ORTEC®

ISOTOPIC-32 V3.0
Advanced Software Solution to Gamma-Ray Waste Assay

New User Interface, New Capabilities

And now…

- An eminently **practical** solution to the quantitative assay of gamma-emitting waste samples.

- Analyze all types of gamma-emitting waste, fissile and non-fissile.

- Measure containers of many shapes and sizes, surfaces and even soils; independently verified analysis methods.

- Use your own HPGe detector(s) and electronics or as part of an integrated ISO-CART™ system. Calibrate ANY detector on site, TRACEABLY, in minutes.

- Combine data from multiple measurements of a single, large container to speed up measurements or improve results: Easily expanded.

- **Seamless** integration of hardware and software, separate supervisor and operator modes.

- Reports the way YOU want them; plus an Industry Standard results database.

…Simply a Better Solution!

ISOTOPIC V3.0 is the latest version of the acclaimed ISOTOPIC software, having undergone many evolutionary, experience-based improvements from earlier versions. ISOTOPIC provides a **practical solution** to a wide range of gamma-ray measurement problems encountered in site characterization prior to remediation and decontamination and decommissioning (D&D) operations. ISOTOPIC V3.0 is based on work done originally at several USDOE sites in the analysis of thousands of fissile waste containers[1] and in methods developed at the US Energy Measurements Laboratory[2,3] (EML-NYC) to measure wide-area contamination of soils and surfaces.

....designed to meet your needs
> • **Use with ANY HPGe detector, calibrated in minutes**
> • **Use of a traceable source gives traceable results**

ISOTOPIC V3.0 is designed to meet your needs. It gets the job done with a minimum of complication. No special procedures are required to get an HPGe detector ready for use with ISOTOPIC. It can be used with almost any HPGe detector[4] and can be calibrated and ready to go in minutes. A practical, semi-empirical approach to efficiency calibration is used.

....for realistic measurement scenarios
> • **Boxes**
> • **Drums**
> • **Pipes**
> • **Surfaces**
> • **Soils (M-1 Methodology)**

ISOTOPIC V3.0 provides a number of standard geometry "templates" from which a specific measurement template may be developed. These include cylinders (from top and side; including lined cylinders (pipes)), boxes, point source (far field), and infinite plane. The infinite plane (soils) mode is for uncollimated measurement of contamination, fall out or wide area spills, either washed into or on top of an infinite plane surface, most typically soil on the ground.
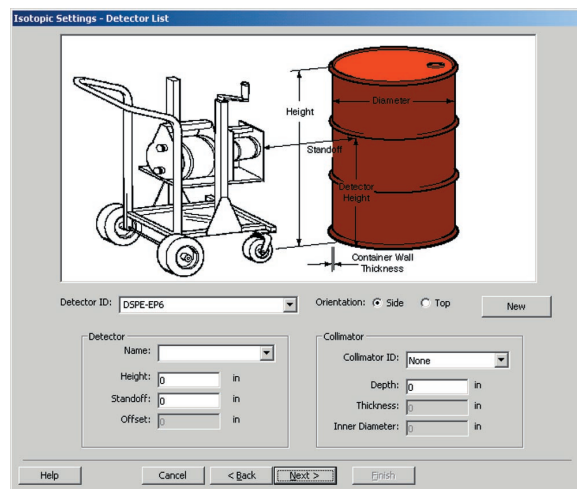
....for containers

For the counting of packages, pipes and surfaces, the detector is characterized by a single point-source measurement, even when a collimator is to be used. This primary calibration, which can be traced to a certified standard, for any detector, is extrapolated or modeled to match the physical situation of the sample; container geometry, material, and matrix composition. The model is based on "point-kernel" methods in which the entire measurement problem is broken down into multiple source/matrix voxels and their contribution to the composite spectrum are calculated and summed. The approach, which is simpler to use than Monte-Carlo Methods is also more practical, because no special pre-characterization of the HPGe detector is required; only the point source calibration. Both this and the Monte-Carlo approaches yield efficiency calibrations which are typically much more accurate than the measurement problem demands, because other sources of error, (e.g. sample and matrix inhomogeneity), dominate the overall uncertainty of the measurement.

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[1]Hagenauer, R.C., "Nondestructive Assay Quantification of Poorly Characterized Radioactive Isotopes," Proceedings of the 4th Nondestructive Assay and Nondestructive Waste Characterization Conference, Salt Lake City, 1995.

