

This guide is designed to assist the user of an ISO-CART<sup>®</sup>/ISOTOPIC system in performing accurate nondestructive measurements of radioactive items in various containers and configurations. This guide addresses mode selection, collimator settings, detector positioning, background measurements, counting times, and other best measurement practices. The guide is consistent with ISO 17025<sup>1</sup>.

## Definitions

Backshield	Shielding positioned behind the detector to minimize the activity entering the detector from the rear.
Blank	A prepared sample with no significant radioactivity whose density and average atomic number are similar to the items being measured.
Collimator Standoff	Distance from the face of the collimator to the surface of the item being measured.
Crosstalk	Unwanted activity from a nearby item that is detected by the counting system.
Detector/Collimator Assembly	A detector surrounded by a shield that defines a directional response on the collimated detector.
Detector Standoff	Distance from the face of the detector to the surface of the item being measured.
Effective Matrix Density	Density of the matrix that gamma rays penetrate between the activity and detector.
FOV	Field of view i.e., the conical detection range in front of a collimated gamma-ray detector.
Holdup	Residual special nuclear material in processing or support equipment areas.
Item	Generic term used here to mean drum, pipe, object or surface to be measured.
Staging Areas	Locations for storing items prior to measurements.

## ISO-CART/ISOTOPIC Basic Description

There are three critical parts of the in-situ measurement system:

- (1) an ISO-CART
- (2) a portable high-resolution germanium detector (HPGe) spectroscopy system
- (3) ISOTOPIC software.

The ISO-CART provides the mechanism to move the detector into place, raise and lower the detector, and change the angle of the detector in order to measure items overhead or near the surface. See Figure 1. The ISO-CART can be disassembled into several small pieces for easy transportation in an automotive trunk or other storage containers.

The portable high-resolution spectroscopy system includes an HPGe detector and an ORTEC digiDART<sup>®</sup> (Figure 2). The HPGe detector includes a 3-, 5-, or 7-liter multi-attitude Dewar that allows the detector to be positioned in many directions without a significant loss of liquid nitrogen. The digiDART provides the battery-operated digital spectroscopy system which (1) applies high voltage to the detector, (2) acquires and stores the data, and (3) provides limited data manipulation ability. The digiDART is designed to operate on battery power for a working day. The digiDART can also be interfaced to a portable computer for an complete on-the-spot analysis.



Fig. 1. ISO-CART Detector Positions.

<sup>1</sup>General Requirements for the Competence of Testing and Calibration Laboratories.

A recent innovation is the trans-SPEC-100, a complete spectrometer system, including HPGe Detector (>45% relative efficiency), long-life low power Stirling-cycle cooler and digital MCA system in an integrated, easy to handle package. The trans-SPEC-100 entirely eliminates the need for liquid nitrogen and eliminates almost all system interconnecting cables. See Figure 3.

The ISOTOPIC software is designed to control the spectroscopy system, calibrate the system, and develop models for the item being measured and use these models for accurate nondestructive analyses. Once the measurement system is setup, it can be easily implemented by an operator in a turnkey manner.

The ISOTOPIC software consists of two separate software components, a **Supervisor** program, and an **Operator** program. The **Supervisor** program is used to calibrate the HPGe detector, setup the analysis instructions, and establish models of the items being analyzed. The **Operator** program is used to: (1) record weight and other minor equipment adjustments, (2) measure the activity, and (3) analyze the items in near-assembly line fashion. Archived data can be analyzed using the Operator program with previously established templates.

Two completely independent measurement modes, **Container** and **Soil** modes, are available in the **Supervisor** and **Operator** programs. The choice of measurement mode is dependent on the dimensions of the item. If measuring an item with discrete parameters (height, length, diameter, or width) use the **Container Mode**. Use the **Soil Mode** for the measurement of fallout and naturally occurring radioactivity evenly distributed in the soil over a wide area.

## Ways to Use the ISO-CART and ISOTOPIC software for In Situ Measurements

There are several ways to use ISOTOPIC software at a nuclear facility. It can be used for measurement stations at which the detector is relatively stationary, for holdup measurements where the detector is moved to the activity within a building, or for measurements of soil.

- Measurement stations are used when the items to be measured have similar container and material characteristics. Usually the items are samples with ID numbers. Only a few templates are needed to model the waste stream. The detector can be raised or lowered to make minor positioning adjustments. **Container Mode** is used for these measurements.
- In process holdup measurements, each item being measured may have geometry, matrix, and container shapes that vary dramatically among the items. In this situation, a data sheet must be prepared for each item being measured. The data sheet contains critical parameter information necessary to establish a model which will be used to analyze the item. A typical data sheet is shown on the back of this brochure. In tight locations the detector/collimator can be removed as a unit and repositioned as shown in Figure 4. **Container Mode** is used for these measurements.
- To measure radioactivity in soil, the collimator is removed and the detector is positioned facing downward. It is assumed that the activity is relatively homogeneous. The area of concern is mapped out in a grid, and each grid location is measured independently. **Soil Mode** is used in this situation.



Fig. 2. Portable Spectroscopy System.



Fig. 3. ISO-CART with trans-SPEC-100.



Fig. 4. Detector/Collimator Unit.

