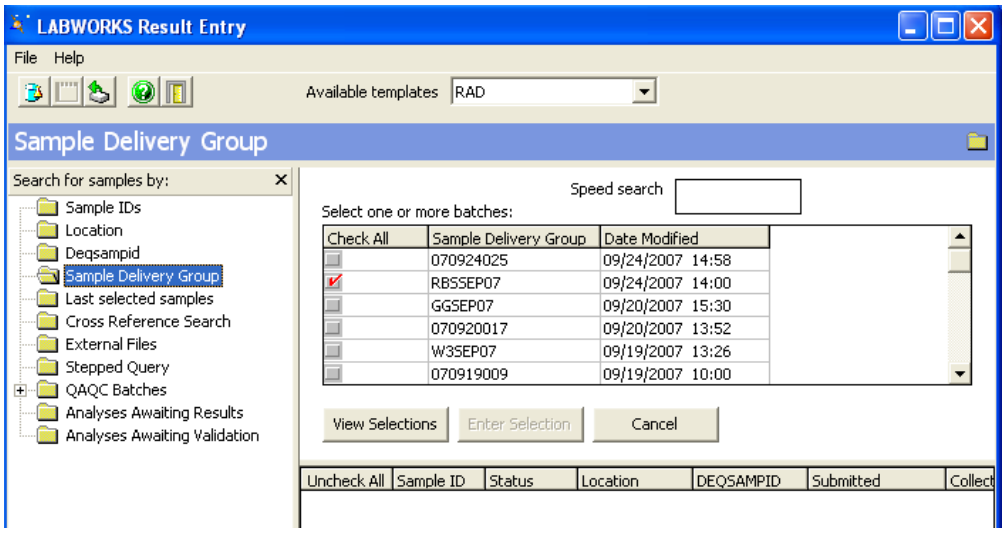
A2.1 The procedure for Sample Login is found in Appendix A of current official LDEQ SOP 1023, "Preparation of Samples for Gamma Spectroscopy and Gross Beta Analysis."

A3.0 Entering Data into LIMS

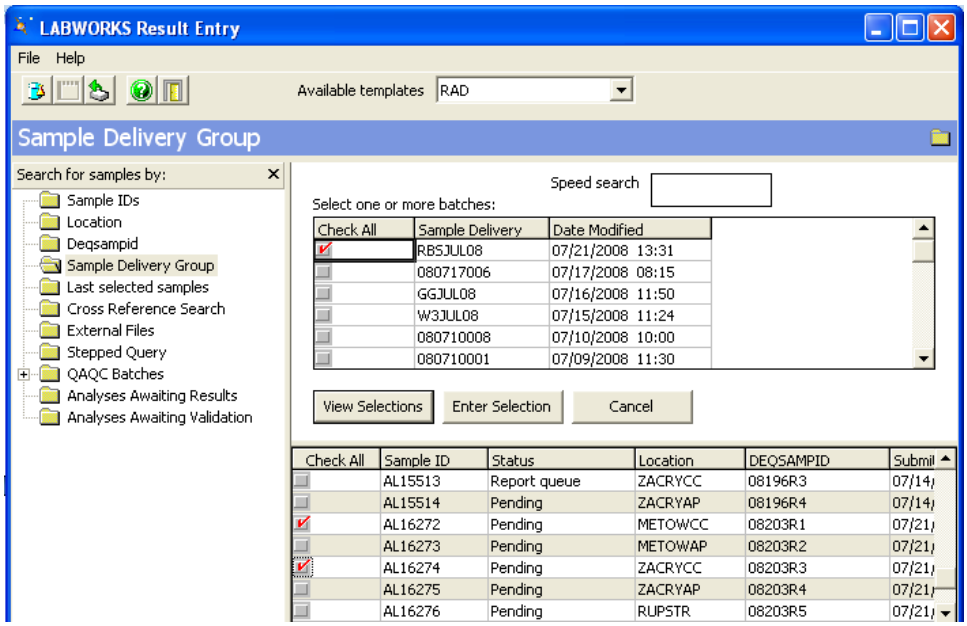
A3.1 Select Result Entry in the Results menu



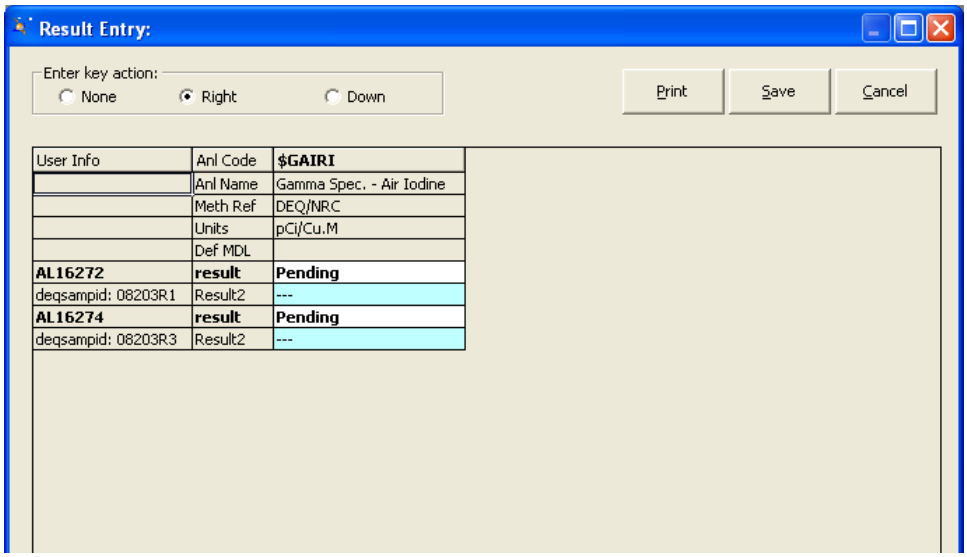
A3.2 In the "**Search for samples by"** menu, select **Sample Delivery Group.** Check the desired sample delivery group and click **View Selections.**



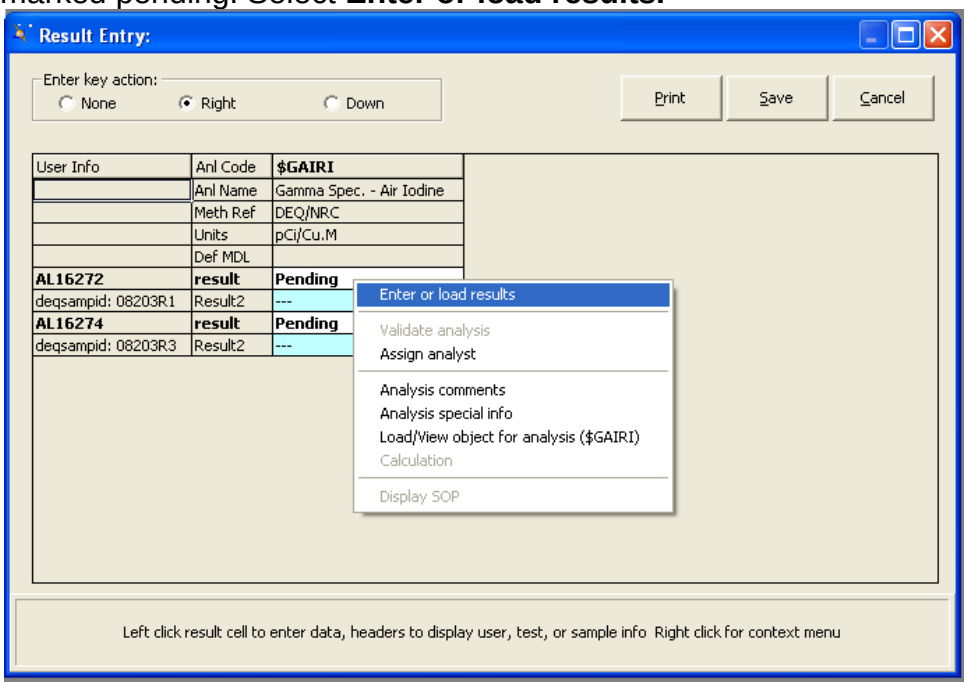
A3.3 A list of samples will appear in the field at the lower right corner of the window, as shown below. Samples for which results have not yet been entered will be listed with status "Pending." Click the header of the first column to uncheck all samples and then check the samples for which you want to enter results.



