A Collimated CZT Detector for Quantitative Gamma Assays
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ABSTRACT

Cadmium-Zinc-Telluride [CZT] detectors for gamma spectroscopic measurements and room-temperature operation have had a long history of promising good performance. Very small detectors [0.05-0.5cm3] have been commercially available for many years, but their small size creates problems for spectroscopy because of very low photopeak efficiency, especially at medium and high energies. Large CZT [4-6cm3] detectors have been shown to work nicely in a research environment when complicated electronic and data processing algorithms are applied. We report here test results from a commercially available 1 cubic centimeter CZT detector housed in a portable custom Tungsten shield with a set of collimators with different apertures. The detector has 2-2.5% FWHM resolution at Cs-137 energies, and near-Gaussian shaped peaks. Efficiency calibrations can be quickly made for a wide variety of geometries using the ISOCS mathematical efficiency software. We show successful validation tests comparing accuracy of measurements on reference calibration point sources, line sources, and 200 liter drums. The low weight of the device [9kg including the shield and collimator] and low power [powered via USB from the PC] makes these devices particularly suitable for human-deployed in-situ measurements of large objects containing medium levels of activity – e.g. characterization of objects encountered during decommissioning, emergency response, truck alarm investigation, or waste being shipped to a disposal facility.

INTRODUCTION

The past few years have seen many improvements in detector technology, electronics, computing power, and analytical tools. Today, a variety of commercial devices exist allowing good quality gamma spectroscopic measurements with sufficient size and portability that they can be used in the field for quantitative measurements. Figure 1 is a composite showing several such devices from Mirion Technologies (Canberra), herein simply called Canberra within this document. Similar devices are available from other vendors.

The common theme in all of these instruments is that they generate adequate quality gamma spectra, some better than others, and that the Canberra ISOCS mathematical efficiency calibration software can be used on each of those detectors to allow quantitative measurements.

Figure 1 Various In-situ measurement instruments: ISOCS shield set and detector, Ge detector on tripod, scintillation detector with InSpector1000 MCA, collection of small CZT probes, and InSpector1000 with small CZT probe attached.

The Germanium detector on a tripod [Fig 1] measuring radioactivity in soil has been a common method since the 1970s. Efficiency calibration methodology using a combination of traceable point sources and mathematical extensions to infinite size soil geometries was developed by the DOE Health and Safety Laboratory [1] for NaI in the '60s and then extended to Ge detectors [2].

In 1995, that efficiency calibration method [combination of point sources and mathematical extensions to other geometries] was significantly improved by Canberra with the introduction of the InSitu Object Calibration Software [ISOCS] fully mathematical software. The user no longer needs to purchase and make the source measurements, and the software can compute efficiency for a very wide range of object sizes and shapes and distances. Currently the ISOCS software has 21 different templates [sample shapes] and these samples can be any distance from contact out to 500 meters [3, 4].

At the same time, the ISOCS shield [Fig 1 shows the current version] was also introduced . This device supported the Ge detector and cooling system, a battery operated Multi-Channel Analyzer [MCA], a PC, along with a flexible set of lead side shields and back shields and collimators. The wheeled cart allowed this device to be moved around the site for measurements of walls, pipes, boxes, tanks, drums, and many other types of objects [5]. But it weighs 190 kg [with both 25mm and 50mm shield sets] which limits its portability, and the detector required liquid nitrogen for operation.

The InSpector1000 was introduced in 2003 [Fig 1]. This single battery operated device incorporates the MCA and computer, along with supplying power to the detectors. Various scintillation detectors are available [NaI, LaBr] in different sizes, and also CZT detectors in various small sizes [$5mm^3$, $20mm^3$, $60mm^3$, and $500mm^3$]. The scintillation detectors are compatible with the ISOCS efficiency calibration software, but not the CZT detectors due to their very small size. While the InSpector1000 is vastly more portable than the ISOCS shield, the scintillation detectors had much worse resolution than Ge, and the compatible CZT detectors were very small and also of not very good resolution and peak shape.