[2]H.L. Beck, et al., "In Situ Ge(Li) and NaI(Tl) Gamma Ray Spectrometry," U.S. Dept. of Energy, Environmental Measurements Laboratory, HASL-258, September (1972).

[3]I.K. Helfer and K.M. Miller, "Calibration Factors for Ge Detectors Used for Field Spectrometry," Health Physics, Vol. 55, No. 1, pp 15-29 (1988).

[4]For use in M-1 mode for soil characterization, an HPGe with crystal length/diameter in the range of 0.5 to 1.3 is recommended. 80% of HPGe detectors meet this criteria. The ORTEC PROFILE M Series detectors are ideal for this and the ISOTOPIC container measurements.

....for soils

For the uncollimated wide area counting of soils, the "1-meter" methodology developed by the USDOE EML[2] and later extended[3] is used. It is applicable in many situations:

- **Decontamination assessment of previously used sites**
- **Assessment of nuclides deposited during emergencies**
- **Routine environmental monitoring near nuclear facilities**

The EML methodology reduces a complex measurement problem to the product of three, simply-determined factors. The gamma-ray peak areas are related to the nuclide-specific activity by the product of the three factors. These factors have been determined for a range of detector types and soil conditions and are tabulated within the program. The efficiency calibration is determined using the stated efficiency according to the usual ANSI/IEEE 325-1996 convention at 1.33 MeV, and from the crystal length and diameter.

No special (and costly) Monte-Carlo characterizations of the detector are necessary. The attenuation correction is determined by selection of the soil type and type of nuclide distribution: recent (surface) deposits, older (washed-in) deposits or natural (uniform) deposits. The energy and peak shape calibration are performed using any multiline source and may be entirely automated. However you plan to use ISOTOPIC, there will be no unexpected detector calibration costs.

....for real users

- **Seamless integration**
- **Separate operator and supervisor modes**
- **No operator confusion. No redundant operator entries**
- **Results stored in a Microsoft® Access™ database**

ISOTOPIC V3.0 is a 32-bit Windows 98/2000/NT application which, like all ORTEC *CONNECTIONS* Applications software products, is compatible with all ORTEC MCA hardware. This means that for a wide variety of MCA hardware, directly connected or networked (including wireless), ISOTOPIC V3.0 automatically determines what hardware is attached. The operator screens match only the capabilities of the attached hardware . . . no confusion is possible.

The user-interface has two modes: supervisor and operator. The operator need make choices only from the minimum subset of system options defined by the supervisor. The supervisor mode defines what operations the operator is allowed to carry out. There are even two separate user manuals: supervisor and operator. An operator is not confused by the presence of more options than are necessary for the job at hand.

....for multiple measurements of a single object

In the measurement of any large container of waste, several measurements are usually made from different directions to ensure the best results are representative. This will be done sequentially if only one hardware system is available or simultaneously if there is access to multiple sets of hardware. ISOTOPIC V3.0 can automatically combine the results taken either way by a user-defined weighted average. When multiple detectors are used at the same time, live spectra may be displayed on screen simultaneously from each of them, increasing user confidence.

….for your reporting needs

ISOTOPIC V3.0 output reports are easily customized. All analysis results are stored in an Access-compatible database from which they are easily printed, or exported for further processing into summary reports.

ISOTOPIC V3.0 In Use

ISOTOPIC V3.0 has two levels of operation, supervisor and operator. The supervisor sets up the analysis options and security for the operator. That means that even semi-skilled operators in the field will collect good data with less wasted time for repeats (lower cost per measurment item).

In supervisor mode, all features and functions of ISOTOPIC are available, note the large number of menu options on the bar at the top of the supervisor display. The supervisor may calibrate the system, create libraries, define sample geometries, matrices, collimators to be used and other functions for later use by the operator. He can also define which features the operator may access.