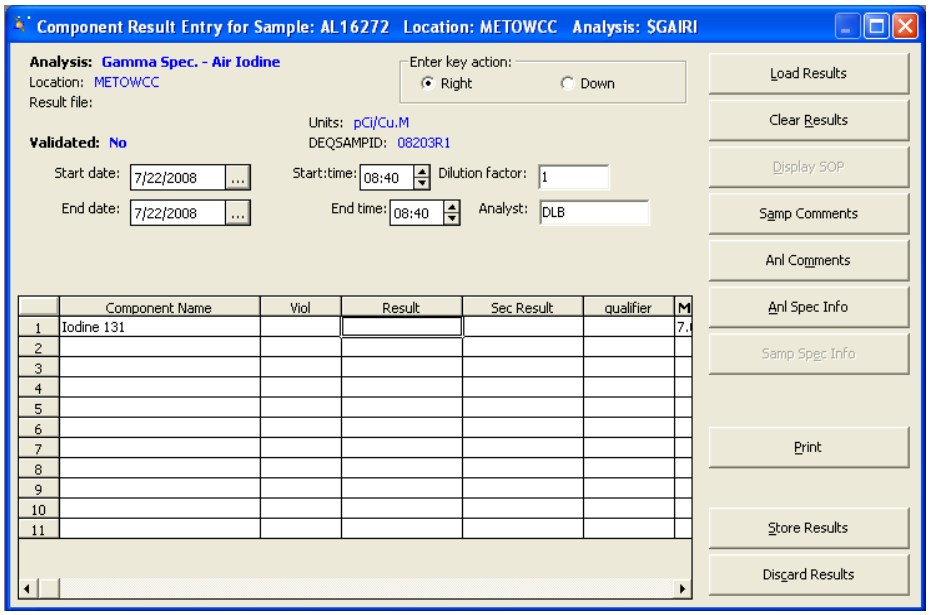
A3.4 After all of the desired samples have been selected, click **Enter Selection.** The **Result Entry** spreadsheet will appear, as shown below.



A3.5 The samples in the batch are listed in the rows, the analysis selected are listed in the columns. Select a sample analysis by left clicking on the box marked pending. Select **Enter or load results.**

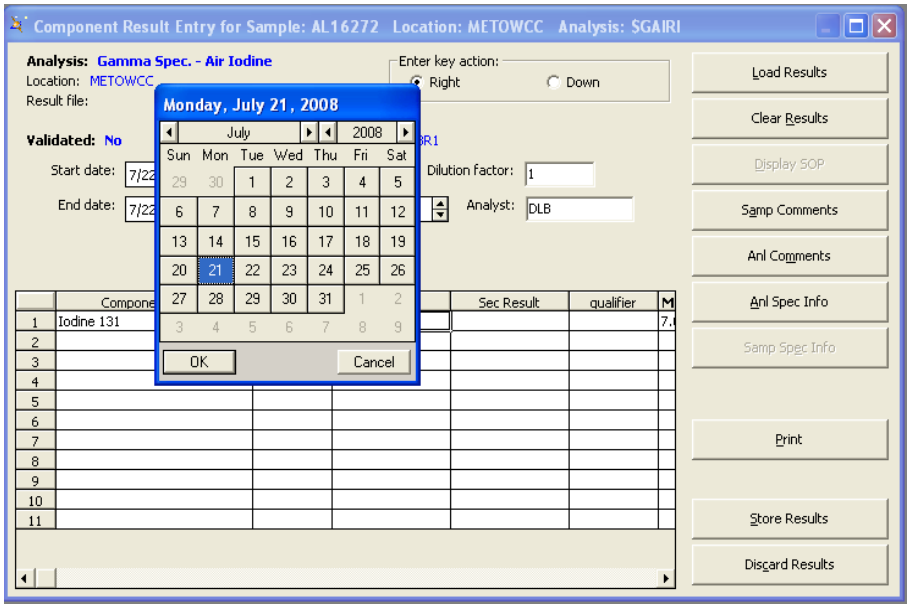


A3.6 The **Component Result Entry for Sample** ###### is displayed. Fill in the appropriate data fields. The information needed to complete the fields is found on the "Analysis Report" print-out that is generated by the Apex software when the analysis is complete.



A3.6.1 The Start Date and Start Time are "Acquisition Started" date and time on the first page of the printout.

A3.6.2 The End Date and End Time are the date and time listed in the header on each page of the printout.



A3.7 The nuclides you need to find results for (i.e. the nuclides of interest) are listed on the LIMS “Component Results Entry” screen in the column labeled “Component Name.” In the example shown above, the nuclide of interest is Iodine-131.

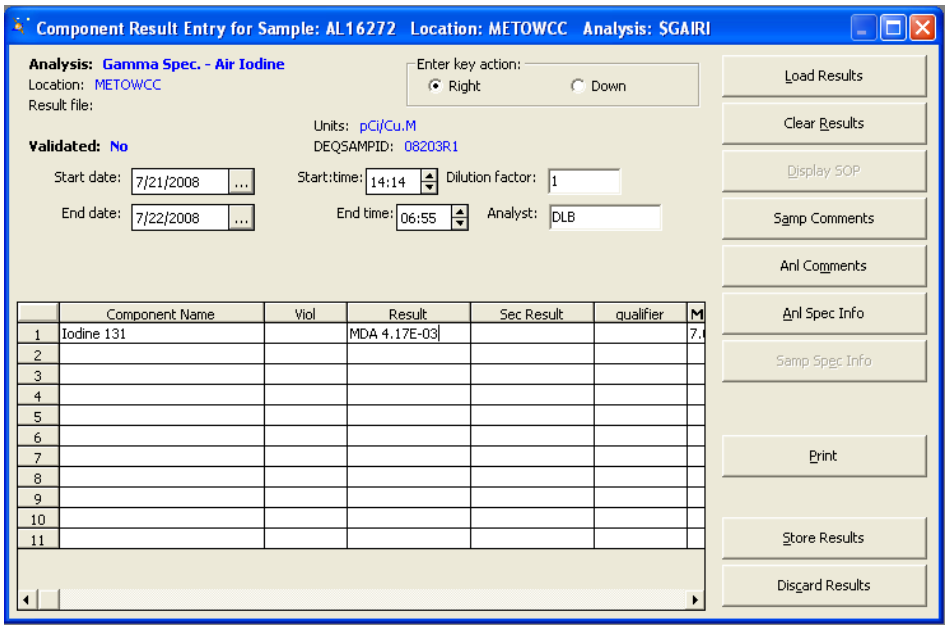
A3.8 There are two places on the Analysis Report printout that you need to look for results: the “Nuclide Identification Report”, which is the third section of the report printout; and the “Nuclide MDA Report”, which is the last Section of the Analysis Report.

A3.8.1 If there is no result in the Nuclide Identification Report for the nuclide of interest: In the “Result” column of the LIMS screen, enter the letters “MDA” followed by the Nuclide MDA numerical result listed on the Nuclide MDA Report. For example, if the Nuclide MDA for Iodine-131 on the printout is 4.17E-03, enter “MDA 4.17E-03” in the results field.

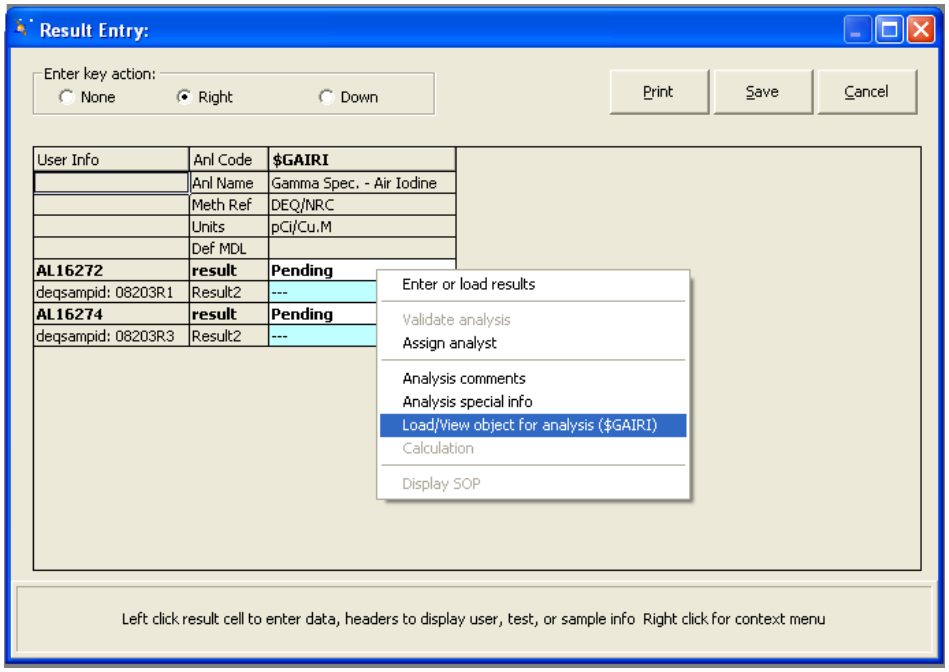
A3.8.2 If there is a result listed for the nuclide of interest in the Nuclide Identification Report: Enter the number for the Activity from the Nuclide Identification Report in the “Result” column of the LIMS screen, then enter the MDA in the “Secondary Result” column. Use the same format for entering the MDA as described in the previous paragraph.

A3.8.3 **Sample comments** are used to report any violations of collection or storage, failed QC results in the batch, and reporting of TICS.