Therefore, goal of this project was to develop a device with energy resolution adequate to handle most gamma nuclide mixtures, adequate sensitivity to accurately measure radioactive waste, the flexibility of the ISOCS shield set to measure a wide range of objects, but much easier to deploy in the field. A further goal is a device that is priced lower than the full ISOCS instrument, and therefore more available to a wider group of users.

THE GR1 CZT DETECTOR

Several years ago, the CZT technology had advanced to a state where good quality "large" detectors were commercially viable. And electronics had advanced to where good quality electronics could be made very small and very low power. Kromek has incorporated these into their GR1 detector. This device incorporates a 1000mm^3 detector and a 4096 channel MCA all in a device that is 25x25x63mm in size. Canberra is a distributer of a special version of this device [Fig 2]. Four flavors of the device are available; there is a basic device with <2.5% FWHM resolution, and an enhanced device with <2.0% FWHM resolution. Both resolution devices are available with and without special external signal outputs, as shown in the figure.

Figure 2 GR1A detector on left; GR1 on right. The square hole in the middle of each detector is for the USB connection.

As compared to the NaI detector, the GR1 has much better energy resolution – nominally <2% FWHM for Cs-137 vs. 7-8% for NaI. While this is not as good as Ge [~0.3%] it is entirely suitable for a very wide variety of common D&D and ER nuclide combinations, and especially applications where there are multiple radionuclides present.

Figure 3 shows the spectra from a mixture of Co-60, Zn-65 and Fe-59, a common mixture in nuclear power plants. The Ge spectrum clearly has the best resolution, and is very easy for the software to analyze. The NaI spectrum is clearly the worst, and the individual peaks cannot be separated. Both the LaBr scintillator and the GR1 CZT have similar resolution [~3% for LaBr and ~2%

for CZT], and both are entirely capable of resolving and accurately quantifying all of the peaks in this mixture with the appropriate software.