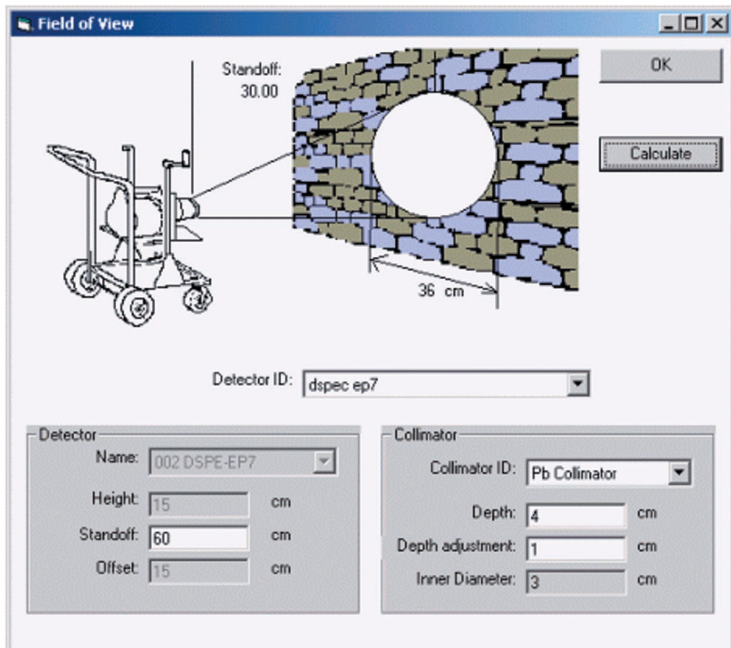A handy "field of view" calculator provides a simple way to set up the detector to sample distance for the current collimator.
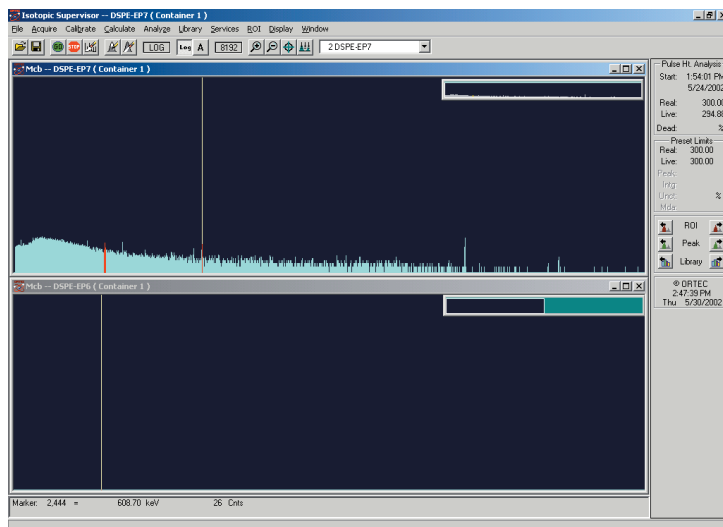
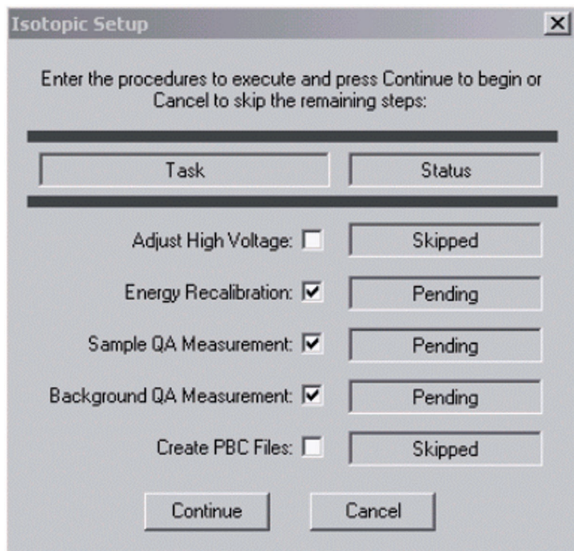**Supervisor Main Screen. Two Detector Configuration.**
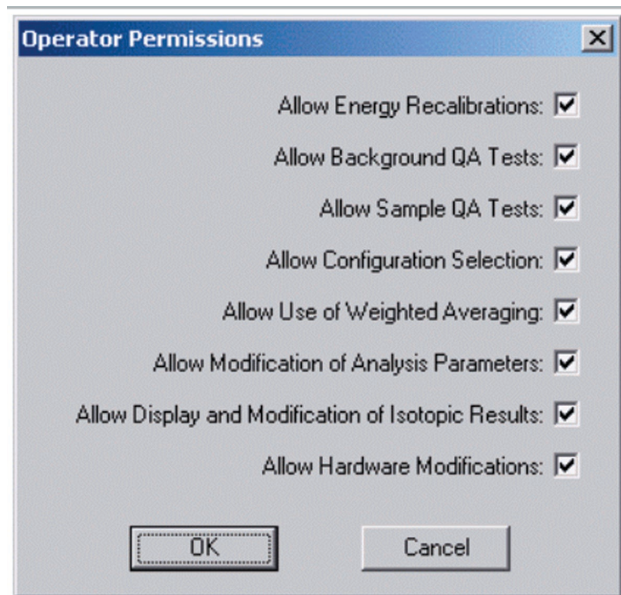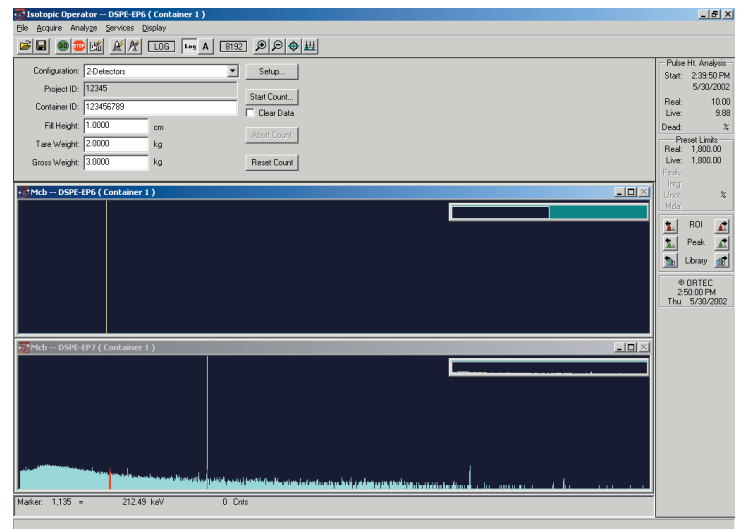