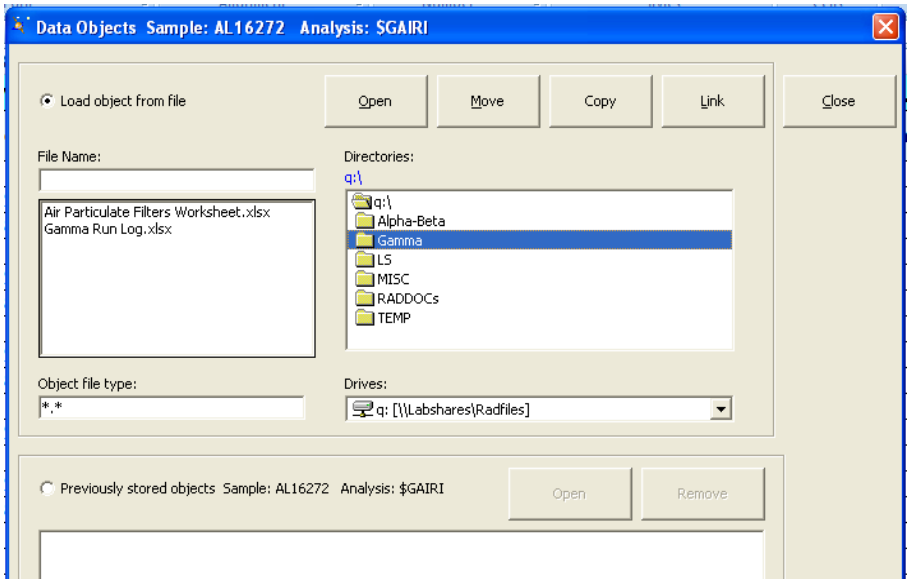
A3.9 When all data has been entered for the analysis, click the “**Store Results” button.**



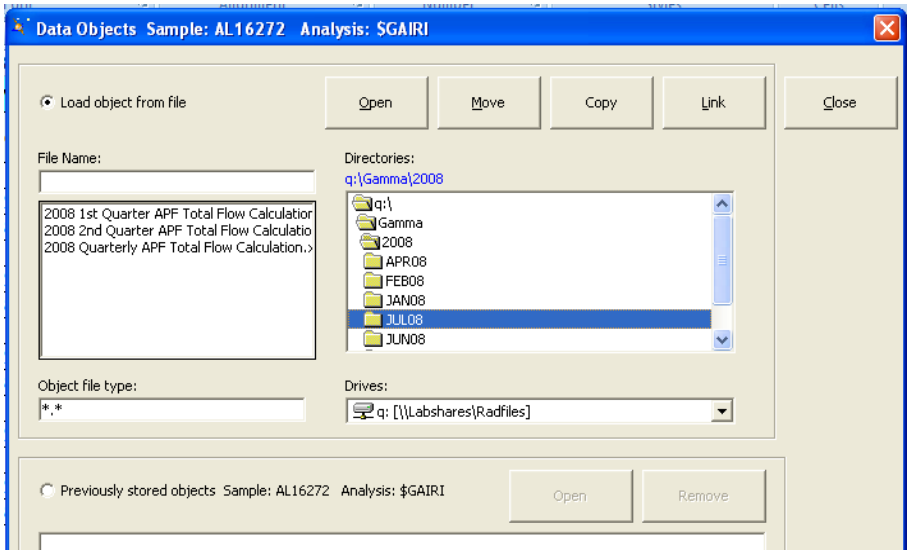
A3.10 The **Result Entry for Login record file screen** will displayed again. The next step is to link the appropriate Quality Control data files to the result. To start, right-click and select **Load/View object for analysis**.



A3.11 The **Data Objects Sample: ####### Analysis** screen will appear. Select the **\\labshares\Radfiles** network drive on the pull-down menu labeled "Drives." On computers in the Radiation lab, this will be mapped as the "Q:" drive.



A3.12 Select the folder that contains the Gamma QC and Analysis Report files for the current month and year. The pathname is in the format: \Gamma\2008\JUL08\ for samples collected in July 2008. Double-click the folder to open it.



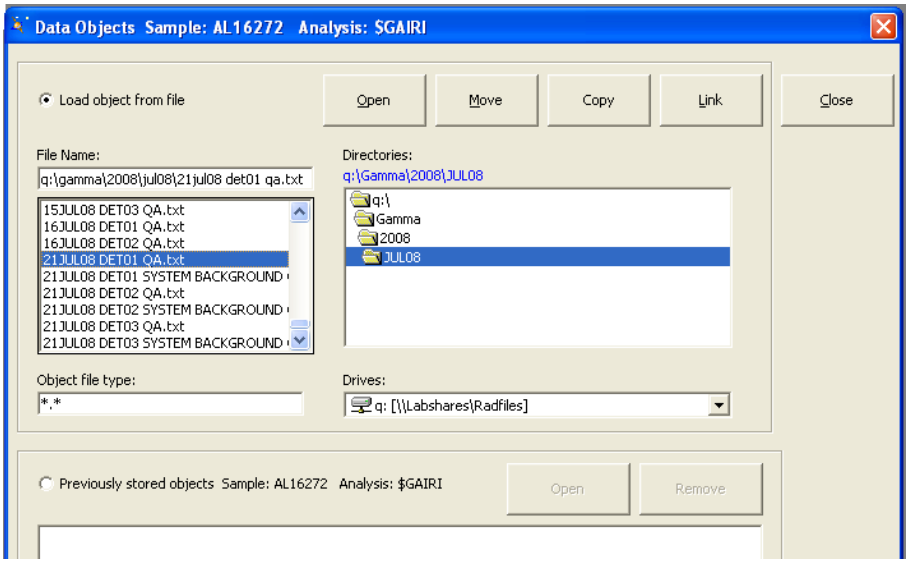
A3.13 You will be linking the following files, in the order shown below:

A2.1.1 The "Last Measurement Q.A. Report" text file that you created for the detector used (See Section 14.3.8 for the procedure to create this file).

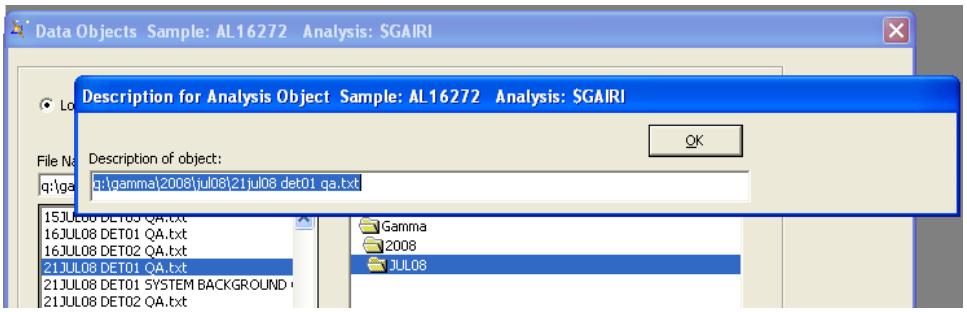
A2.1.2 The numbered Analysis Report PDF file for the Calibration QA Check that you performed for the detector used.

A2.1.3 The numbered Analysis Report PDF file for the Sample Analysis.

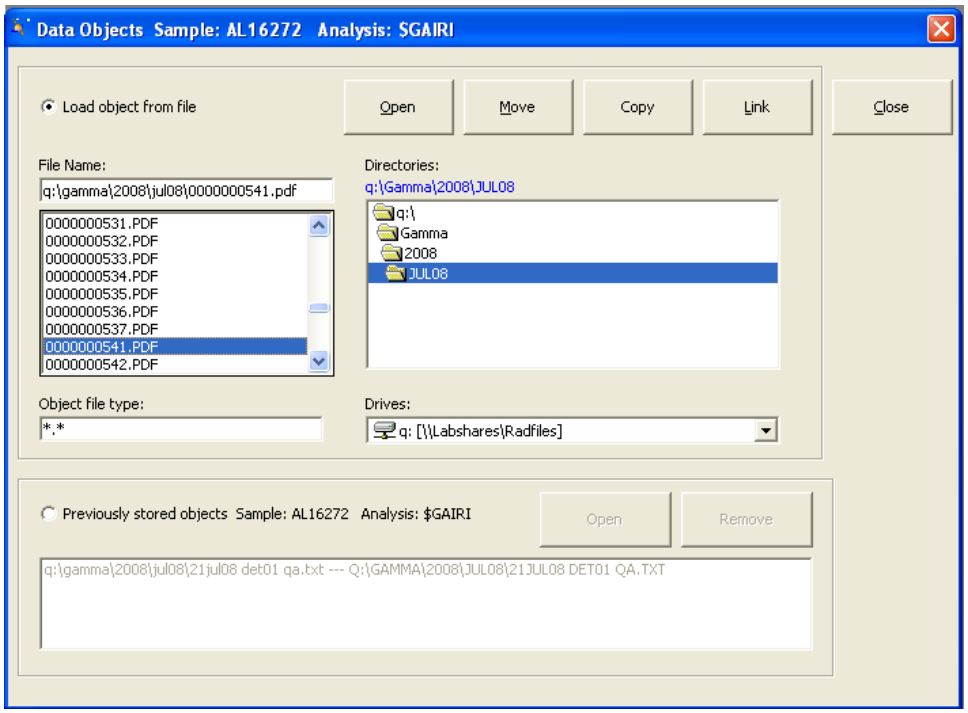
A3.14 Highlight the file name for the date and the detector used when the sample was counted, then click **Link.**