# Using the ORTEC ISO-CART and ISOTOPIC Software for In-Situ Gamma Spectroscopy Measurements of Bulk Samples

## Measurement Hints

### Collimator Considerations

The collimator is used to shield the detector in order to reduce the radiation from surrounding areas and to provide a directional response to gamma-ray detection. Background radiation is everywhere, so always use a collimator except when measuring fallout or natural activity in the soil. Several collimator options are available for the ISO-CART. The selection of the collimator depends on the measurement situation. Use the standard-duty collimator which has a thickness of 1.59 cm (5/8th in.) for portable applications, especially when the detector/collimator assembly is removed from the cart. Use the heavy-duty collimator, which has a nominal lead thickness of 4.5 cm (2 in.), when increased sensitivity is needed or ambient background activity is especially high.

For soil mode, no collimator should be used for two reasons: (1) the general-purpose DOE Environmental Measurements Laboratory calibration was performed with uncollimated detectors, and (2) an uncollimated detector is much more efficient for infinite plane measurements because a large fraction of the gamma rays penetrate the detector from the side. The detector efficiency will increase by a factor of 2 to 4 (high energy to low energy) when the collimator is removed.

To reduce the detection of unwanted activity near the item being measured, recess the detector within the collimator. The length of recess will depend on where the unwanted activity is located in the measurement area. Staging areas have activity that could contribute to the item being measured if the staging area is within the FOV. A collimator recess can help reduce this effect.

For general purpose recess settings, use a 2.5 cm (1 in.) recess. If very large containers are being measured (more than about 2 m (6 ft) in length), reduce the collimator recess to zero if the background is low enough. For background areas with significant activity, approximately in the line of sight of the item being measured, increase the collimator thickness to 5.0 cm (2 in.).

Backshields are seldom necessary as the internal copper cup holding the germanium crystal, the cryostat and the liquid nitrogen in the Dewar are equivalent to 2 in. of lead shielding for most gamma rays.

### Establishing the Collimator Standoff

Once the detector recess within the collimator is established, then the FOV of the detector/collimator combination must be determined. Understanding the FOV is the key to knowing how to position the detector. See Figure 5. Note that the FOV is a circle because the collimator is round.

A helpful rule of thumb is: the ratio between the detector recess within a collimator and the inside collimator radius should be the same as the ratio of the detector standoff distance and the diameter of the FOV. That is, if the detector recess is 2.5 cm (1 in.) and the inside radius of the collimator is 5.0 cm (2 in.) then the minimum detector standoff distance to container height ratio is 1:2. Thus, for a drum that is 86 cm (34 in.) high, the detector standoff should be at least 43 cm (17 in.).

Use the Table 1 FOV estimate to determine the minimum standoff for the detector. First determine the largest container parameter (usually the height or length) that will be measured. This is FOV necessary for measurement. For 200-l (55-gallon) drums this will be 86 cm (34 in.) due to the height. For a B-25 box the FOV would be determined from the length of 183 cm (72 in.). For a detector recess of 5.0 cm (2 in.) the detector standoff: FOV ratio should be 1:1.

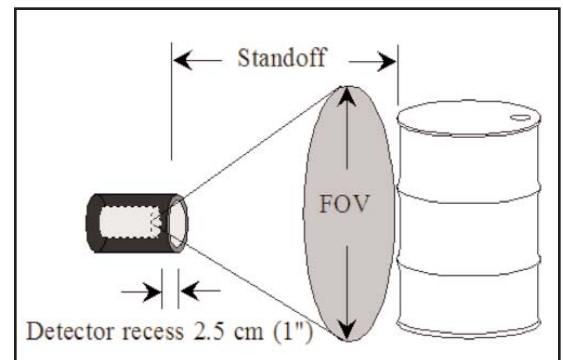


Fig. 5. Field-of-View (FOV).

Table 1. Selection of Collimator Standoff for Typical Configurations.

Detector Recess (cm)	FOV* (cm)	Minimum Detector Standoff (cm)
2.54 (1 in.)	91.4 (36 in.)	45.7 (18 in.)
	183 (72 in.)	91.4 (36 in.)
5.08 (2 in.)	91.4 (36 in.)	91.4 (36 in.)
	183 (72 in.)	183 (72 in.)
7.62 (3 in.)	91.4 (36 in.)	137 (54 in.)
	183 (72 in.)	274 (108 in.)

\*The FOV is intended to be approximate. Actual FOV dimensions vary with HPGe crystal diameter.

For more accurate FOV determinations where a sharp cut off from nearby activity is needed, some additional experimentation may be necessary to establish an exact cut off at a fixed distance. Measure sources along an axis perpendicular to the detector. Consider a drop in count rate of 80% compared to an uncollimated measured count rate of a point source as the definition of cut off. This can be obtained from a deep detector recess within the collimator.

Other factors to consider when positioning the sample item:

- (1) Initial configurations as modeled in the software assume that the item being measured is homogenous. Nearly all nuclear waste items are nonhomogeneous to some degree. If the radioactivity within the item is positioned closer or further away from the detector than assumed by the configuration, then the geometry and matrix correction will be incorrect. Both of these errors can be minimized by positioning the detector farther from the sample than the minimum distance the table recommends and/or rotating drums about a vertical axis, if possible, during a counting period to simulate a homogenous container.
- (2) Collimation, angular correlation, and geometry errors can be reduced if the gamma rays enter the detector at normal incidence. In other words, if the sample-to-detector distance is large, gamma rays entering the detector are closer to normal to the detector, which reduces errors associated with approximations in the model. Try not to position the detector closer than the FOV table recommends.
- (3) Sensitivity will increase significantly if the detector is positioned closer to the item being measured. For example: sensitivity will improve a factor of 1.45 by positioning the detector 30 cm (12 in.) inches from a 208-liter drum instead of 46 cm (18 in.).