Operator Permissions.

Field of View Calculator.

Startup Procedure

The operator startup procedure may be customized from the supervisor mode so that the operator is prompted to carry out the necessary procedures to ensure meaningful measurements based on good quality data.

Operator Main Screen. Two Detector Configuration.
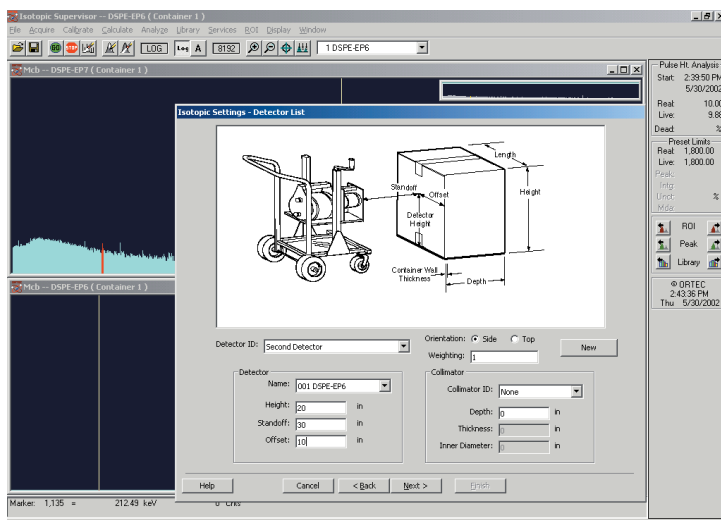
The operator main screen, which is customized by the permissions granted by the supervisor, is much simpler than supervisor screen. In routine use, for container analysis, the operator need only start the acquisition, select the configuration (nearest standard container configuration), and enter the "book keeping data" such as container ID, type, weight and the critical measurement data, such as detector-to-container distance.

Container Configuration.

The standard container configurations and collimator configurations are defined and specified by the supervisor. A container configuration includes the default dimensions, materials, and matrix detail. Any number of these configurations may be specified and recalled by the operator when needed.

When the analysis is complete, the operator can adjust the container/matrix physical parameters (such as matrix density or container wall thickness) to optimize the results, by the use of the isotope plot.