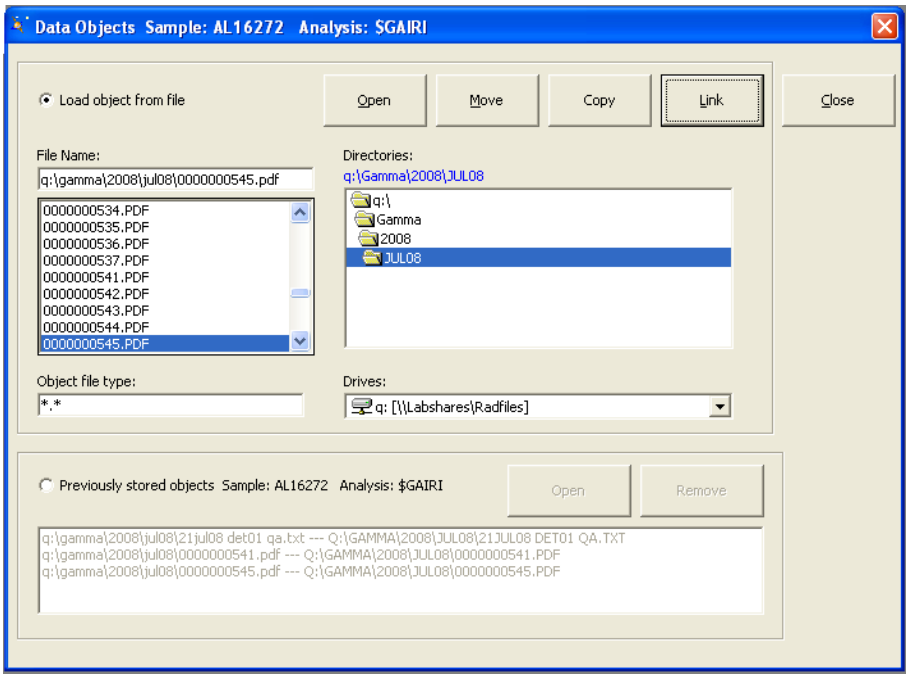
A3.15 The **Description for Analysis Object Sample: ####### Analysis** message will appear. Click **OK.**



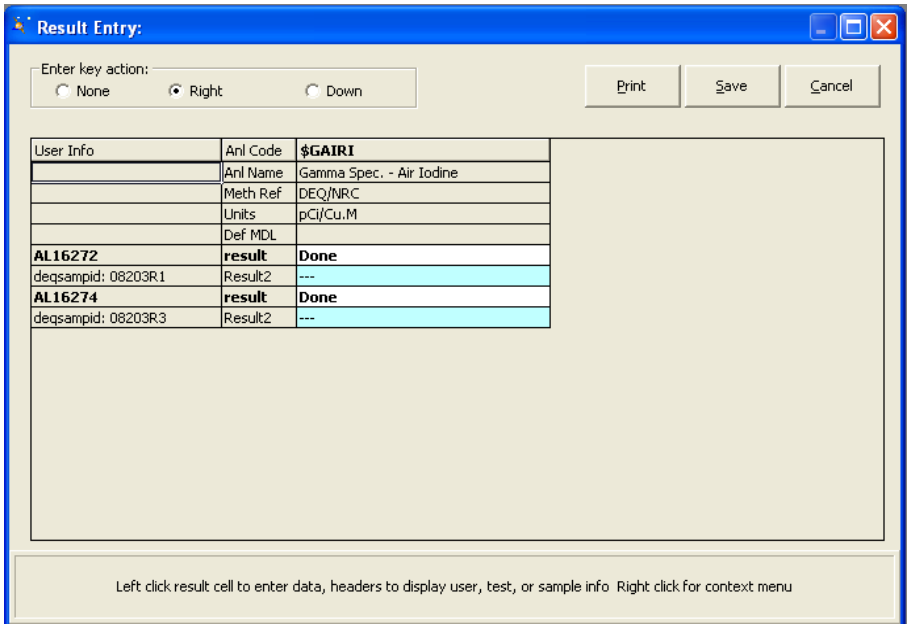
A3.16 The **Data Objects Sample:####### Analysis** screen will appear again. Select the Analysis Report PDF file for the QA Calibration Check, and Link the file as described in Section A3.14-15. Repeat this procedure a third time, and link the Analysis Report PDF file for the Sample itself.



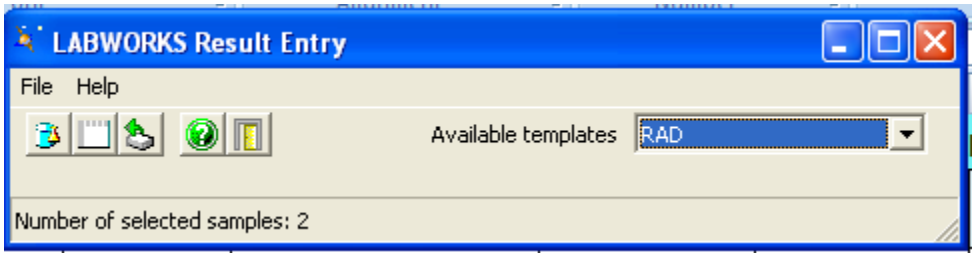
A3.17 After all the QA and Analysis Report files have been linked, click the "Close" button to return to the results entry menu.



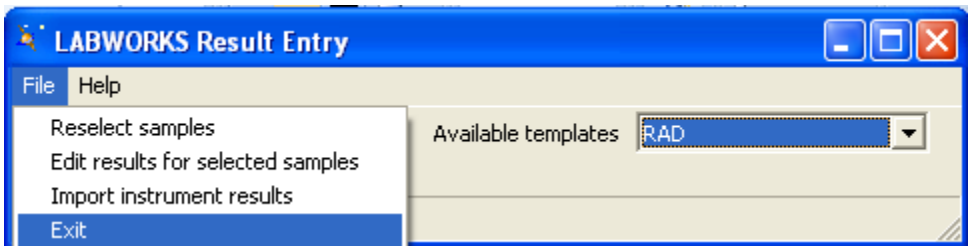
A3.18 After all of the results have been entered and the QA and Analysis Report files have been linked, all of the results on the Result Entry window will be listed as Done. Clink the "Print" button. After the page has printed, click "**Save**." File the printed page in the designated binder.



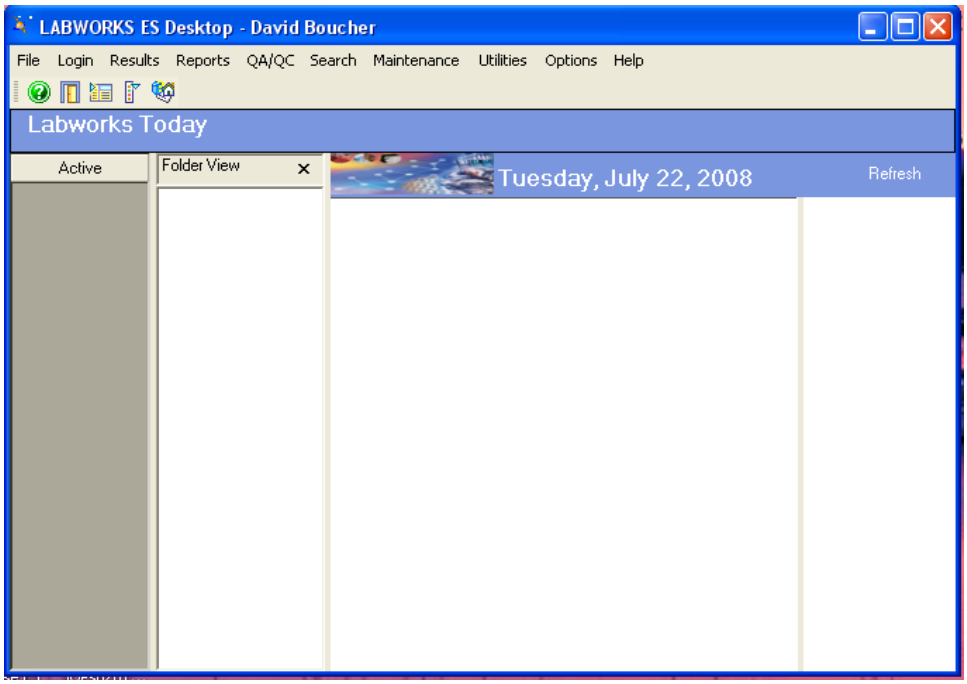
A3.19 Once this window is closed, an abbreviated **Results Entry** menu will appear.



A3.20 Click on the file menu for further options. If you need to enter results for other samples, select "**Reselect samples**" to return to the full **Results Entry** menu as shown in Section A3.2. If you are finished, select "**Exit**."



A3.21 The program will return to the **LABWORKS ES Desktop** window. Close the window and exit LABWORKS.