Thus, detector positioning becomes a compromise. The greater the distance from the face of the detector to the item being measured, the less the measurement uncertainty will be, but at the price of lower sensitivity. If there is enough activity to accommodate a reasonable counting time, then increase the detector standoff.

Note that in ISOTOPIC, the **Collimator Standoff** is used to define the configuration instead of the detector standoff. Thus, a detector standoff of 45.72 cm (18 in.) should be entered as a **Collimator Standoff** of 43.28 cm (17 in.) if the detector recess (depth) is 2.5 cm (1 in.). See Figure 6.

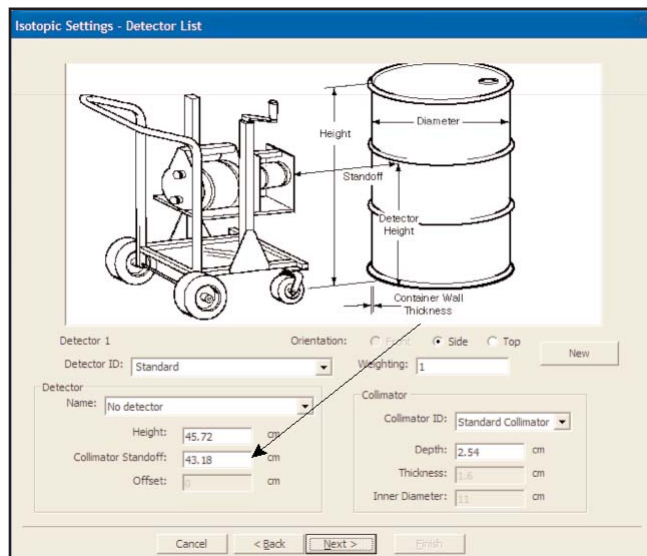


Fig. 6. Collimator Standoff Setting.

## Background Measurements

The area used to measure items may contain gamma-ray activity that will appear in the spectrum. It is important to subtract this activity, especially if the background activity contains nuclide activity that is being analyzed for in the item. The collimator will shield much of this activity but not all. Thus, it is good practice to obtain a background spectrum so that this activity can be subtracted.

Taking a background measurement is not as simple as it seems. One of the common mistakes in measuring a background is to measure the area with nothing in front of the detector. This will give an artificially high background because as an item is being measured it will shield some of the background activity. The best method is to position, measure, and analyze a blank as if it were a sample. The matrix of the blank should be as free as possible of radioactivity yet contain similar gamma-ray absorbing material and density that a sample item is expected to have.

If the radioactive items in the staging area are contributing significantly to the background, try to position the staging area as far as possible from the measurement station area. If background activity is a significant contribution to the activity of the item being measured, then the counting time for a background measurement should be at least twice the typical counting time of an item. Remember the background activity table may be used to subtract activity from many spectra. Thus, it is important to obtain a background with good peak area counting statistics. The ISOTOPIC software provides a mechanism to develop a table for peaked background subtraction.

# Using the ORTEC ISO-CART and ISOTOPIC Software for In-Situ Gamma Spectroscopy Measurements of Bulk Samples

If counting stations are positioned close together, crosstalk could occur between the detectors at different stations. Thicker collimators or additional separate shields minimize that effect.

## Preliminary Survey with a Scanning Nal Detector

An extremely helpful tool for preliminary item measurements is a scanning Nal detector. This is a Nal detector interfaced to a rate meter and is used to indicate the location of gamma-ray activity within the item being measured or to determine matrix fill heights within a container. The Nal detector should be lightly collimated to provide directional activity yet portable enough for personnel to use for long time periods. The size of the Nal detector will vary as depending on the intensity of the activity within a drum. For a 200 L drum, usually a 1 in. to 2 in. diameter Nal detector will suffice. For large containers such as a B-25 box, a 3 in. diameter Nal detector may be necessary. Dose rate meters will work if the activity in the container is high enough.

## Sample Fill Height

It is good facility practice to completely fill the waste containers. If it cannot be assumed that the container is full and if facility regulations prohibit the removal of a lid, measure the fill height before the measurement. Error in effective (average) matrix density is one of the largest sources of measurement bias. Thus, it is important to accurately determine the matrix density. This is done by measuring the weight of the item, subtracting the weight of the empty container, called the tare, and dividing by the volume. The ISOTOPIC software does this automatically. Measured results from containers improperly assumed to be full will be biased low because the average density has been computed based on the volume of a full drum. To determine the height of the contents without opening the drum, perform simple transmission measurements using a low-energy transmission source. Position the source on one side of the container and use a collimated Nal detector on the other side. Move both down the container concurrently, so that the collimated detector will always "see" the transmission source. A drop in count rate will reflect the top level of the matrix. Note that the activity of the sample being measured will contribute to the transmission source measurement, thus the activity of the transmission source should be more intense than the sample.

In the Operator program, ISOTOPIC includes a feature to allow the user to adjust the fill height of the container if different from the configuration. In this situation the average density is adjusted to compensate for the adjusted fill height. See Figure 7. In the Supervisor program, enable the **Detector Position** screen by marking the **Ask for Detector Positions** checkbox as shown in Figure 8.