The plot shows the percentage difference between the corrected measured activity and the activity calculated for the reference peak for each nuclide. The supervisor selects the reference peak. The operator may optimize the analysis, adjusting the container, matrix, and weight fraction uranium, to refine the results. The visual evidence of a good result is immediately seen when the points from a multi-peaked isotope are distributed normally about the "zero-line." In the case of uranium analysis, if the U-235 enrichment is known, it may be entered and then the U-238 and U-234 values are computed more accurately for samples containing weak uranium activity. Homogeneous and inhomogeneous samples are analyzed with increased accuracy by this method. A good

Isotope Plot.

indication that a package contains an inhomogeneous distribution of materials is that the user can obtain a combination of parameters which makes the activity plot flat for some nuclides but not others.
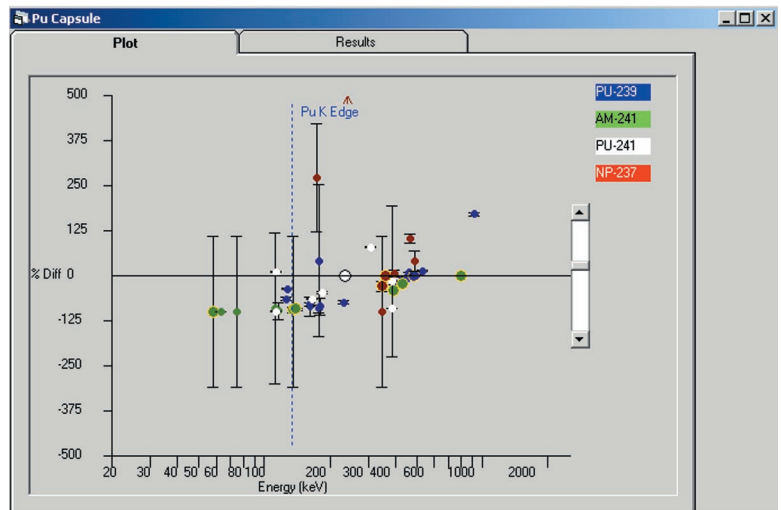
Soil Analysis Mode Data Entry

In soil analysis mode, the operator only needs to enter the detector height and the alpha/rho value (see specification section). The geometry is pre-specified to be an infinite plane, below an uncollimated detector.

Reports

When the fine-tuning is finished the operator selects a report for each isotope showing the activity and weight. These results may then be printed and archived. The report files are written in either a database summary or as complete reports showing all input and correction information. Custom reports may be generated by the use of the report generator option.

The tabulated correction factors can be used to help the user decide if counting longer is likely to significantly improve the precision of the result. The user is also warned if any of the corrections appear to be excessively large.

Minimum Detectable Activities (MDA) are calculated for each isotope.

An "unknown peaks" file records the unidentified peaks (sample-by-sample) so that any nuclide that has been overlooked and not placed in the analysis library, will be in the mystery peak file as a warning to the operator. These warnings mean that the library should be changed to include these nuclides. Activities, grams of U or Pu, or MDA's from multiple measurements may be reported as weighted averages. The weighting is user definable.

Accuracy of Results

It is not easy to give a precise estimate for the accuracy to be expected. Several factors are influential: statistics and counting time, matrix density and inhomogeneity, calibraiton uncertainty, and the number of measurements carried out on a single container or object. A range of 10 to 50% accuracy should be considered representative, the smaller being for well-defined geometries in homogeneous and light matrices.

ISOTOPIC V3.0 Specifications

General
The acquisition control and quantitative analysis functions are integrated into a concise package for use in PC-based in-situ gamma spectroscopy systems for the determination of radioactive content of containers, objects, surfaces and soils. Semi-empirical methods allow calibration with a single point source. Support for multiple detector systems or sequentially gathered spectra with choice of averaging methods. Operates in both supervisor and operator modes with supervisor-controlled operator access to specified functions.

Operating System
32-bit application for Windows 98, NT, 2000, and XP network capabilities; support for preemptive multitasking; and ORTEC CONNECTIONS-32 compliant. Some data collection hardware may not operate in all Windows systems due to limitations of the Microsoft operating system (e.g. Windows NT does not support USB).

Spectroscopy Hardware Support
ISOTOPIC V3.0 is recommended for use with the ORTEC digiDART® Portable MCA system. However, all ORTEC MCBs (past and present) and all other devices supported by ORTEC CONNECTIONS-32 (see CONNECTIONS literature) are compatible. Support is built-in for advanced operations (where provided in hardware): amplifier gain/shaping control, Auto-PZ, "optimize" and InSight™ mode, digiDART and DART® field mode, graphical setting of MCB spectrum stabilizer and statistical uncertainty peaks.

File Formats Supported
ORTEC .SPC and .CHN, and ASCII ".SPE" are supported as standard in file save, recall, and compare functions. Other file formats may be imported by the use of A48-B32 Data Master.