Appendix B. Apex Reports

B1.0 Last Measurement Q.A. Reports

B1.1 QA Calibration Check, Last Results Report.

```
Last Measurement Q.A. Report       7/22/08  12:14:51 PM        Page  1

*************************************************************************
*****         G E N I E   Q U A L I T Y   A S S U R A N C E         *****
*************************************************************************

                          Last Results Report
                          7/22/08  12:14:51 PM

QA File:\\IN015421\ApexRoot\ERL_GAMMA_SYSTEM\QA\D00000000032007GEO11C.QCK

Detector:        DET03
Geometry:        <None>
Certificate:     2007GEO11
Sample ID:         QA Calibration C
Sample Quantity:    1.0000E+000
Sample Date:       7/1/07   11:00:00 AM
Measurement Date:  7/22/08  11:33:30 AM
Elapsed Live Time:     1000.0 seconds
Elapsed Real Time:     1017.0 seconds

Parameter Description           Value                Deviation/Flags
 [Mean +/- Std. Dev.]                             < LU : SD : UD : BS >

Peak Energy - 88.034          8.7939E+001             2.4312E-002
 [SD: 8.7938E+001+/- 0.028]                       <    :    :    :    >

Peak Energy - 661.657         6.6174E+002             1.0177E-001
 [SD: 6.6173E+002+/- 0.109]                       <    :    :    :    >

Peak Energy - 1332.501        1.3328E+003             4.1406E-001
 [SD: 1.3327E+003+/- 0.193]                       <    :    :    :    >

Peak FWHM - 1332.501          1.8742E+000             6.7458E-002
 [SD: 1.8702E+000+/- 0.059]                       <    :    :    :    >

Decay Cor. Act. - Cd-109      1.5824E+006             7.4509E-001
 [SD: 1.5357E+006+/-62703.]                       <    :    :    :    >

Decay Cor. Act. - Cs-137      4.3327E+004             9.6297E-001
 [SD: 4.1274E+004+/-2131.7]                       <    :    :    :    >

Decay Cor. Act. - Co-60       6.8800E+004             8.6728E-001
 [SD: 6.6038E+004+/-3184.6]                       <    :    :    :    >


Flags Key:   LU = Lower/Upper Bounds Test     (Ab = Above, Be = Below)
             SD = Sample Driven N-Sigma Test  (In = Investigate, Ac = Action)
             UD = User Driven N-Sigma Test    (In = Investigate, Ac = Action)
             BS = Measurement Bias Test       (In = Investigate, Ac = Action)
```

B1.2 QA Background Check, Last Results Report.

```
Last Measurement Q.A. Report       7/22/08  12:14:15 PM        Page  1

*************************************************************************
*****         G E N I E   Q U A L I T Y   A S S U R A N C E         *****
*************************************************************************

                          Last Results Report
                          7/22/08  12:14:15 PM

QA File:\\IN015421\ApexRoot\ERL_GAMMA_SYSTEM\QA\D0000000003B.QCK

Detector:        DET03
Geometry:        <None>
Certificate:     <None>
Sample ID:         QA Background Ch
Sample Quantity:    1.0000E+000
Sample Date:       7/22/08  11:15:00 AM
Measurement Date:  7/22/08  11:15:02 AM
Elapsed Live Time:     1000.0 seconds
Elapsed Real Time:     1000.1 seconds


Parameter Description           Value                Deviation/Flags
 [Mean +/- Std. Dev.]                             < LU : SD : UD : BS >

Low Region                    5.6600E+002              1.1312E+000
 [SD: 5.3592E+002+/-26.594]                       <    :    :    :    >

High Region                   1.0240E+003              1.9088E+000
 [SD: 9.7133E+002+/-27.591]                       <    :    :    :    >


Flags Key:   LU = Lower/Upper Bounds Test     (Ab = Above, Be = Below)
             SD = Sample Driven N-Sigma Test  (In = Investigate, Ac = Action)
             UD = User Driven N-Sigma Test    (In = Investigate, Ac = Action)
             BS = Measurement Bias Test       (In = Investigate, Ac = Action)
```

B2.0 Analysis Reports

B2.1 QA Calibration Check Analysis Report

7/22/2008 11:50:53AM Page 1 of 2

Analysis Report for QA Calibration Check
QA Count

GAMMA SPECTRUM ANALYSIS

Sample Identification	: QA Calibration Check
Sample Description	: QA Count
Sample Type	: QA Calibration Check
Sample Size	: 1.000E+00 units
Facility	: ERL_GAMMA_SYSTEM
Sample Taken On	: 7/1/2007 11:00:00AM
Acquisition Started	: 7/22/2008 11:33:30AM
Procedure	: QA Calibration
Operator	: dboucher
Detector Name	: DET03
Geometry	: Quality Control Poly-Jar
Live Time	: 1000.0 seconds
Real Time	: 1017.0 seconds
Dead Time	: 1.67 %
Peak Locate Threshold	: 3.50
Peak Locate Range (in channels)	: 50 - 4096
Peak Area Range (in channels)	: 50 - 4096
Identification Energy Tolerance	: 1.000 keV
Energy Calibration Used Done On	: 6/23/2008
Efficiency Calibration Used Done On	: 6/23/2008
Efficiency Calibration Description	: Efficiency Calibration Geo 11
Sample Number	: 551

PEAK LOCATE REPORT

Peak Locate Performed on	: 7/22/2008 11:50:35AM
Peak Locate From Channel	: 50
Peak Locate To Channel	: 4096
Peak Search Sensitivity	: 3.50

Peak No.	Energy (keV)	Centroid Channel	Centroid Uncertainty	Peak Significance
1	87.94	176.76	0.0772	105.99
2	122.06	245.01	0.0870	76.10

Analysis Report for QA Calibration Check
QA Count

Peak No.	Energy (keV)	Centroid Channel	Centroid Uncertainty	Peak Significance
3	136.47	273.83	0.1593	23.35
4	165.87	332.63	0.1017	52.58
5	255.34	511.56	0.3359	5.00
6	279.34	559.57	0.2939	5.59
7	391.89	784.65	0.1103	39.15
8	661.74	1324.20	0.0672	92.92
9	898.18	1796.83	0.0954	43.21
10	1173.35	2346.76	0.0626	92.64
11	1332.76	2665.27	0.0625	88.18
12	1836.35	3671.19	0.0955	33.36

? = Adjacent peak noted
Errors quoted at 1.000 sigma

PEAK ANALYSIS REPORT

Peak Analysis Performed on : 7/22/2008 11:50:35AM

Peak Analysis From Channel : 50
Peak Analysis To Channel : 4096

Peak No.	Energy (keV)	ROI start	ROI end	Peak Centroid	Net Peak Area	Net Area Uncertainty	Continuum Counts	FWHM (keV)
1	87.94	168 -	184	176.76	6.04E+04	291.82	1.19E+04	1.12
2	122.06	236 -	253	245.01	2.42E+04	198.18	7.52E+03	1.14
3	136.47	270 -	277	273.83	2.79E+03	82.39	2.76E+03	1.12
4	165.87	325 -	339	332.63	1.23E+04	144.42	4.66E+03	1.21
5	255.34	508 -	520	511.56	2.63E+02	75.75	3.30E+03	1.20
6	279.34	553 -	564	559.57	2.45E+02	69.32	2.84E+03	1.33
7	391.89	776 -	791	784.65	6.49E+03	109.21	3.15E+03	1.37
8	661.74	1313 -	1333	1324.20	2.79E+04	181.27	2.65E+03	1.52
9	898.18	1790 -	1803	1796.83	6.32E+03	96.73	1.97E+03	1.70
10	1173.35	2332 -	2361	2346.76	2.79E+04	176.86	1.63E+03	1.82
11	1332.76	2656 -	2676	2665.27	2.54E+04	161.98	5.14E+02	1.87
12	1836.35	3657 -	3678	3671.19	3.84E+03	63.46	1.13E+02	2.14

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet
Errors quoted at 1.000 sigma

B2.2 Sample Analysis Report.