## Preliminary Gamma-Ray Scans for Model Adjustments

Model the activity to be measured as if the activity is homogeneously distributed in a container. As a precaution, scan the item with a Nal detector interfaced to a ratemeter. See Figure 9. If the ratemeter

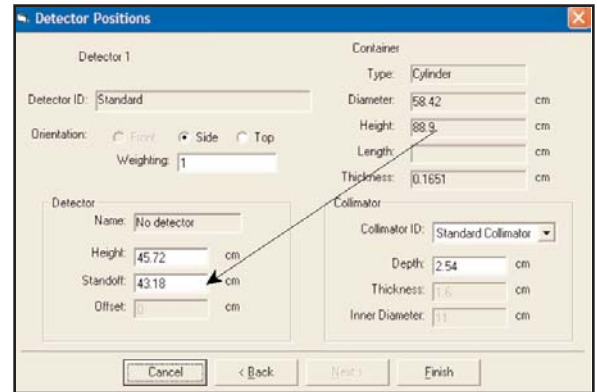


Fig. 7. Adjust the Detector Position in the Operator Program as Needed.

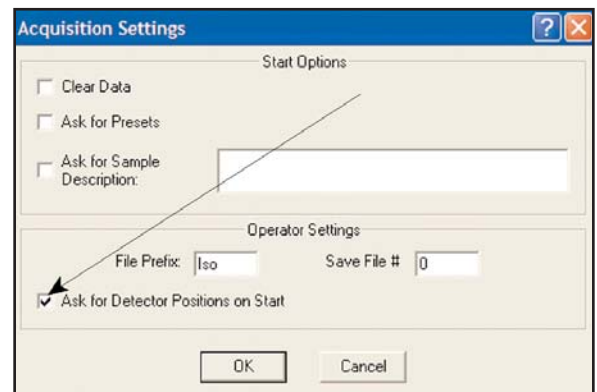


Fig. 8. Supervisor Program Setting to Enable Detector Position Screen.



Fig. 9. Scanning for a "Hot Spot."

activity of a "hot spot" is approximately 10 times greater than the ratemeter activity of the remaining item, then model the item being measured as a point source.

### Quantifying a "Hot Spot" in a Box, Drum or On the Floor

The important information necessary for the model adjustment is distance through the matrix (absorber 2), container thickness (absorber 1), and distance from the "hot spot" to the detector. The matrix density is obtained assuming average matrix density of the entire container. Use the point source model instead of models where volume is used for the geometry correction. See Figure 10.

Results will be reported as activity (Bq) instead of a concentration (Bq/g). The information needed for the analysis is: (1) distance from the detector to the "hot spot," (2) thickness, density, and material of matrix that the activity penetrates before reaching the detector, and (3) wall thickness of the container. The scanning NaI detector is useful to locate the item in the container to establish the thickness of matrix. A separate weight measurement will be necessary to establish the average matrix density which is represented as the density of absorber 2.

It is important to model the activity within the container, not just the container itself. Consider a 200-L drum with the vast majority of the activity in the bottom fourth of the drum. This is frequently the case. Best results are obtained when the container is modeled to match what the gamma rays "see" as they exit the item and are collected in the detector. If all of the activity were located in the bottom half of the container then the software model should be set up as if the container is only one half the PHYSICAL height in order to get the correct "per container" result. Use this information to develop a model and position the detector. Note however, that if the activity were only in the bottom fourth of the container, the gamma rays would still "see" the average density computed by the weight and volume of the matrix measured as if the drum were full.

In practice, it is not practical to set this measurement template before hand. Usually, the spectrum is archived and the data specific to the measurement is collected outside the ISOTOPIC program. Then a special template is prepared for that item in the Supervisor program and activity results obtained accordingly in the Operator program.

Frequently, activity is located in the bottom fourth of the container. In these cases, an adjustment to the model must be made. If more than one hot spot is located in the drum, best results will be obtained if the measurement model is kept simple and the item is modeled as if the activity is homogenous.

For nonuniform contamination on floors and walls, scan and identify areas of increased activity and treat as hot spots or small spill areas. Mark the contaminated area so that the contamination in the area can be modeled and later analyzed.

### Measuring Activity in a Pipe

Use a preliminary scan with a NaI detector to indicate if the piping is evenly contaminated, contains localized activity, or has significant activity at all.

If the piping is evenly contaminated, then only a few sections need to be counted, analyzed, and averaged to obtain activity/length of piping. In this situation the FOV table (Table 1) will establish an approximate standoff. However, in this case, determine a more accurate FOV. Report the activity in units of activity/meter of piping. The difficult part is to determine where the FOV has a sharp cutoff. Note that the FOV calculations determine where collimator corrections begin. However, there may be considerable activity beyond the FOV that is partially collimated. Several HPG measurements should be taken along the pipe to assure that the activity within the pipe is uniform.

If the pipe has an uneven continuous distribution of activity, then the pipe should be measured in overlapping segments and an average activity/meter given to the entire pipe. If there are only a few localized "hot spots" with no continuous activity, then best results will be obtained by measuring the activity of each "hot spot" separately.

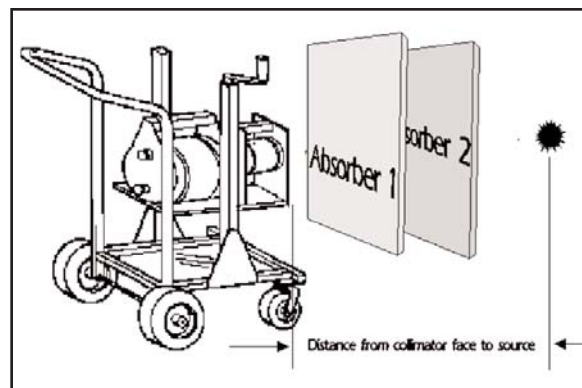


Fig. 10. Template Used to Define a Hot Spot.