Semi-Quantitative "SMART" MCA Functions (Supervisor mode only)
"Instant" Mariscotti peak search and "nearest match" suspected nuclide identification. Net/Gross peak areas with uncertainty calculation, peak centroid, and shape.

Quantitative Spectrum Analysis Methods
Peak Search
Peak Search by library direction for specified nuclides, plus Mariscotti peak search for non-specified nuclides, both main library and supplemental ("suspect") library are used.

Interactive Reanalysis Mode (supervisor only)
Iterative refitting of multiplets, addition or deletion of deconvolution peak centroids, adjustment of energy calibration with visual display of residuals. (Recommended for the most complex analysis problems.)

Interactive Bulk Sample Parameter Adjustments
Interactive Matrix and container adjustments and automatic attenuation correction for new matrix. Easy to use graphical display of relative analysis results to show the best matrix.

Deconvolution Method
Both peak finder and library are used to direct the deconvolution process. Automatic recalibration of Energy/channel based on identified peaks where possible.

Background Methods
Wide range of background methods — automatic, multi-point, parabolic, directed fit, and stepped. Selection by user or automatically applied to improve analysis results.

Multi-Peak Activity Averaging
Peaks are averaged on the basis of their relative abundance in the nuclide to produce the lowest possible uncertainty in the calculated activity.

Choice of Detection Limit Formalisms
ORTEC MDA
ORTEC Critical Level
No MDA (report zeros if less than MDA)
KTA MDA
Detection Limit 2 sigma — Japan
Detection Limit 3 sigma — Japan
Currie Limit
Riso MDA
ORTEC LLD
Peak Area
Air Monitor — Gimrad method
Nureg 4.16 Method
Counting Lab — USA
DIN 25482.5 Erkennungsgrenze
DIN 25482.5 Nachweisgrenze
GTN5/CEA/EDF (France)

Decay Corrections
• Decay correct to any date/time, either back or forward
• Decay corrections for losses or changes in count rate during acquisition

Spectral Corrections
• Peaked Background Correction
• Random summing (high-rate counting losses)
• True Coincidence Summing Correction
• Library-based peak interference correction

Reporting
Choose any ORTEC Standard report option:
• Direct to printer
• To Notepad.exe or other word processor
• To disk file
• Automatically written to database
• Optional A44-B32 Report Writer

Calibration

Energy Calibration
• Multipoint, quadratic for energy and FWHM
• Automatic Energy Calibration (Patent No. 6,006,162)

Semi-Empirical Efficiency Calibration Fit Options:

ISOTOPIC Mode
A point source calibration is established via one of the following methods:

> Single Function Polynomial (x-Point)
> Interpolative above and below "knee"
> Quadratic above or below user-set "knee"
> Linear above or below user-set "knee"

The point source calibration is extrapolated to the physical geometry-matrix situation via point-source Kernel calculations internal to the program.

Infinite Plane Mode (for Soils and Surfaces)
The Beck[2] 1-meter methodology, with extension to large detector sizes[3], as used by USDOE Environmental Measurements Laboratory (EML). The EML methodology is used to produce an efficiency curve based upon detector dimensions and IEEE efficiency value. The soil density and attenuation is specified in user-editable alpha/rho files.

In M-1 mode, external efficiency calibration data, either measured or calculated, may also be entered and fitted to any of the available efficiency curve formalisms. The interpolative mode supports any energy-efficiency function, thereby allowing a system user to import efficiency values determined by other means.

Soil Attenuation Factors
In soil, attenuation depends on the soil thickness and density, which is modeled by the parameter α/ρ (*where α is the reciprocal of the relaxation length, defined to be the soil thickness required to reduce the flux at a particular energy by a factor of e, and ρ is the soil density in gm/cc)*. For a surface distribution α/ρ is infinite, while for uniform (natural emitters) distribution, alpha/rho is 0. Values of α/ρ ranging from 0.05 to 0.5 have been found to describe realistic fallout distributions accurately, the more aged fallout being represented by the smaller α/ρ values.

The α/ρ values are nuclide-specific and are stored in a table which may be edited by the user to reflect the measurement conditions.