7/22/2008 6:54:38AM Page 1 of 5

Analysis Report for AL16272 METOW
METOW CC 07/21/08 RBS

GAMMA SPECTRUM ANALYSIS

Sample Identification	: AL16272 METOW
Sample Description	: METOW CC 07/21/08 RBS
Sample Type	: Charcoal Cartridge
Sample Size	: 4.266E+02 m3
Facility	: ERL_GAMMA_SYSTEM
Sample Taken On	: 7/18/2008 12:00:00AM
Acquisition Started	: 7/21/2008 2:14:02PM
Procedure	: METOWCC
Operator	: dboucher
Detector Name	: DET01
Geometry	: Charcoal Cartridge
Live Time	: 60000.0 seconds
Real Time	: 60003.5 seconds
Dead Time	: 0.01 %
Peak Locate Threshold	: 3.50
Peak Locate Range (in channels)	: 50 - 4096
Peak Area Range (in channels)	: 50 - 4096
Identification Energy Tolerance	: 1.000 keV
Energy Calibration Used Done On	: 6/23/2008
Efficiency Calibration Used Done On	: 6/23/2008
Efficiency Calibration Description	: Efficiency Calibration Geo 06
Sample Number	: 547

PEAK ANALYSIS REPORT

Peak Analysis Performed on : 7/22/2008 6:54:17AM
Peak Analysis From Channel : 50
Peak Analysis To Channel : 4096

Peak No.	Energy (keV)	ROI start	ROI end	Peak Centroid	Net Peak Area	Net Area Uncertainty	Continuum Counts	FWHM (keV)
1	63.27	118 -	132	127.10	2.44E+02	48.88	1.27E+03	1.57
2	77.37	143 -	159	155.31	2.93E+02	54.32	1.55E+03	1.15
3	92.71	181 -	192	185.99	6.86E+02	48.17	1.08E+03	1.42

Analysis Report for AL16272 METOW

METOW CC 07/21/08 RBS

Peak No.	Energy (keV)	ROI start	ROI end	Peak Centroid	Net Peak Area	Net Area Uncertainty	Continuum Counts	FWHM (keV)
4	185.72	367 -	380	372.02	4.88E+02	44.90	9.84E+02	1.36
5	238.69	469 -	491	477.99	5.00E+02	54.70	1.32E+03	1.43
6	294.90	583 -	595	590.39	8.36E+01	31.80	6.17E+02	1.64
7	352.15	701 -	709	704.90	1.45E+02	24.32	3.36E+02	1.02
8	510.95	1011 -	1034	1022.46	1.25E+03	47.14	5.39E+02	2.48
9	583.42	1164 -	1174	1167.38	1.62E+02	20.95	2.00E+02	1.97
10	609.27	1215 -	1225	1219.07	1.37E+02	22.24	2.59E+02	1.54
11	1460.96	2916 -	2928	2921.57	6.27E+02	26.81	6.74E+01	2.01

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet
Errors quoted at 1.000 sigma

No background subtract performed on this spectrum.

NUCLIDE IDENTIFICATION REPORT

Nuclide Library Used : \\IN015421\ApexRoot\ERL_GAMMA_SYSTEM\Library\LIBRARY1.NLB

IDENTIFIED NUCLIDES

Nuclide Name	Id Confidence	Energy (keV)		Yield(%)	Activity (pCi/m3)	Activity Uncertainty
K-40	0.99	1460.81	*	10.67	3.96E-01	1.92E-02
PB-212	0.62	74.81		9.60		
		77.11	*	17.50	2.29E-02	4.57E-03
		87.20		6.30		
		238.63	*	44.60	1.44E-02	1.62E-03
		300.09		3.41		
PB-214	0.62	74.81		6.33		
		77.11	*	10.70	3.75E-02	7.48E-03
		87.20		3.70		
		241.98		7.49		
		295.21	*	19.20	6.63E-03	2.53E-03
		351.92	*	37.20	6.94E-03	1.17E-03
		480.43		0.32		
		511.00	*	0.03	9.73E+01	4.17E+00
TH-234	0.99	63.29	*	4.50	1.32E-01	4.56E-02
		92.38	*	2.60	3.19E-01	7.76E-02
U-235	0.49	89.96		1.50		
		93.35	*	2.50	2.96E-01	2.27E-02
		105.00		1.00		
		109.14		1.50		
		140.76		0.22		

Analysis Report for AL16272 METOW

METOW CC 07/21/08 RBS

Nuclide Name	Id Confidence	Energy (keV)		Yield(%)	Activity (pCi/m3)	Activity Uncertainty
U-235	0.49	143.76		10.50		
		163.35		4.70		
		185.71	*	54.00	9.76E-03	9.43E-04
		198.93		0.04		
		202.12		1.00		
		205.31		4.70		

* = Energy line found in the spectrum.
\- = Manually added nuclide.
? = Manually edited nuclide.
@ = Energy line not used for Weighted Mean Activity
Energy Tolerance : 1.000 keV
Nuclide confidence index threshold = 0.30
Errors quoted at 1.000 sigma

INTERFERENCE CORRECTED REPORT

	Nuclide Name	Nuclide Id Confidence	Wt mean Activity (pCi/m3)	Wt mean Activity Uncertainty	Comments
	K-40	0.996	3.96E-01	1.92E-02	
	PB-212	0.623	1.49E-02	1.53E-03	
	PB-214	0.628	7.01E-03	1.05E-03	
X	RA-226	0.961			
	TH-234	0.994	2.56E-01	2.04E-02	
	U-235	0.496	9.84E-03	9.25E-04	

? = nuclide is part of an undetermined solution
X = nuclide rejected by the interference analysis
@ = nuclide contains energy lines not used in Weighted Mean Activity

Errors quoted at 1.000 sigma

UNIDENTIFIED PEAKS

Peak Locate Performed on : 7/22/2008 6:54:17AM
Peak Locate From Channel : 50
Peak Locate To Channel : 4096

Peak No.	Energy (keV)	Peak Size (CPS)	Peak CPS (%) Uncertainty	Peak Type	Tolerance Nuclide
9	583.42	2.70126E-03	12.93	Tol.	

Analysis Report for AL16272 METOW
METOW CC 07/21/08 RBS

Peak No.	Energy (keV)	Peak Size (CPS)	Peak CPS (%) Uncertainty	Peak Type	Tolerance Nuclide
10	609.27	2.27698E-03	16.28	Tol.	

M = First peak in a multiplet region
m = Other peak in a multiplet region
F = Fitted singlet
Errors quoted at 1.000 sigma

NUCLIDE MDA REPORT

Nuclide Library Used : \\IN015421\ApexRoot\ERL_GAMMA_SYSTEM\Library\LIBRARY1.NLB

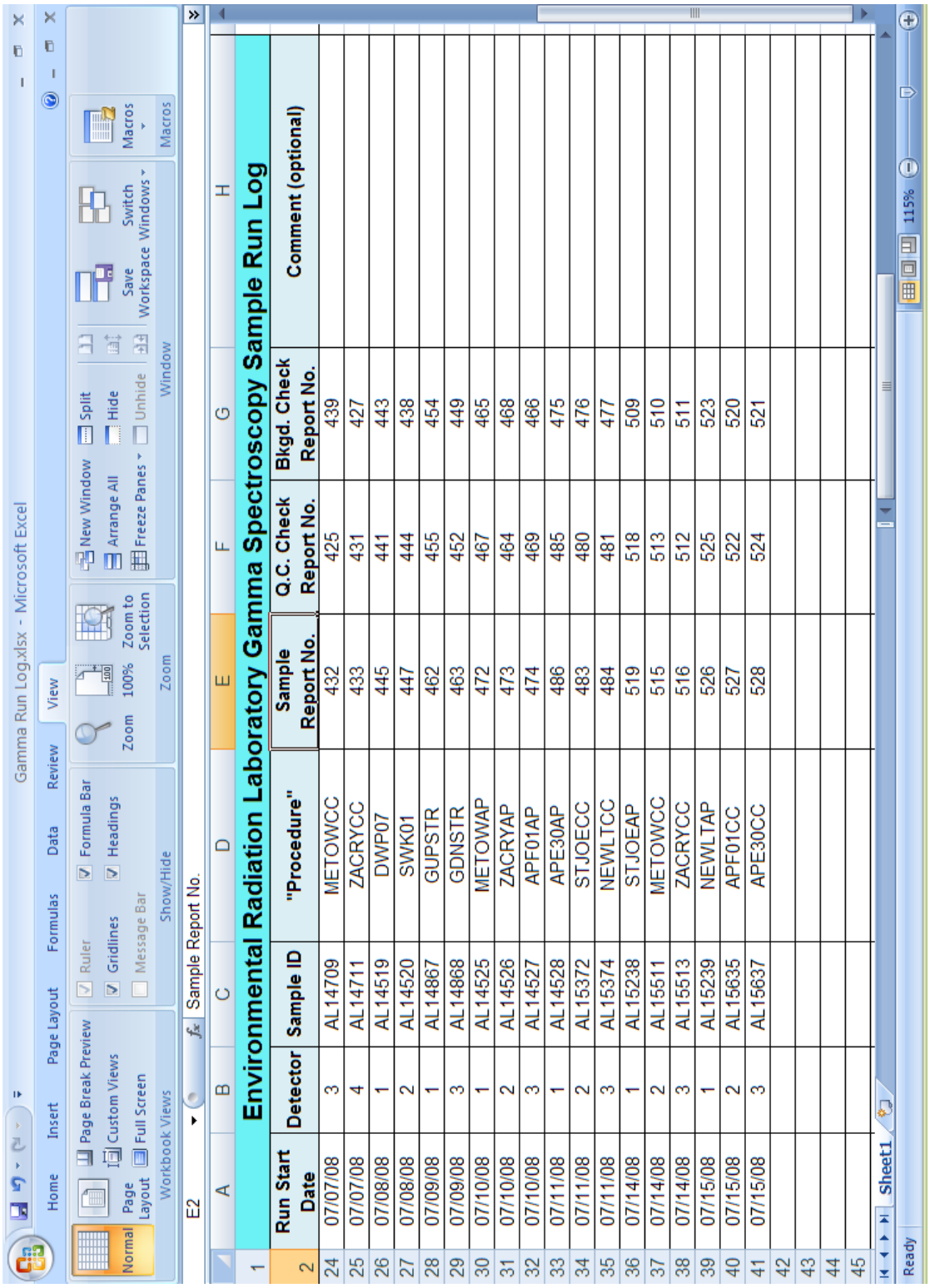
Nuclide Name	Energy (keV)	Yield(%)	Activity (pCi/m3)	Nuclide MDA (pCi/m3)	Line MDA (pCi/m3)
MN-54	834.83	99.97	-5.13E-05	3.48E-03	3.48E-03
CO-58	810.76	99.40	-8.20E-04	3.55E-03	3.55E-03
FE-59	192.34	3.11	-1.11E-01	7.65E-03	6.50E-02
	1099.22	56.50	1.20E-03		7.65E-03
	1291.56	43.20	-2.76E-03		9.54E-03
CO-60	1173.24	99.97	-1.20E-04	4.02E-03	4.13E-03
	1332.50	99.98	-3.28E-04		4.02E-03
ZN-65	1115.52	50.75	1.01E-03	8.66E-03	8.66E-03
NB-95	765.79	99.81	3.94E-04	3.69E-03	3.69E-03
ZR-95	724.18	43.70	1.79E-03	6.28E-03	8.15E-03
	756.72	55.30	1.53E-03		6.28E-03
I-131	284.30	6.05	-2.44E-02	4.17E-03	5.29E-02
	364.48	81.20	-2.27E-03		4.17E-03
	636.97	7.26	2.37E-02		6.15E-02
CS-134	563.23	8.38	-3.74E-03	3.94E-03	3.50E-02
	569.32	15.43	5.45E-03		2.01E-02
	604.70	97.60	3.64E-04		3.94E-03
	795.84	85.40	-1.27E-04		4.07E-03
	801.93	8.73	1.35E-02		4.14E-02
	1365.15	3.04	5.83E-02		1.38E-01
CS-137	661.66	85.10	1.72E-03	3.80E-03	3.80E-03
BA-140	162.64	6.70	4.45E-03	1.44E-02	3.40E-02
	304.84	4.50	-1.18E-02		6.61E-02
	423.70	3.20	-6.76E-02		9.51E-02
	537.32	25.00	7.12E-03		1.44E-02
LA-140	328.77	20.50	-7.52E-03	5.75E-03	1.47E-02
	487.03	45.50	2.20E-03		7.62E-03
	751.79	4.40	7.83E-04		8.96E-02
	815.85	23.50	-2.65E-03		1.79E-02
	867.82	5.63	1.27E-02		8.25E-02
	925.24	7.09	-6.56E-02		6.25E-02
	1596.49	95.49	1.13E-03		5.75E-03