# Using the ORTEC ISO-CART and ISOTOPIC Software for In-Situ Gamma Spectroscopy Measurements of Bulk Samples

## Contaminated Wall and Floor Measurements

Contaminated walls and floors are similar to piping. A preliminary scan of the surface will help find localized activity. If the floor or wall is homogeneously contaminated, the FOV will establish the area of the circle of activity. Divide the item being measured into a matrix. The diameter of the circle is established by the field of view. See Figure 11. Average the results of the measured circles to obtain a measure of the item. Activity beyond the FOV may enter the detector to complicate the real area "seen." Recess the detector to obtain a sharp cutoff and then experimentally determine when 80% of the activity is attenuated. This cutoff establishes the radius of the measured circle. Then determine the area measured. If there are hot spots, measure these separately.

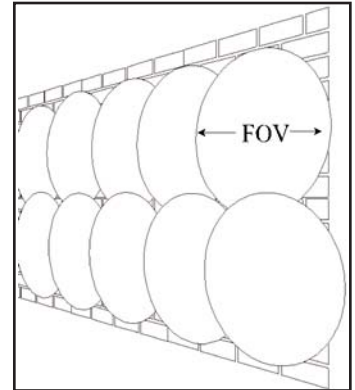


Fig. 11. Map the Wall in Overlapping Circles.

## ISOTOPIC Mode Selection — Container or Soil

Spills of radioactivity should be measured using a collimated system as the collimator masks out the surrounding activity. The critical parameter is a diameter of approximately 10 m (39'). That is, if the diameter of the spill activity is greater than 10 m and relatively homogenous, remove the collimator and use **Soil Mode** for that activity measurement. Otherwise, use **Container Mode**. Position the detector 1 m from the surface of the soil facing downward when making soil mode measurements. If the diameter of the soil spill is greater than 2 m, then do not recess the detector in the collimator. The soil mode algorithm also allows you to take account of the exponential "wash in" of fall out into the soil by rainfall over time.

## Common Measurement Mistakes

### Measuring the Opposite Side of the Container

In general, nuclear waste is very nonhomogeneous and matrix attenuation corrections dominate the correction factors for large containers. If drums can be rotated, the matrix "appears" to be more homogeneous and the uncertainty in matrix attenuation will be lower. This does not solve the geometry error of different activity levels within a drum, but the geometry error is usually smaller than the matrix error.

For large boxes with a depth greater than 46 cm (18 in.) it is very important to measure from both sides. ISOTOPIC has the option to use multiple detectors for item counting. If multiple detectors are available, then concurrently measure both sides of the box. If multiple detectors are not available, then measure both sides successively. In both cases ISOTOPIC will average the results.

### Minimizing Uncertainty

There are several measurement techniques that can be used to minimize the measurement uncertainty. These can be characterized by minimizing the correction factors. The following tips will help make detector position decisions.

- (1) Increasing the item-to-detector distance will reduce the error due to geometry correction. Counting statistics are seldom a major contributing factor to the overall uncertainty, so you don't have to worry about the reduced count rate. You may have to count longer if the activity is too low to meet sensitivity requirements.
- (2) Matrix attenuation corrections usually dominate the correction factors. Count boxes through the thinnest (front to back) dimension (maximum area normal to the detector) to minimize this correction and thus the uncertainty in the correction. See Figure 12.
- (3) Position the item at the distances shown in Table 1 or greater to avoid collimator corrections. The corrections should not vary significantly from 1.00 (no correction).

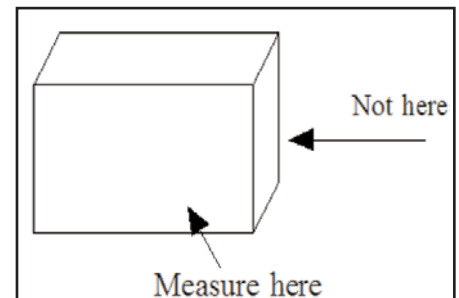


Fig. 12. Proper Measurement Position to Minimize the Matrix Correction.

## Software Hints

### Working with the Fine-Tune Adjustments

When an item being measured is initially modeled, it is assumed that the activity within a matrix is homogeneous. In practice, however this is seldom the case. Nonhomogeneity will affect the results in several ways.

- (1) The matrix within a container usually has several air pockets. Alternately, the activity being measured might be situated near an item with high attenuation properties. This is common for samples such as large containers of contaminated steel.
- (2) Note also that gamma rays will likely penetrate the container at an angle that is not normal to the detector. Thus, the container attenuation will be greater than is generally considered from the wall thickness only. The container correction accounts for this but it assumes that the activity is homogeneously distributed within the container.
- (3) Heavy elements such as uranium and plutonium often exhibit self-attenuation of their emitted gamma-rays. The matrix mass attenuation coefficients need to include contributions from uranium or plutonium when these elements are present. As the weight percentage of uranium or plutonium is increased, the mass attenuation correction in ISOTOPIC will adjust the mass attenuation coefficients according to the entered weight percent of uranium or plutonium. This simulates what the gamma ray "sees" as it penetrates the matrix. This provides a good "lump" correction for uranium and plutonium.

The ISOTOPIC software has a fine-tune adjustment allowing the user to vary the modeled values of matrix density, container thickness, and heavy-element contributions. The user must then decide how much of these adjustments are necessary from each of the contributions. If the product of all the gamma ray corrections at each energy is correct, the corrected gamma-ray peak areas from the same nuclide will show the same activity. If the item has been incorrectly modeled the low-energy gamma ray corrected peak areas will be higher or lower than high energy gamma ray peak areas. This is graphically presented in a graph of % deviation from the reference gamma-ray activity vs energy as shown in Figure 13.