Analysis Library Manager
ISOTOPIC V3.0 includes a comprehensive library editor for building custom analysis libraries. The editor allows the operator to cut and paste nuclides and peaks from master libraries, add flags to individual peaks for identification (single escape peak, x-ray, or other) and analysis (key line or exclude from activity calculation), and save the library as any name. It also includes full integration of the Nuclide Navigator library tool (sold separately as model C53-B32). ISOTOPIC will use Nuclide Navigator if installed, and can read Nuclide Navigator libraries in Microsoft Access Database format (no conversion necessary), and save libraries in database format for use by Nuclide Navigator.

Quality Assurance
ISOTOPIC quality assurance complies with the demands of ANSI N13.30. For each detector the following are monitored:

> Total detector background
> Total (decay corrected) activity for all calibration nuclides
> Average FWHM ratio (spectrum to calibration standard)
> Average FW1/10M ratio (spectrum to calibration standard)
> Average peak shift from library values
> Actual peak centroid energies

Calculational Details

Summary of the ISOTOPIC Mode Methodology for Containers

The activity of an isotope in a container is given by

$$A_{isotope} = \frac{PA_{meas}\,(CF_{cont})(CF_{mat})(CF_{sam})(CF_{geo})(CF_{col})}{BR\gamma_{ray}\,(\varepsilon_{det})}$$

where

$A_{isotope}$	=	activity of the isotope to be reported (Bq/µCi),
PA_{meas}	=	measured peak area for a reference gamma ray of the isotope (c/s),
CF_{cont}	=	container attenuation correction factor,
CF_{mat}	=	matrix attenuation correction factor,
CF_{sam}	=	sample self-attenuation correction factor,
CF_{geo}	=	geometry correction factor,
CF_{col}	=	collimator correction factor,
$BR_{\gamma ray}$	=	gamma-ray branching ratio,
ε_{det}	=	detector efficiency measured using a NIST-traceable point source. (cps per Bq, µCi)

When gram quantities, $Mass_{isotope}$, of reported isotopes are needed, these are given by:

$$N = \frac{A_{isotope}}{\lambda_{isotope}} \qquad\qquad Mass_{isotope} = \frac{N(At)}{Av}$$

where

N	=	number of atoms of a reported isotope,
$\lambda_{isotope}$	=	decay constant of a reported isotope (sec^{-1}),
At	=	atomic number of the measured isotope (g/Av),
Av	=	Avogadro's number.

Result Averaging of Multiple Measurements

When results of multiple measurements are combined, a weighted average is calculated according to

$$A_{average} = \sum A_i\, w_i/\sum w_i$$

where

A_i	=	individual activity (gram or MDA) results
w_i	=	user-defined weighting factors

Container Wall Attenuation

The attenuation in the wall of any container is given by:

$$CF_{cont} = e^{\mu_{cont}\rho_{cont}x_{cont}}$$

where

μ_{cont}	=	mass attenuation coefficient of the container (cm^2/g),
ρ_{cont}	=	density of container material (g/cm^3),
x_{cont}	=	container thickness (cm).

Two such corrections are available to handle lined or overpacked containers.

ISOTOPIC Mode offers a variety of selectable container materials (e.g., steel, glass, plastic, zircaloy, monel, and copper) to help determine the container attenuation correction factor.

Matrix Attenuation

If the matrix is relatively homogeneous, the matrix correction is given by:

$$CFmat = \frac{\mu_{mat}\rho_{mat}x_{mat}}{1-e^{-\mu_{mat}\rho_{mat}x_{mat}}}$$

where

μ_{mat}	=	mass attenuation coefficient of the matrix (cm^2/g),
ρ_{mat}	=	matrix density (g/cm^3),
x_{mat}	=	gamma-ray distance through the material (cm).

The user selects the matrix type. Choices available include: combustible, concrete, water, uranium, steel, Al_2O_3, UF_6, U_3O_8, UO_2, and calcined ash.

If uranium is present in a nonhomogeneous configuration, the program determines the matrix attenuation and uranium attenuation separately. The equation used to determine the attenuation of an inhomogeneous matrix is the same used to determine the attenuation of a container.

$$CF_{mat} = e^{\mu_{mat}\rho_{mat}x_{mat}}$$

Geometry Correction

ISOTOPIC Mode geometry corrections utilize the inverse-square law to compute the detector efficiency for this container. The container is divided up into volume elements or voxels. The distance from the activity voxel within the measured item to the detector is compared to the distance from the point-source standard to the detector used initially to calibrate the HPGe detector for absolute efficiency. The correction to the point source calibration is given by:

$$CF_{geo} = \left(\frac{D_{meas}}{D_{std}}\right)^2$$

where

CF_{geo}	=	geometry correction factor,
D_{meas}	=	distance from detector face to center of a sample (cm),
D_{std}	=	distance from detector face to a point-source standard (cm).

