G3700-B25

Waste Segregation Gamma Box Scanner

1. Introduction

1.1 General

The ANTECH Model G3700-B25 is a modular, high efficiency, high-resolution gamma-ray spectroscopy assay system for the detection of radiation 'hot spots' and accurate assay measurements of radionuclides in waste crates and boxes. Although it was originally designed for the measurement of B25 boxes, it is capable of measuring a wide rang of boxes, crates and objects that can be placed on the measurement platform which has dimensions 2.0 m x 1.5 m and within a height envelope of 1.3 m.

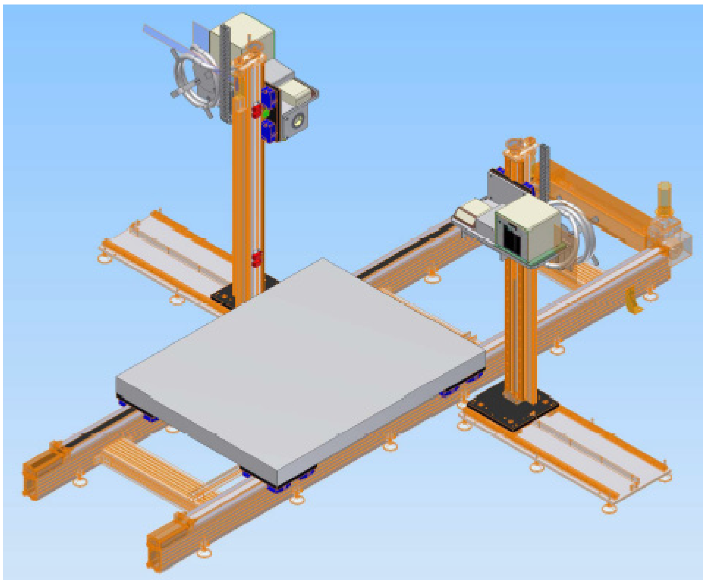
The standard unit is supplied with two detectors (one on each side) although a 4-detector system (2 on each side) can also be supplied for applications requiring higher throughput. In the two-detector (standard system) each detector is located on a motorized pillar so that both upper position and subsequently lower position measurements can be performed on each side of the box or object. See Figure 2 (over page).

The Model G3700-B25 may be used for accurate assay, segregation and screening of gamma-ray emitting waste in large containers, such as a B25 box, Standard Waste Box (SWB) or any other container or object that fits within that envelope. Although physically large, a rectangular box such as the B25 offers relatively simple assay geometry and the principle of the assay system is that of making multiple measurements of the same container from different measurement points thereby obtaining multiple estimates for the activity that is inside the box or object. The measurement system has a load cell which weighs the box or object and produces the net weight of waste from which (given the fixed volume of the box) can be derived the average density of the waste for attenuation correction purposes. The waste in the box is counted using hyper-pure germanium (HPGe) detectors and the acquisition results (after corrections for geometry and for attenuation) may then be combined to produce a best estimate of the container total activity. "Outliers" from the container average are pointers to inconsistencies, which lie in either matrix or source distribution inhomogeneity.

In use, the container passes through the pair of HPGe detectors, one on either side of the longest side of the box (the detector measurement station) and stops automatically at a single or multiple measurement points. Typically, the multiple measurement points are set at 25%, 50% & 75% of the length of the B25 box (or other container). At each point the two (or four) collimated HPGe detectors perform multiple simultaneous measurements. Smaller boxes or objects will require fewer measurement positions.

Figure 1. The ANTECH Model G3700-B25 Crate and Box Assay System in operation

Figure 2. The ANTECH Model G3700-B25 Crate and Box Assay System



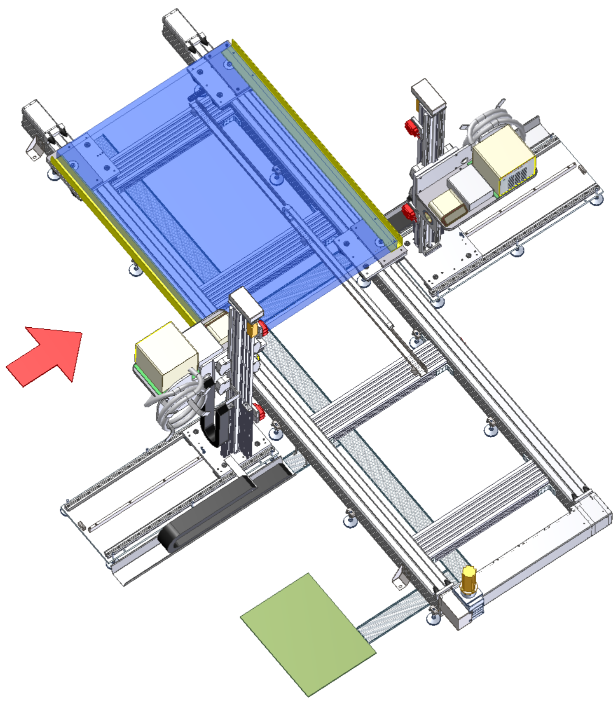
In a typical configuration six measurements are made on the upper half of the box or object (3 on each side). When the first phase of the scan is complete, the two detectors are moved to the lower measurement position to measure the lower half of the box or object. In this example a total of 12 assay measurements (3 on the upper half and 3 on the lower half of each side of the box for a total of 6 on each side of the box or crate) will have been performed. Note that the user can configure the number of measurements, which are made on each side of the box or object.