It is important to know your spectrum when working with the adjustment plot. Use the nuclide with the most intense activity and the widest range of gamma-ray energies. Disregard the nuclides with low activity because their gamma-ray peak areas may add scatter to the plot. In Figure 13 five nuclides are plotted, but  $^{239}\text{Pu}$  is the nuclide with the widest gamma-ray energy range and gamma-ray intensity. Thus,  $^{239}\text{Pu}$  should be the isotope used to adjust the parameters. In this example the 413-keV gamma ray is chosen as the reference gamma ray. As shown in this plot there is some scatter. This scatter is primarily because the peaks cannot be fit well in complicated multiplets. That is, when analyzing a plutonium item, there are many gamma- and x-ray peaks positioned in difficult-to-fit multiplets. These peaks should generally be disregarded for the fine-tune adjustments. A few well

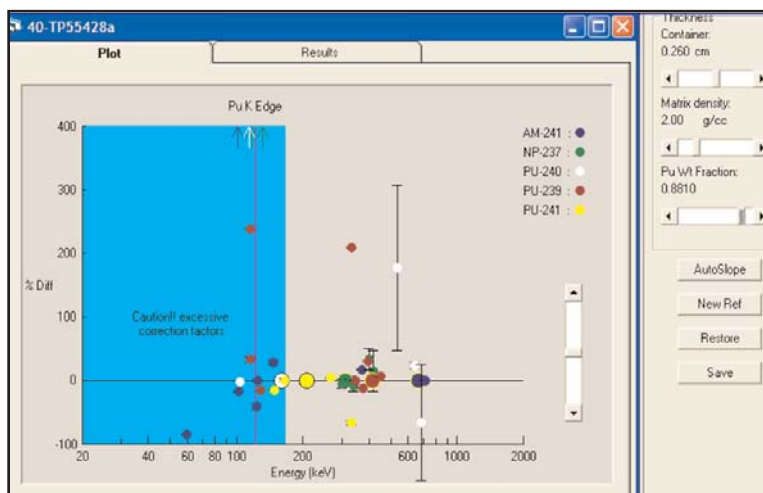


Fig. 13. Fine-Tune Adjustment for a Plutonium Spectrum.

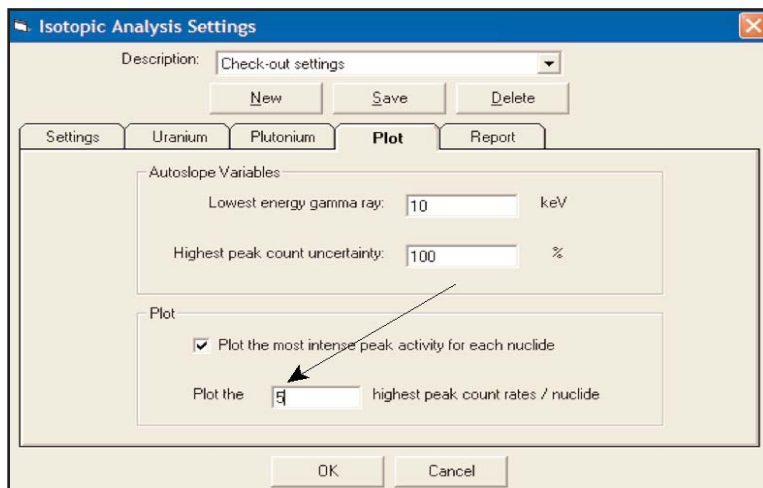


Fig. 14. Screen to Determine Plot Settings.

# Using the ORTEC ISO-CART and ISOTOPIC Software for In-Situ Gamma Spectroscopy Measurements of Bulk Samples

separated and intense peaks are better to use for the adjustment than many poorly-fitted peaks. Using this reasoning, set the number of peak count rates/nuclide shown on the plot to a number between 5 and 10 as shown in Figure 14. Make certain that the reference gamma rays are not eliminated from display in the process of selecting the highest quality peaks for adjusting.

**Caution!!** Be careful with your adjustments. Do not increase or decrease the density of the sample to more than twice the average density of the sample. Keep in mind that the effective container thickness will always be greater than the measured thickness as most gamma rays go through the container wall at an angle. However do not increase the thickness by more than 50% of the actual thickness. Usually, the matrix adjustment is the first adjustment to be made and container thickness is the last fine-tune adjustment.

## Hints for Setting Up the ISOTOPIC Analysis Library

Developing a library is a continuous process; typically, the more analyses you perform on a particular type of sample or at a particular site, the more you will modify the library. There are a number of considerations to understand before you start.