For cylinder and box configurations the container is evenly divided into many activity voxels and the contributions summed. Matrix and container attenuation correction factors are computed separately.

Collimator Correction Factors

If a container is large enough, some gamma rays will penetrate any collimator that may be surrounding the germanium detector. The collimator correction factor is heavily dependant on the diameter of the collimator, the depth of collimation, and the wall thickness of the collimator.

The equation for the gamma-ray attenuation through a collimator, CF_{coll}, is:

$$CF_{coll} = e^{\mu\rho x_{pen}}$$

where

μ	=	mass-attenuation coefficient for the collimator (cm^2/g),
ρ	=	density of the collimator (g/cm^3),
x_{pen}	=	length of gamma-ray path through the collimator.

The path length through the collimator, x_{pen}, for one volume element is given by:

$$X_{pen} = X_{coll}\sin\Theta$$

where

X_{coll}	=	collimator thickness (cm)
and		
Θ	=	the angle of incidence of the gamma ray with respect to the collimator side wall (zero for normal to the wall)

The path length is computed for all volume elements and an average path length for the entire collimator is then computed.

Methodology for Soils

The specific activity, A (Bq/m^2 or Bq/g) is related to the net peak count rate N_f by:

$$A\ (activity) = \frac{N_f\ (net\ peak\ count\ rate)}{\left(\dfrac{N_f}{N_0}\right)\left(\dfrac{N_0}{\Phi}\right)\left(\dfrac{\Phi}{A}\right)}$$

where

N_f/N_0	=	angular correction factor of the detector at that energy for a given source distribution in the soil,
N_0/Φ	=	peak count rate (cpm) per unit uncollided flux ($cm^2 s^1$) for a parallel beam of gamma rays of the peak energy that is incident normal to the detector face, and
Φ/A	=	total uncollided flux ($cm^2 s^1$) at the peak energy arriving at the detector per unit inventory or concentration of the nuclide in the soil.

The method of estimating calibration factors uses information about the detector and the distribution(s) of radionuclides being measured:

• Detector Efficiency (expressed as %)
• Detector Orientation (up or down)
• Detector Aspect Ratio (calculated as crystal length/crystal diameter)
• Deposition Profile Parameter (α/ρ value(s))

α/ρ is assumed to be 0 (for uniform distribution) for all natural emitters. α/ρ is assumed to be infinite (for surface only distribution) for fallout on undisturbed soil.

Beck's method is implemented in ISOTOPIC V3.0 by calculating values for each of the calibration parameters.

The calculation is carried out for each gamma ray of all the nuclides identified.

System Prerequisites

As a CONNECTIONS-32 product, ISOTOPIC V3.0 requires a Windows 98, 2000, NT, or XP platform. Interfacing of MCB hardware to the system may be by USB, Ethernet, printer port, serial port, or ORTEC Dual-port Memory. (Check hardware literature for details). ISOTOPIC V3.0 will run on any PC that uses Windows and has 20 MB of disk space.

Ordering Information

To order, specify:

Model	Description
ISOPLUS-B32	ISOTOPIC-32 V3.0
ISOPLUS-G32	Documentation for ISOPLUS-B32
ISOPLUS-K32	Upgrade from ISO-B32 or M-1-B32 to ISOPLUS-B32
ISOPLUS-N32	ISOPLUS-B32 Network Copies
ISOPLUS-U32	Update to ISOPLUS-B32

Related Products

ISO-CART™ Mobile Assay System A Complete *In-Situ* NDA Gamma-Ray Analysis for a Wide Variety of Samples

- Measures all common geometries: pipes, cylinders, floors, ceilings, walls, drums, boxes, and soils
- Easy-roll cart for maneuvering over any surface
- Wide selection of collimators and shields available for different measurement situations
- Continuous height adjustment and variable tilt adjustment
- Easily disassembles to fit into your car
- ISOTOPIC software, proven results on thousands of real-world samples
- Simple to calibrate with a single inexpensive mixed isotope point source
- Flexible reporting: measurement results can be reported in grams or activity (Bq or Ci)

Specifications subject to change
072302

ORTEC®