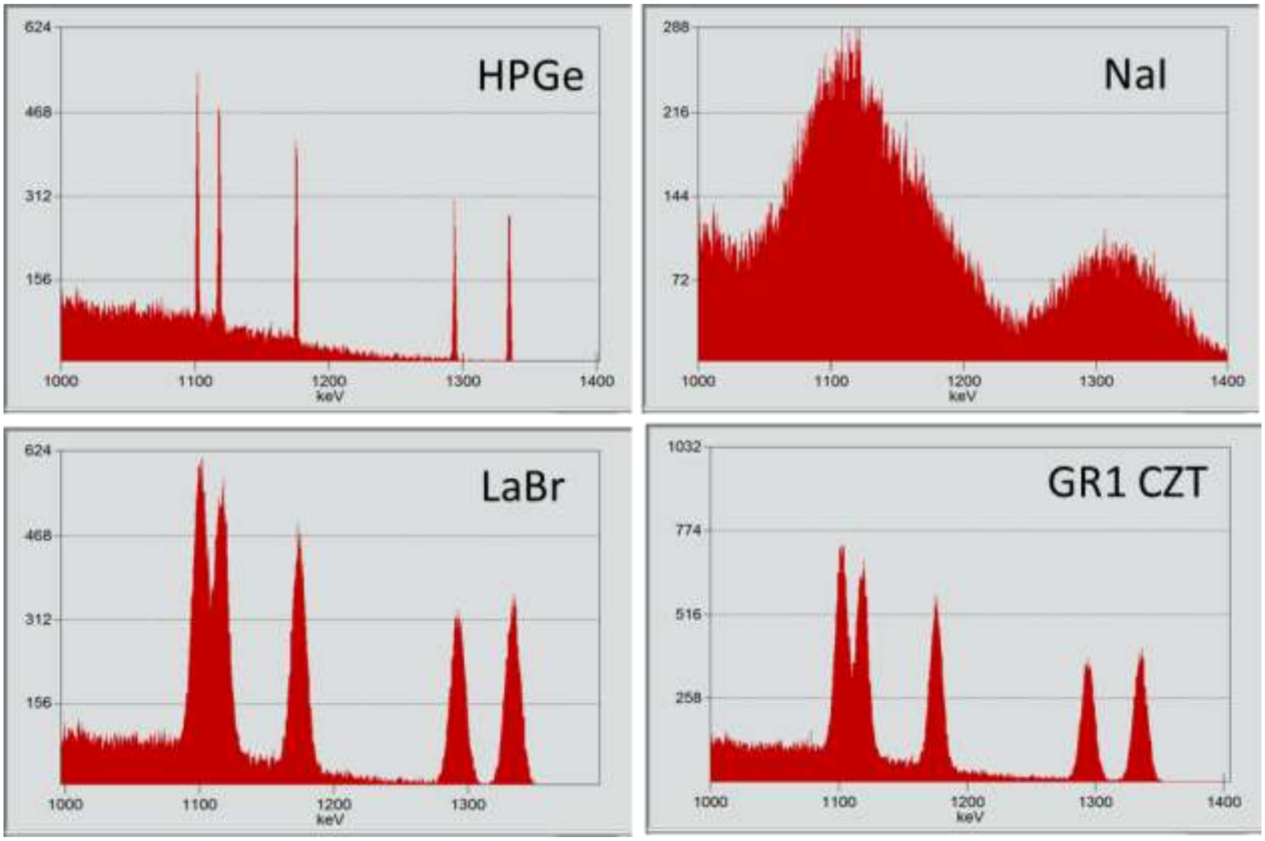


Figure 3 Comparison spectra of NaI LaBr HPGe and CZT detectors. All spectra on the same expanded energy scale of 1000-1400 keV. Nuclides are Co-60, Zn-65 and Fe-59.

A series of tests was conducted by Canberra to determine the adequacy and the limits of performance of the GR1 CZT. The following is a summary of the key tests and findings.

Figure 4 shows the results of measuring 23 different gamma energies. As long as the energy range is less than 1 MeV full scale, then a linear fit for channel vs. energy is adequate. But if the energy scale goes to 3 MeV, which would be a normal range to encompass most all nuclear power and NORM nuclides, then a 2nd order fit is much better.

Figure 5 shows the energy resolution in %FWHM for each of those 23 energies, as well as the predicted residuals from the two different fit equations. There seems to be little advantage of the extra fit parameter. This particular detector had a FWHM of 8.55 keV at 60 keV, 11.65 keV [1.8%] at 662 keV, and 14.26 at 1332 keV.