The HPGe detectors are connected to a digital gamma-ray spectroscopy system such as the ORTEC DSPEC or ANTECH Model G3081 Digital Pulse Analyzer (DPA). Control of the multi channel analyser (MCA) and data acquisition is via a personal computer running ANTECH Master Box Scan (MBS) software. This software interfaces with ORTEC GammaVision-32 spectroscopic analysis software. ANTECH IsoCorr software manages the gathering of the multiple detector spectra and processes the results. Each detector to be used in the assay is calibrated with a simple multi-line point source and the IsoCorr then extrapolates the calibration to the actual geometry and matrix conditions present at each measurement point. The results from each detector are then averaged and stored within an industry standard database. IsoCorr and GammaVision are described in more detail in section 4 below.

1.2 Typical Features

- 25% GEM, Gamma-X or Profile HPGe detectors.
- HPGe detectors are provided with both a graded shield as well as a collimator.
- HPGe detectors are cooled using X-Cooler-II units. The only service required by the system is 110VAC.
- High specification digital spectrometer/MCA for each HPGe detector – ORTEC DSPEC or DPA.
- Analysis performed using ORTEC GammaVision-32 and the ANTECH IsoCorr software code.
- Automatic movement of the B25 box using a PLC, which is computer controlled. The operator can adjust the measurement positions and the movement of the box or object.
- The vertical positions of the detectors are motor controlled and adjustment can take place under manual operator control or automatically as part of an automated measurement sequence. The detector can be adjusted vertically and horizontally and each detector lifting-pillar can be manually adjusted in the horizontal plane.
- Integral load cell measures the weight of the box and this information is used for density correction and to determine the specific activity.
- Monte Carlo calculations are provided as part of the calibration process.
- The software allows the user to select from a number (10) of calibrations (profiles or fingerprints) and for each calibration allows the user to establish correlation factors.

Figure 3. Loading position of the G3700-B25



2. Mechanical Handling

With reference to Figure 3 (left), the B25 Box (or equivalent) is loaded from the left hand side of the unit using conventional fork-lift truck (not part of the supply). (Note that the dimension of the B25 box are: 1.194 metres high x 1.829 metres length x 1.156 metres wide and has a capacity of 2.5m^3). The material of construction of the box can range from plywood, fibre-glass resin and stainless steel or aluminium depending upon the country of origin and regulatory guidelines. The weight can therefore vary. For the purposes of providing a robust design a maximum weight of 6 tones has been assumed.

The crate is loaded by fork-lift truck on to a load platform which is moved with a robust belt drive. A PLC motion controller is used to move the waste box. The motion control equipment is housed in a separate control panel, which is not shown.

The movement of the waste box is pre-set in the measurement program, but can be overridden for safety reasons or for ease of calibration and maintenance. Emergency stop buttons are provided on the control station and at other points around the assay system. The crate or box is centred on the load platform (and hence is centred between the detectors either side). A load cell is built into the load platform and is used to weigh the crate or box. Given the crate or box ID, the software selects the appropriate crate dimension from a ‘pick list’ in the program, subtracts the tare weight to produce a net weight of waste. The software then derives the density of the waste from this information and the known volume of the crate. The average matrix density (calculated using the measured box weight) is used to correct the measured gamma-rays for attenuation, which takes place in the waste. It is also used to determine the specific activity. The gamma-ray signal is also corrected for attenuation suffered in passing through the waste container walls.

As described earlier the waste box is moved to pre-selected positions, typically representing 25%, 50% & 75% of the total length of the waste box (these positions are alterable in the software to suite the particular waste box or crate). The waste box then stops at that position while the detectors acquire data for a pre-set measurement time. The measurement time can be automatically adjusted to minimise and optimise the counting time i.e. data acquisition until a precision of 1% or better is achieved. When the measurements are completed at the three upper longitudinal positions, the detectors are re-positioned to the lower half of the box and the remaining measurements are made at the lower longitudinal positions. When all measurements are completed, the crate is moved back to the un-load position so that the crate may be removed using the fork lift truck or a crane.