Analysis Report for AL16272 METOW

METOW CC 07/21/08 RBS

+	=	Nuclide identified during the nuclide identification
*	=	Energy line found in the spectrum
>	=	MDA value not calculated
@	=	Half-life too short to be able to perform the decay correction

Appendix C. Gamma Spectroscopy Sample Run Log



Environmental Radiation Laboratory Gamma Spectroscopy Sample Run Log

Run Start Date	Detector	Sample ID	"Procedure"	Sample Report No.	Q.C. Check Report No.	Bkgd. Check Report No.	Comment (optional)
07/07/08	3	AL14709	METOWCC	432	425	439	
07/07/08	4	AL14711	ZACRYCC	433	431	427	
07/08/08	1	AL14519	DWP07	445	441	443	
07/08/08	2	AL14520	SWK01	447	444	438	
07/09/08	1	AL14867	GUPSTR	462	455	454	
07/09/08	3	AL14868	GDNSTR	463	452	449	
07/10/08	1	AL14525	METOWAP	472	467	465	
07/10/08	2	AL14526	ZACRYAP	473	464	468	
07/10/08	3	AL14527	APF01AP	474	469	466	
07/11/08	1	AL14528	APE30AP	486	485	475	
07/11/08	2	AL15372	STJOECC	483	480	476	
07/11/08	3	AL15374	NEWLTCC	484	481	477	
07/14/08	1	AL15238	STJOEAP	519	518	509	
07/14/08	2	AL15511	METOWCC	515	513	510	
07/14/08	3	AL15513	ZACRYCC	516	512	511	
07/15/08	1	AL15239	NEWLTAP	526	525	523	
07/15/08	2	AL15635	APF01CC	527	522	520	
07/15/08	3	AL15637	APE30CC	528	524	521	

Appendix D. Nuclide Libraries.

D.1 Nuclide Library 1 is used for characterization of samples.

Nuclide Library 1						
Nuclide	**Half/Life (Seconds)**	**Energy (keV)**	**Key Line**	**Energy Uncert. (keV)**	**Yield (%)**	**Yield Uncert. (Abs +/-)**
Be-7	4.604E+006	477.606	x	0.000	10.5200	0.1800
K-40	4.030E+016	1460.810	x	0.000	10.6700	0.1100
Cr-51	2.393E+006	320.082		0.000	9.9200	0.0500
Mn-54	2.702E+007	834.827	x	0.000	99.9750	0.0050
Co-58	6.117E+006	810.757	x	0.000	99.4000	0.3000
Fe-59	3.856E+006	192.344		0.000	3.1100	0.0000
		1099.220	x	0.000	56.5000	1.0000
		1291.560		0.000	43.2000	1.0000
Co-60	1.663E+008	1173.237		0.000	99.9700	0.0000
		1332.501	x	0.000	99.9800	0.0000
Zn-65	2.112E+007	1115.520	x	0.000	50.7500	0.1000
Nb-95	3.029E+006	765.790	x	0.000	99.8080	0.0060
Zr-95	5.531E+006	724.184		0.000	43.7000	0.8000
		756.715	x	0.000	55.3000	1.1000
Tc-99m	2.167E+004	140.508	x	0.000	89.0700	0.2400
Cd-109	3.997E+007	88.032	x	0.000	3.7200	0.1100
I-131	6.947E+005	284.298		0.000	6.0500	0.0800
		364.480	x	0.000	81.2000	1.1000
		636.973		0.000	7.2600	0.1000
Cs-134	6.507E+007	563.227		0.000	8.3800	0.0500
		569.315		0.000	15.4300	0.1100
		604.699	x	0.000	97.6000	0.3000
		795.845		0.000	85.4000	0.4000
		801.932		0.000	8.7300	0.0400
		1365.150		0.000	3.0400	0.0000
Cs-137	9.480E+008	661.657	x	0.000	85.1000	0.2300
Ba-140	1.105E+006	162.640		0.000	6.7000	1.0000
		304.840		0.000	4.5000	0.6000

Nuclide Library 1						
Nuclide	**Half/Life (Seconds)**	**Energy (keV)**	**Key Line**	**Energy Uncert. (keV)**	**Yield (%)**	**Yield Uncert. (Abs +/-)**
		423.700		0.000	3.2000	0.5000
		537.320	x	0.000	25.0000	4.0000
La-140	1.105E+006	328.770		0.000	20.5000	0.3000
		487.030		0.000	45.5000	0.7000
		751.790		0.000	4.4000	0.0900
		815.850		0.000	23.5000	0.5000
		867.820		0.000	5.6300	0.0800
		925.240		0.000	7.0900	0.1100
		1596.490	x	0.000	95.4900	0.0700
Ce-141	2.808E+006	145.441	x	0.003	48.2000	0.3000
Tl-208	1.832E+002	277.351		0.000	6.3100	0.0000
		510.770		0.100	22.6000	0.3000
		583.191	x	0.002	84.5000	0.7000
		763.130		0.000	1.8100	0.0000
		860.564		0.005	12.4200	0.1000
		1093.900		0.000	0.4000	0.0000
Pb-210	7.037E+008	46.539		0.000	4.2500	0.0400
Bi-212	3.633E+003	288.070		0.000	0.3100	0.0000
		727.330	x	0.000	6.5800	0.0600
		785.370		0.080	1.1020	0.0130
		1078.620		0.000	0.5640	0.0000
		1620.500		0.100	1.4900	0.0400
Pb-212	4.434E+017	74.810		0.000	9.6000	0.0000
		77.110		0.000	17.5000	0.0000
		87.200		0.000	6.3000	0.0000
		238.625	x	0.000	44.6000	0.0000
		300.087		0.000	3.4100	0.0000
Bi-214	5.049E+010	405.740		0.000	0.1700	0.0000
		595.230		0.000	0.0170	0.0000
		609.312	x	0.000	46.3000	0.0000
		665.453		0.000	1.4600	0.0000
		768.356		0.000	5.0400	0.0000