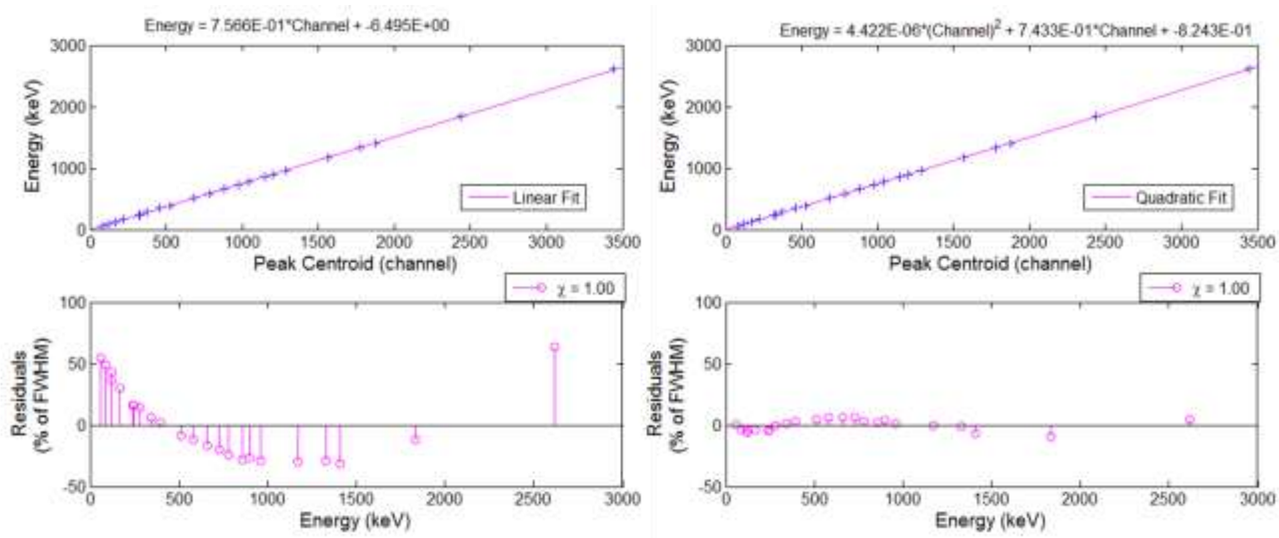


Figure 4 Comparison of energy linearity between linear [left] and quadratic fit [right]. Upper graph shows fit to data; Lower graph shows difference between actual data and energy calibration prediction.

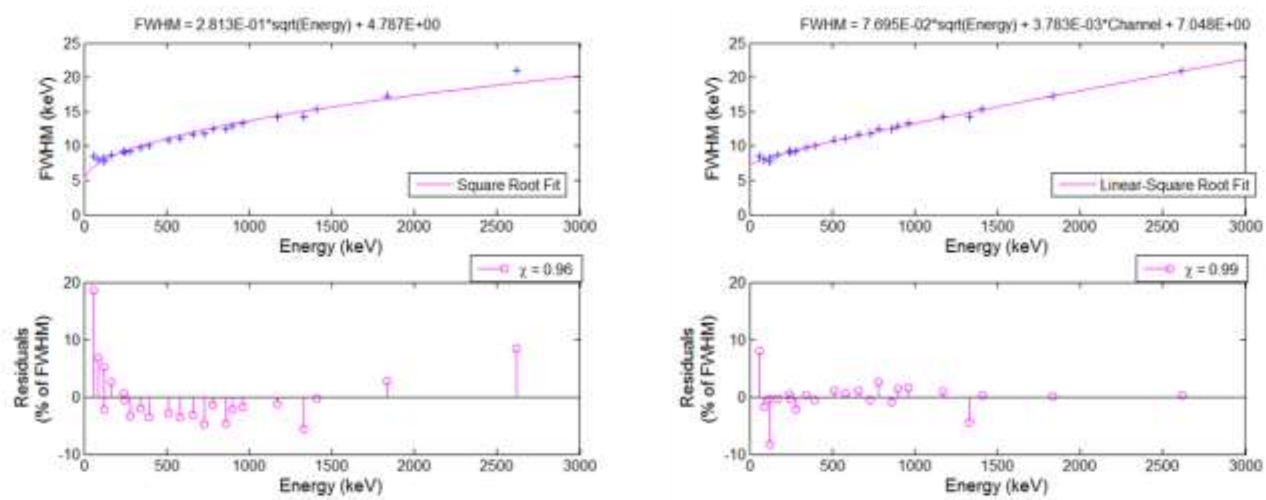


Figure 5 Comparison of FWHM fit equations between a simple square root fit with offset [left] and a linear square root fit [right]. Upper graph shows fit to data; Lower graph shows difference between actual data and FWHM calibration prediction.

The peaks of the GR1 are also very well shaped and have no obvious problems with incomplete charge collection which shows up as low energy tailing. This has been a major issue with earlier CZT detector-electronics combinations, especially at high energies. Figure 6 on the left shows a Co-60spectrum from a smaller 500mm^3 detector connected to the InSpector1000. On the right is the GR1 detector and integrated MCA showing a long background spectrum. Both figures are the same energy scale [1100-1700 keV] and count scale [0-1000 counts full scale, logarithmic display]. Note the severe low energy tailing on the small detector, whereas the two peaks on the larger GR1 are nearly symmetrical.