3. Detectors and Measurement System

3.1 HPGe detectors

The ANTECH Model G3700-B25 is provided with two 25% GEM, Gamma-X or Profile HPGe detectors. The detectors are ORTEC PopTop to connect to the X-Cooler electro-mechanical cryostat system.

3.2 X-Cooler

Each of the two detectors constituting the Model G3700-B25 crate counter will be supplied with ORTEC X-Cooler™ for liquid nitrogen free operation.

The major components of the X-Cooler are the compressor, transfer hose, the heat exchanger and the cold head. The compressor box is attached to the detector via the cold head and the transfer hose. The standard length of the transfer hose is 2.44 metres and it is coiled at the side of the detector shelf.

The X-Cooler electrically driven cooling system contains the Compressor unit, which drives a mixed-gas refrigerant around a closed loop cooling system. The refrigerant cools the Cold Head on which the detector head is mounted. The power for the above X-Cooler unit and the nucleonic electronics can be supplied via a UPS.

3.3 The Digital MCA System

Each of the two HPGe detectors requires its own separate DPA or DSPEC digital gamma-ray spectroscopy instrument, which is used for data acquisition and signal processing. Each spectroscopy instrument is complete with high voltage power supply, shaping amplifier, analogue to digital converter (ADC) and multi-channel analyser (MCA).

The system is a self-contained unit and is fully integrated with and controlled by a computer. It consists of the following major spectroscopy elements:

- ADC
- High Voltage DC Power supply
- Low Voltage DC Power supply
- Spectroscopy Amplifier
- Digital Spectrum Stabilisation
- Digital Filter
- Digital Spectrometer/Multi Channel Analyser (MCA)

The system is controlled and data is transmitted from the MCA by a USB or Ethernet data transmission system. The functions of variable time constants, pulse shaping, pulse pile up rejection and spectrum stabilization are all provided by the MCA unit, with user selection provided on the computer. The high voltage bias supply to the detector is controllable from the computer as is the output voltage polarity.

Advantages of the digital MCA systems are as follows:

- The signal is digitized at the preamplifier stage.
- The amplifier handles digital signals so no user involvement is required in setting pole zero or gain stabilization.

- Pulse shaping is performed automatically and optimized for the measurement.
- The system requires significantly less space than conventional spectroscopy systems.

When it is used with appropriate analysis software the digital MCA can perform a variety of functions, including:

- Peak search
- Region of interest definition
- Gross and net peak area calculations including calculation of standard deviations (errors)
- Peak resolution calculations
- Energy calibration
- Spectrum strip (i.e. the ability to subtract a multiple of one spectrum from another)
- Storage and retrieval of spectral data from disk

3.4 Detector Collimator

The collimator and shield define the detector's viewing angle and shield the detector from ambient radiation. Each HPGe detector is fitted with a graded detector shield constructed of lead (Pb) and a fluted collimator (of given exit diameter) such that each detector's field of view is sufficient to provided coverage for the full half height of the box. The detectors can be moved to a variety of different vertical positions to cover various heights of crate containers and waste boxes.

4. Analysis Software

4.1 General

The ANTECH Model G3700-B25 uses ANTECH proprietary IsoCorr software.

The ANTECH IsoCorr Program runs in conjunction with ORTEC GammaVision-32 for HPGe detector gamma-ray analysis. GammaVision controls the acquisition, saves the spectrum and does the peak analysis. IsoCorr then "post processes" the results further to correct for matrix, container, collimator and geometry effects using operator-supplied information about dimensions, weights, distances and materials, along with internal databases of geometry and matrix correction information.

GammaVision is the ORTEC peak-fitting software for general-purpose gamma-ray analysis of spectra taken with an HPGe detector. GammaVision has analysis features and options, which provide flexibility.

IsoCorr is a "post processor" to GammaVision. GammaVision "hands over" to IsoCorr a list of peak-by-peak activities computed for each isotope in turn, uncorrected for geometry or absorption, and determined using a calibration which the user makes with a simple traceable multi-nuclide point source. IsoCorr uses the peak results from GammaVision along the source-to-detector distance employed for calibration. Sample physical data (size, distance, weight, material) are entered into IsoCorr via easy to use data entry screens. IsoCorr then performs the necessary attenuation corrections to the peak-by-peak activities and geometry corrections to the reference activity. Efficiency calibration requires a traceable point source only, and all other secondary efficiency calibrations for the actual sample non-point-source geometries are derived from this calibration by calculation within the program, ensuring that they too are traceable. Completely automatic recalibration for efficiency is based on a predetermined library and file containing data from the standard source certificate. Corrections are calculated for field of view and penetration of the sides of the collimator, taking account of the shielding effects of the collimator material.