Nuclide Library 1						
Nuclide	**Half/Life (Seconds)**	**Energy (keV)**	**Key Line**	**Energy Uncert. (keV)**	**Yield (%)**	**Yield Uncert. (Abs +/-)**
		806.174		0.000	1.2200	0.0000
		934.061		0.000	3.0300	0.0000
		1032.370		0.000	0.0780	0.0000
		1120.287		0.000	15.1000	0.0000
		1155.190		0.000	1.6300	0.0000
		1238.110		0.000	5.9400	0.0000
		1280.960		0.000	1.4300	0.0000
		1377.669		0.000	4.1100	0.0000
		1385.310		0.000	0.7570	0.0000
		1401.500		0.000	1.2700	0.0000
		1407.980		0.000	2.1500	0.0000
		1509.228		0.000	2.1100	0.0000
		1538.500		0.000	0.3760	0.0000
		1661.280		0.000	1.1500	0.0000
		1729.600		0.000	3.0500	0.0000
		1764.494		0.000	15.8000	0.0000
		1838.360		0.000	0.3600	0.0000
		1847.420		0.000	2.1100	0.0000
		1873.160		0.000	0.2190	0.0000
Pb-214	5.049E+010	74.810		0.000	6.3300	0.0000
		77.110		0.000	10.7000	0.0000
		87.200		0.000	3.7000	0.0000
		241.981		0.000	7.4900	0.0000
		295.213		0.000	19.2000	0.0000
		351.921	x	0.000	37.2000	0.0000
		480.430		0.000	0.3200	0.0000
		511.000		0.000	0.0320	0.0000
Ra-226	5.049E+010	186.211	x	0.000	3.2800	0.0300
Ac-228	4.434E+017	93.350		0.000	3.5000	0.0000
		99.509		0.000	1.2600	0.0000
		129.080		0.000	2.8000	0.0000
		153.977		0.000	0.7220	0.0000

Nuclide Library 1						
Nuclide	**Half/Life (Seconds)**	**Energy (keV)**	**Key Line**	**Energy Uncert. (keV)**	**Yield (%)**	**Yield Uncert. (Abs +/-)**
		209.280		0.000	4.4000	0.0000
		270.230		0.000	3.6000	0.0000
		321.646		0.000	0,2260	0.0000
		327.640		0.000	3.2000	0.0000
		338.320		0.000	11.4000	0.0000
		409.462		0.000	1.9200	0.0000
		463.000		0.000	4.4000	0.0000
		562.500		0.000	0.8700	0.0000
		583.410		0.000	0.1110	0.0000
		726.863		0.000	0.6200	0.0000
		755.315		0.000	1.0000	0.0000
		772.291		0.000	1.4900	0.0000
		782.142		0.000	0.4850	0.0000
		794.700		0.000	4.6000	0.0000
		835.600		0.000	0.0100	0.0000
		840.377		0.000	0.9100	0.0000
		904.190		0.000	0.7700	0.0000
		911.600	x	0.000	27.7000	0.0000
		919.010		0.000	0.0270	0.0000
		964.600		0.000	5.2000	0.0000
		969.110		0.000	16.6000	0.0000
		1000.690		0.000	0.0050	0.0000
		1495.930		0.000	0.8600	0.0000
		1501.570		0.000	0.4600	0.0000
		1588.190		0.000	3.2200	0.0000
		1630.627		0.000	1.5100	0.0000
		1638.280		0.000	0.4700	0.0000
Th-228	6.034E+007	84.373		0.003	1.2200	0.0200
		131.613		0.004	0.1305	0.0000
		166.410		0.004	0.1036	0.0000
		205.930		0.050	0.0196	0.0000
		215.983		0.005	0.2540	0.0030

Nuclide Library 1						
Nuclide	**Half/Life (Seconds)**	**Energy (keV)**	**Key Line**	**Energy Uncert. (keV)**	**Yield (%)**	**Yield Uncert. (Abs +/-)**
Th-234	2.082E+006	63.290	x	0.020	4.5000	0.9000
		92.380		0.010	2.6000	0.6000
U-235	2.221E+016	89.960		0.000	1.5000	0.0000
		93.350		0.000	2.5000	0.0000
		105.000		0.000	1.0000	0.0000
		109.140		0.000	1.5000	0.0000
		140.760		0.000	0.2200	0.0000
		143.760		0.000	10.5000	0.8000
		163.350		0.000	4.7000	0.4000
		185.715	x	0.000	54.0000	1.0000
		198.928		0.000	0.0420	0.0000
		202.120		0.000	1.0000	0.0000
		205.310		0.000	4.7000	0.4000

D.2 Nuclide Library 5 is used for standards calibration checks.

Nuclide Library 5						
Nuclide	**Half/Life (Seconds)**	**Energy (keV)**	**Key Line**	**Energy Uncert. (keV)**	**Yield (%)**	**Yield Uncert. (Abs +/-)**
Co-57	2.348E+007	122.061	x	0.000	85.6000	0.1800
		136.476		0.000	10.6000	0.1800
Co-60	1.663E+008	1173.237		0.000	99.9700	0.0000
		1332.501	x	0.000	99.9800	0.0000
Y-88	9.215E+006	898.042		0.000	94.4000	0.4000
		1836.063	x	0.000	99.2400	0.0200
Cd-109	3.997E+007	88.034	x	0.000	3.6100	0.1100
Sn-113	9.944E+006	255.120		0.000	1.93	0.1000
		391.688	x	0.000	64.100	0.7000
Cs-137	9.480E+008	661.657	x	0.000	85.1000	0.2300
Ce-139	1.189E+07	165.853	x	0.000	79.9000	0.0800
Hg-203	4.027E+06	279.196	x	0.000	81.5000	0.8000
Am-241	1.366E+10	59.540		0.000	35.9000	0.0000

Appendix E. Quality Control Limits for Gamma Spectroscopy.

E.1 The current Quality Control Limits for Gamma Spectroscopy are listed in this section. The limits apply to the Quality Control Standard, Geometry 11, and define the acceptance criteria for the daily QC Check and for Demonstrations of Capability.

N-Sigma Test Quality Control Limits (DET 01)					
Peak Energy	**Mean (measured)**	**% error**	**Std. Dev**	**Warning Limit**	**Action Limit**
Cd-109 (keV)	8.80E+01	0.01%	0.012	±0.024	±0.036
Cs-137 (keV)	6.62E+02	0.01%	0.066	±0.132	±0.198
C0-60 (keV)	1.33E+03	0.01%	0.116	±0.232	±0.348
Peak FWHM at 1332.501	2.00E+00	N/A	0.042	±0.084	±0.126
Decay-corrected Activity	**Mean (measured)**	**% diff from assay**	**Std. Dev**	**Warning Limit**	**Action Limit**
Cd-109 (pCi)	1.56E+06	4.91%	37503	±75006	±112509
Cs-137 (pCi)	4.33E+04	3.45%	505.98	±1011.96	±1517.94
Co-60 (pCi)	6.80E+04	2.26%	834.76	±1669.52	±2504.28
Background	**Mean (measured)**	**Std. Dev**		**Warning Limit**	**Action Limit**
Low Region	5.24E+02	242.5		±485	±727.5
High Region	8.69E+02	206.5		±413	±619.5

N-Sigma Test Quality Control Limits (DET 02)					
Peak Energy	**Mean (measured)**	**% error**	**Std. Dev**	**Warning Limit**	**Action Limit**
Cd-109 (keV)	8.80E+01	0.04%	0.024	±0.048	±0.072
Cs-137 (keV)	6.62E+02	0.01%	0.034	±0.068	±0.102
C0-60 (keV)	1.33E+03	0.02%	0.082	±0.164	±0.246
Peak FWHM at 1332.501	1.91E+00	N/A	0.088	±0.176	±0.264
Decay-corrected Activity	**Mean (measured)**	**% diff from assay**	**Std. Dev**	**Warning Limit**	**Action Limit**

N-Sigma Test Quality Control Limits (DET 02)					
Cd-109 (pCi)	1.56E+06	4.68%	27383	±54766	±82149
Cs-137 (pCi)	4.41E+04	5.29%	708.78	±1417.56	±2126.34
Co-60 (pCi)	7.19E+04	3.30%	962.71	±1925.42	±2888.13
Background	**Mean (measured)**	**Std. Dev**		**Warning Limit**	**Action Limit**
Low Region	5.09E+02	230.6		±461.2	±691.8
High Region	8.91E+02	201.53		±403.06	±604.59

N-Sigma Test Quality Control Limits (DET 03)					
Peak Energy	**Mean (measured)**	**% error**	**Std. Dev**	**Warning Limit**	**Action Limit**
Cd-109 (keV)	8.79E+01	0.13%	0.016	±0.032	±0.048
Cs-137 (keV)	6.62E+02	0.01%	0.075	±0.15	±0.225
C0-60 (keV)	1.33E+03	0.01%	0.128	±0.256	±0.384
Peak FWHM at 1332.501	1.97E+00	N/A	0.039	±0.078	±0.117
Decay-corrected Activity	**Mean (measured)**	**% diff from assay**	**Std. Dev**	**Warning Limit**	**Action Limit**
Cd-109 (pCi)	1.56E+06	4.57%	67736	±135472	±203208
Cs-137 (pCi)	4.34E+04	3.66%	843	±1686	±2529
Co-60 (pCi)	7.07E+04	1.55%	1228.6	±2457.2	±3685.8
Background	**Mean (measured)**	**Std. Dev**		**Warning Limit**	**Action Limit**
Low Region	6.61E+02	242.96		±485.92	±728.88
High Region	9.95E+02	77.696		±155.392	±233.088