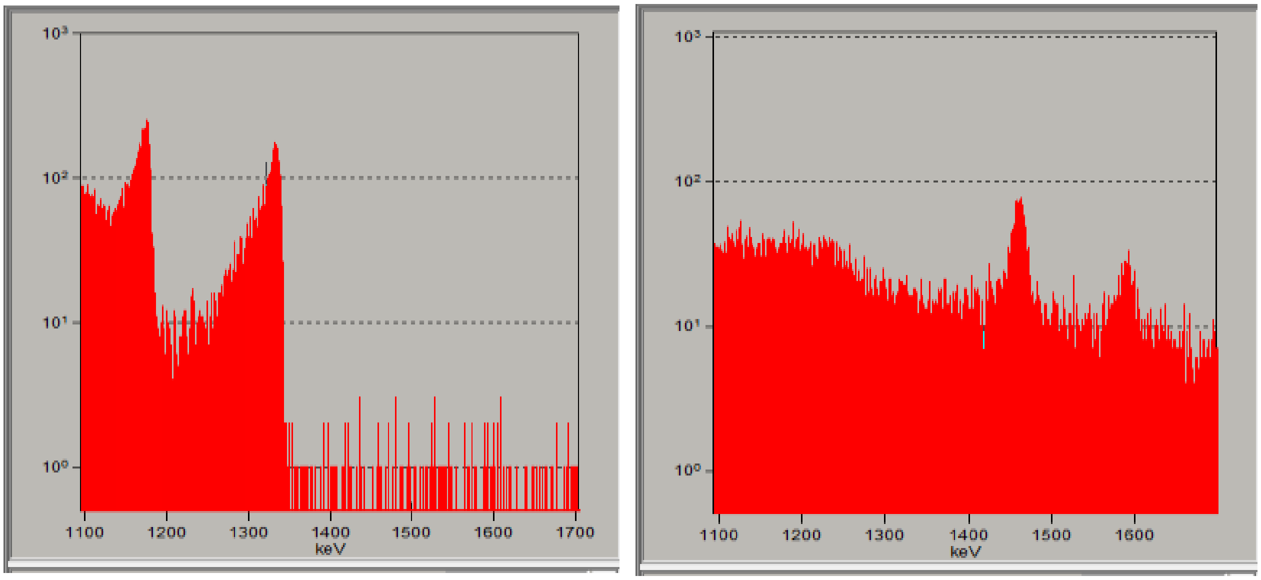


Figure 6 Expanded scale of Co-60 with a small CZT detector [left] and a long unshielded background with the GR1 detector. Both figures are the same scale – 1100-1700 keV, and 0-1000 counts.

Since this detector is intended for in-situ applications, which will encompass a wide range of temperatures, temperature tests were performed, from 0 ^{O}C to 50 ^{O}C [32 – 122 ^{O}F]. Figure 7 shows the results. The position of the Cs-137 peak was quite stable as the temperature increased above 25 ^{O}C. The centroid was slightly reduced at 0 ^{O}C, but well within the ability of the gamma spectroscopy software to handle. The FWHM was also reasonably consistent up to 30 ^{O}C, but increased at 40 ^{O}C and even more at 50 ^{O}C. If the software is configured for a fixed and well-known FWHM, the net peak area should be quite good up to 30 ^{O}C. The net peak counts under the peak are essentially the same at all of these temperatures, but above 30 ^{O}C, the software determining net peak area should allow the FWHM to vary for best peak area accuracy.