GammaVision has the ability to display the individual spectra from the two HPGe detectors employed in the Model G3700-B25.

4.2 Model G3700-B25 Measurement Uncertainty

The assay accuracy is largely dependent on the distribution of sources inside the waste box and the number of measurement points. Typical assay accuracies are between 25% and 65%. For measured items containing dense material, measurement uncertainties of at least 50% can be expected.

The major sources of error are usually in the determination of the matrix correction factor. Usually, the higher the matrix density, the larger the uncertainty in the matrix correction. When using the Model G3700-B25, the uncertainty can be reduced by counting longer or using a more efficient detector so that weaker gamma-rays from a nuclide can be used to correct for the matrix. There will be smaller random errors due to uncertainty in positioning the item in front of the detector and counting statistics. Under most circumstances the errors are dominated by systematic biases.

5. Data Acquisition Analysis & Reporting

5.1 Box/Container Configuration

The operator startup procedure may be customized from the supervisor mode of the Model G3700-B25 so that the operator is prompted to carry out the necessary procedures to ensure meaningful measurements based on good quality data.

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.

5.2 Quality Assurance

ANTECH operates a Quality System to NQA-1 and ISO 9001-2008. All ANTECH software is written to NQA-1 standard and the ORTEC provided GammaVision software complies with the demands of ANSI N13.30.

5.3 System Calibration

The Model G3700-B25 is used for the counting of waste boxes using a collimated detector and the detector is characterized by a single point-source measurement. This primary calibration, traceable to a certified standard for any detector, is extrapolated or modeled to match the physical situation of the waste box 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.

For routine measurements the operator will enter the waste box ID, type and the critical measurement data, such as detector-to-container distance. The box weight is provided by the load cell.

6. Model G3700-B25 System Performance

The following factors affect the accuracy of the measurement:

- Statistics and counting time
- Matrix density and inhomogeneity
- Nuclide self shielding attenuation
- Calibration uncertainty
- Number of measurements carried out on a single container or object

A range of 25 to 65% accuracy should be considered representative, the smaller being for well-defined geometries in homogeneous and light matrices.

Table 1 (below) shows the Minimum Detectable Activities (MDAs) of a similar system when measuring a B25 Box using a collimated detector. In each case the counting time was 1.0 hour. The MDA was calculated according to the Currie convention.

Table 1. B-25 Box (122 x 183 x 122cm - 48 x 72 x 48in) Detector positioned 91 cm (36 inches) from box

Nuclide	Ref Energy (keV)	Combustible Density 0.2 g/cc Wt = 5.44 E+5 g			Metal Density = 1.0 g/cc Wt = 2.72E+6 g		
		Grams	pCi/g	Bq/kg	Grams	pCi/g	Bq/kg
Co-60	1332.5		3.54E-01	1.31E+01		2.37E-01	8.76E+00
Cs-137	661.6		1.53E-01	5.65E+00		1.18E-01	4.37E+00
Ra-226	609.3		8.64E-01	3.20E+01		2.60E-01	9.61E+00
U-235	185.7	7.48E-02	2.97E-01	1.10E+01	3.82E-01	3.04E-01	1.12E+01
U-238	1001.0	2.43E+01	1.49-E+01	5.51E+02	8.80E+01	1.08E+01	3.98E+02
Np-237	312.2	2.38E-04	3.09E-01	1.14E+01	9.80E-04	6.56E-01	2.43E+01
Pu-238	152.7	7.04E-04	7.76E+03	2.87E+05	4.24E-03	2.68E+04	9.90E+05
Pu-239	413.7	6.80E-02	2.41E+04	8.91E+05	2.71E-01	6.16E+03	2.28E+05
Pu-240	160.31	1.15E-01	4.84E+04	1.79E+06	6.64E-01	1.08E+05	3.98E+06
Pu-241	208.0	1.8E-04	3.33E+04	1.23E+06	8.80E-04	3.17E+04	1.17E+06
Am-241	59.5		6.20E+00	2.29E+02		3.78E+01	1.40E+03
Cm-243	277.6		1.13E+00	4.19E+01		9.56E-01	3.54E+01
Cm-244	152.6	1.43E-04	2.13E+04	7.87E+05	8.64E-04	2.57E+04	9.52E+05

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