- (1) Determine from the facility which daughter nuclides to report.
- (2) Gamma rays from the daughters that are not reported should be included as parent gamma rays in the library if they appear to exhibit the half-life of the parent. That is, the activities of the daughters are in secular equilibrium.
- (3) The reported activity for a nuclide is based on the activity from the first gamma ray listed in the library. This reference gamma ray peak should be well resolved from neighboring gamma ray peaks.
- (4) Select an intense, high-energy gamma ray for reference. It may not have to be the most intense high energy gamma ray, if that specific one is in an interference for example, but remember that high-energy gamma rays characterize nonhomogeneous matrices better than low-energy gamma rays because of the greater penetration.
- (5) Minimize the primary library to nuclides known to be present in the facility, but be alert to unexpected nuclide gamma-ray activity.
- (6) Investigate unidentified peaks for unexpected nuclides. To minimize the unidentified peak list record every gamma ray ever seen by each nuclide, but do not include gamma rays in the library that have never been seen before in the spectrum as this will introduce clutter. Thus, the library development will be somewhat continuous.
- (7) It is important to be sure that the energy calibration is accurate. If the computed energy of the peak is outside the library tolerance, a nuclide could inadvertently be classified as unidentified. As a general rule of thumb, check the energy of a high-energy gamma ray such as  $^{40}\text{K}$ . If the energy of the peak is approximately 1.0 keV high or low, then energy recalibration may be necessary. The **Auto-Energy Calibration** feature works well if the library is simple and there are not many low-energy x- and gamma rays in it. If the normal sample library gives spurious results when the **Auto Calibrate** feature is used, then prepare an additional simple library containing only 5 or 10 gamma rays spaced throughout the energy range; these should be gamma rays that are likely to be in any spectrum. Select that library before using the Auto Calibrate feature if the sample library will not work. Alternately, calibrate using manual calibration with a few well established peaks.

**Caution!!** When adjusting the energy calibration using the auto-energy calibration feature do not change the FWHM calibration which has been carefully established earlier. Be sure to mark the No FWHM Cal checkbox as shown in Figure 15.



**Fig. 15. Make Sure "NO FWHM Cal" is Marked.**

## Special Hints with Uranium Analysis

Frequently the weight percent (wt%) of  $^{235}\text{U}$  for a waste item is known with high accuracy. This information can be used to obtain more accurate uranium results by normalizing the activity to either the  $^{238}\text{U}$  or  $^{235}\text{U}$  results. For example, if it is known that the wt% of  $^{235}\text{U}$  is 5.0% and the analysis results report 5.0 grams of  $^{235}\text{U}$ , the  $^{238}\text{U}$  analysis can be forced to 95.0 grams. In situations where item densities are high and samples exhibit a high degree of nonhomogeneity, such as a barrel or box of metal parts, the user should select the  $^{238}\text{U}$  analyses on which to normalize, because it is likely that the  $^{238}\text{U}$  analysis obtained from referencing on higher-energy gamma rays will be better than the  $^{235}\text{U}$  analysis because the gamma rays from the  $^{235}\text{U}$  isotope are more highly attenuated.

To use this feature:

- (1) The  $^{238}\text{U}$  nuclides must be quantified via the  $^{234\text{m}}\text{Pa}$  and  $^{234}\text{Th}$  daughters if they are in secular equilibrium with the parent. (When in secular equilibrium, the daughters "appear" to have a very long half-life which is certainly the case in most legacy waste measurements.) To achieve this, the user may modify the library as if the intense  $^{234\text{m}}\text{Pa}$  gamma rays were actually part of the decay of  $^{238}\text{U}$ , since they are in equilibrium. See Figure 16. Note that  $^{238}\text{U}$  isotopes have very few gamma rays that are emitted from  $^{238}\text{U}$  decay directly. However, there are many gamma rays from the  $^{234}\text{Th}$ ,  $^{234}\text{Pa}$ , and  $^{234\text{m}}\text{Pa}$  daughters. These are shown in Figure 16 where they are assigned the half-life of  $^{238}\text{U}$  because of conditions of equilibrium.
- (2) On the fine-tune plot screen under the **Results/Summary** tabs click to highlight the uranium isotope whose activity you wish to fix. See Figure 17.
- (3) Click the Normalize button and enter the wt%  $^{235}\text{U}$  value. If the material were 5.0% enriched then the entry would be 5.0 as shown in Figure 18.
- (4) Next, enter the estimated error in the enrichment value. When the estimated error is entered, the activity and isotope weight analysis of the unfixed isotope will change to reflect the entered  $^{235}\text{U}$  enrichment value. See Figure 19.
- (5) Save the results.

Normally, the  $^{235}\text{U}$  isotope is more accurately determined. However, if the matrix has high density it may be better to use the  $^{238}\text{U}$  isotope to adjust the  $^{235}\text{U}$  activity.

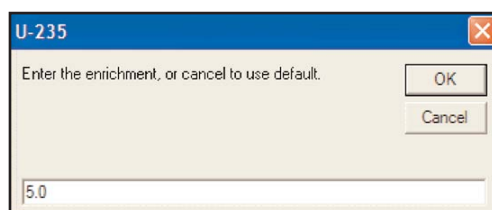


Fig. 18. Enter the wt%  $^{235}\text{U}$ .

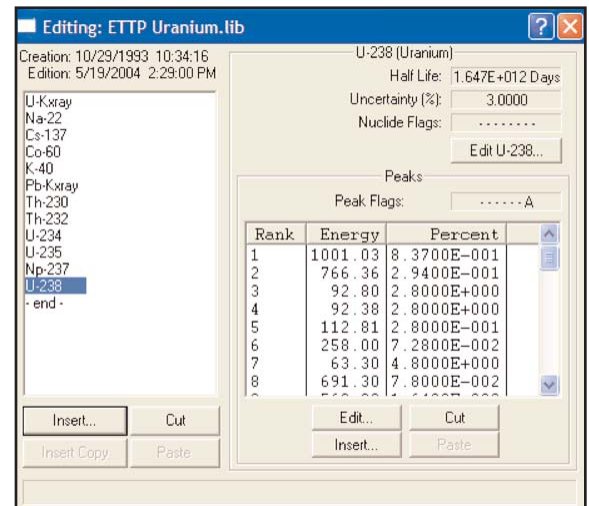


Fig. 16. Choose the High-Energy Gamma Ray for Reference for  $^{238}\text{U}$ .