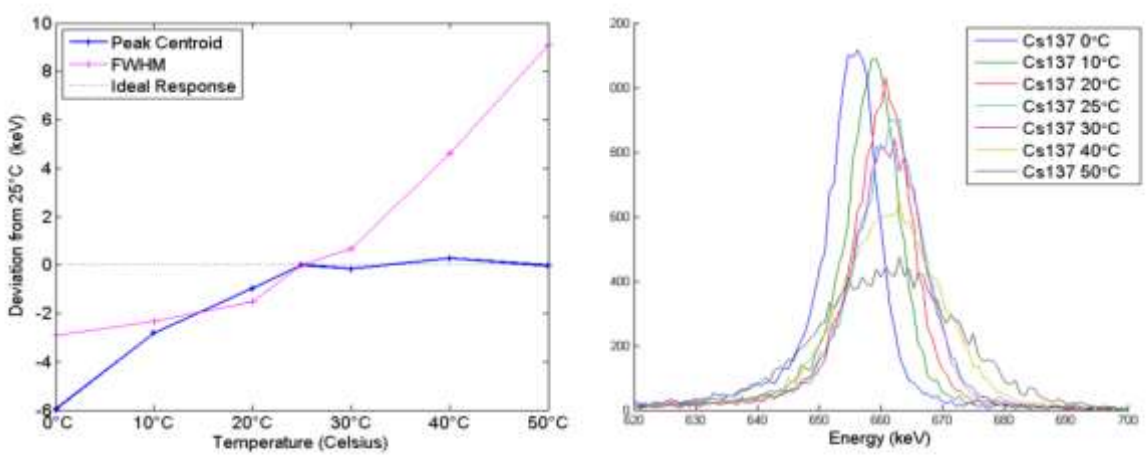


Figure 7 Change in peak position and shape vs. temperature.

The final performance test was to find out what happens at very high countrates. A Cs-137 dose calibrator was used for this test. The GR1 was placed in doserate fields ranging from near background up to 1280 mR/hr [nominally 12.8 mSv/hr]. The data are shown in Figures 8 and 9.