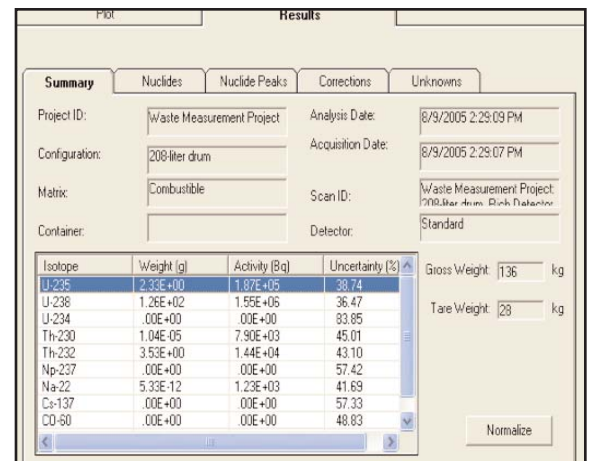


Fig. 17. Select Uranium Isotopic to Normalize On.

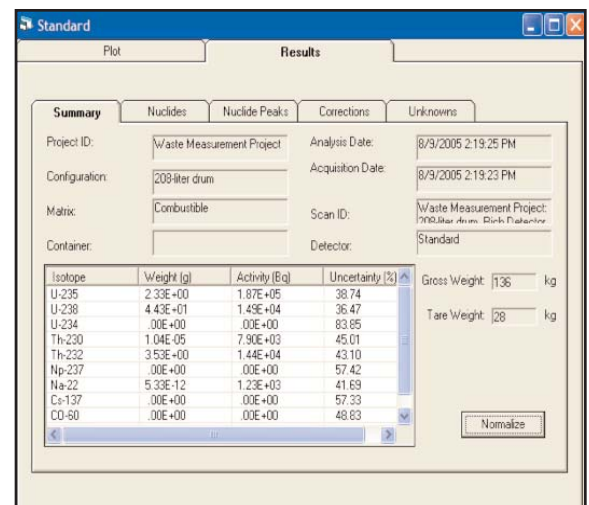


Fig. 19. Results After Normalization.

# Using the ORTEC ISO-CART and ISOTOPIC Software for In-Situ Gamma Spectroscopy Measurements of Bulk Samples

## DigiDART® Hints

### Nuclide Report

In the field it is often useful to get an approximate estimate of activity present in a representative sample, especially if most of the samples are the same shape and approximately the same density. The digiDART allows the user to obtain a nuclide report and display it on the digiDART screen. The simple analysis is performed by determining a Compton-background corrected count rate in a nuclide reference peak, and multiplying it with a Report Factor to obtain the required result. To do this, select the desired reporting units, analyze the spectrum of a typical sample using ISOTOPIC to determine the appropriate factor and adjust the Report Factor in the digiDART.

- (1) Set the ROI by setting the low-energy channel 3 channels lower than the beginning of the true peak and the high energy channel 3 channels higher than the ending of the true peak. In the example shown in Figure 20 the true peak is located between channel 4887 and 4911. Note that 3 channels are used for the low-energy background region and 3 channels for the high-energy background region.
- (2) Select an ROI factor of 1.00.
- (3) Obtain the results from the digiDART Nuclide Report.
- (4) Use ISOTOPIC to determine true answer.
- (5) Adjust the Report Factor so the digiDART Nuclide Report matches the ISOTOPIC report.

Note: The digiDART nuclide analysis is an approximate result and care should be used in the reporting of such results.

## Summary

The combination of the ISO-CART system hardware and ISOTOPIC software provide a powerful set of tools to measure nuclear waste. The hardware and software was designed to provide the flexibility needed to meet measurement needs for process holdup, soil measurements, and waste measurement stations.

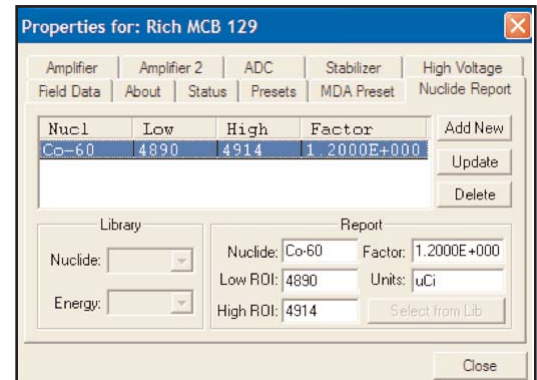


Fig. 20. Setting Up a Nuclide Report for the DigiDART.

# Using the ORTEC ISO-CART and ISOTOPIIC Software for In-Situ Gamma Spectroscopy Measurements of Bulk Samples

## Measurement Data Sheet

Date: \_\_\_\_\_

Analyst(s): \_\_\_\_\_

Room ID \_\_\_\_\_ Grid Location: \_\_\_\_\_

Measured Item description \_\_\_\_\_

Measured Item ID \_\_\_\_\_

Configuration:

\_\_\_\_\_ Point

\_\_\_\_\_ Cylinder

\_\_\_\_\_ Box

Container thickness: \_\_\_\_\_

Collimator Standoff: \_\_\_\_\_

Container dimensions: \_\_\_\_\_

Comments: \_\_\_\_\_

\_\_\_\_\_

Data File Name: \_\_\_\_\_

Specifications subject to change  
021406

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