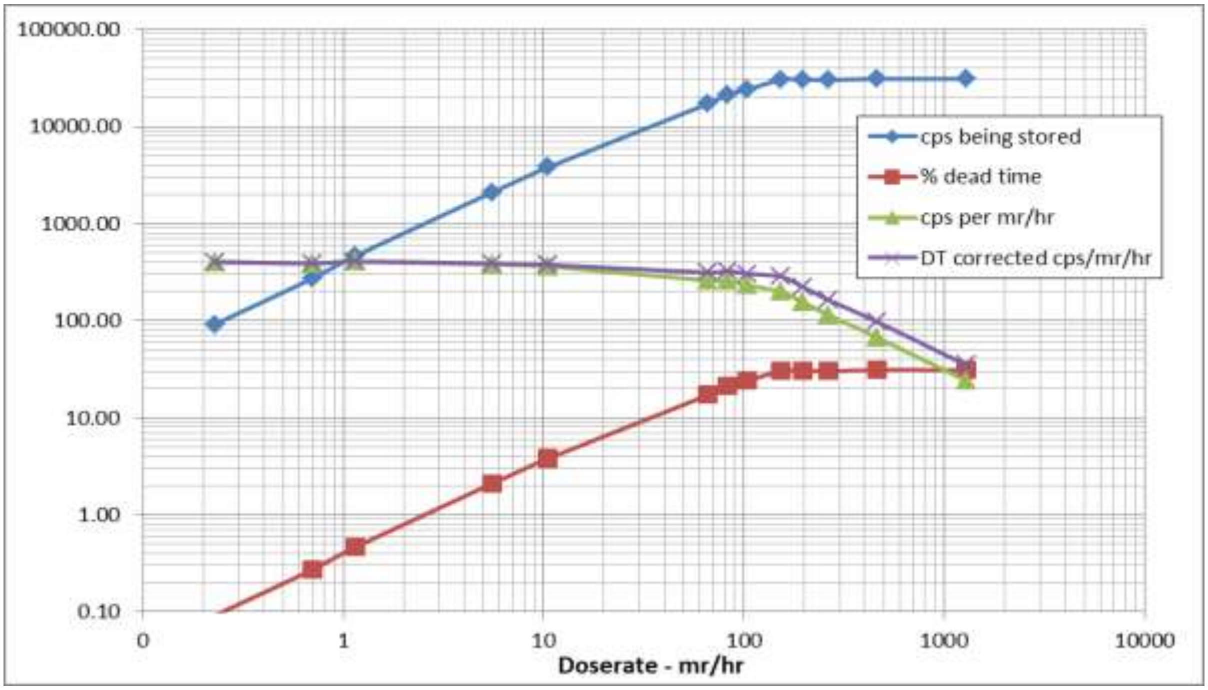


Figure 8 Countrate response vs. doserate exposure field

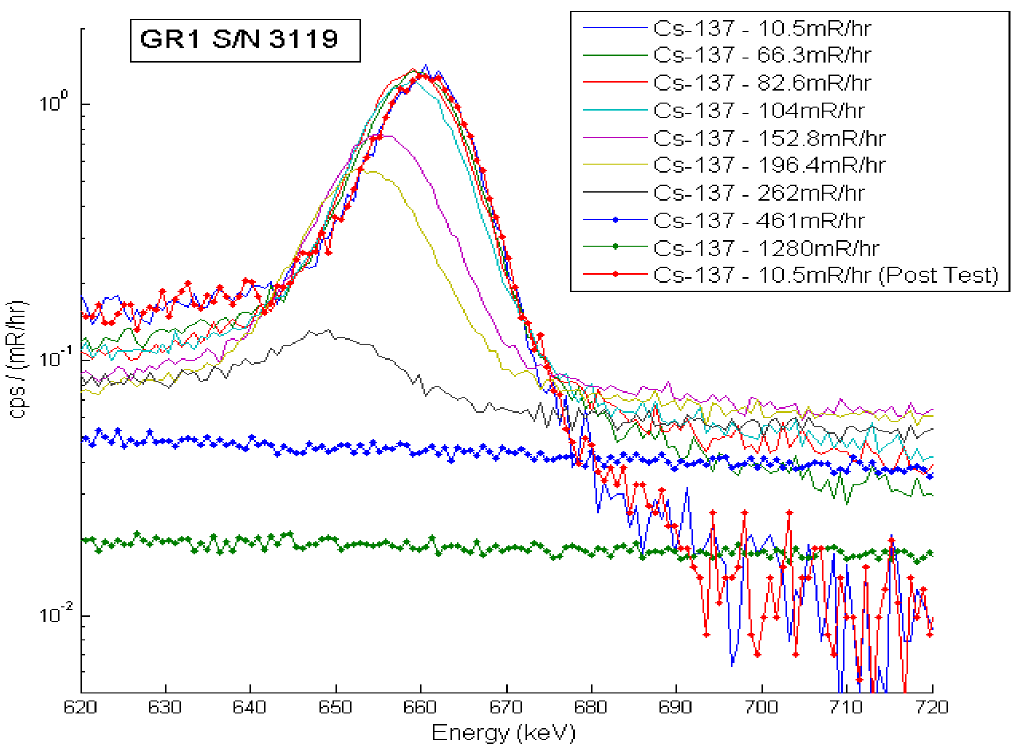


Figure 9 Cs-137 peak position and shape at various doserates

The response was normal up to 10 mR/hr [4000 cps]. Up to 1 mSv/hr [100 mR/hr, 25,000 cps] there was a small loss of accuracy due to deadtime, however the peak position and shape remained normal. Above 1 mSv/hr [25,000 cps] there were both uncorrected deadtime losses and deterioration of the shape of the peak and the area under the peak. Consequently, 25,000 cps is the maximum useful operating range of the GR1, which corresponds for an unshielded device to approximately 1 mSv/hr [100 mR/hr].

THE ISOCS GENERIC CHARACTERIZATION FOR THE GR1

The key to make the ISOCS mathematical efficiency calibration both fast and accurate is the Detector Characterization File. This is a file that tells the ISOCS software the efficiency at any point in space around the detector. This response function is valid from distances from zero up to 500 meters from the detector, in all 4pi directions, and at all energies from 25-7000 keV. The ISOCS software then uses this Characterization file along with a user-defined template to specify the location and size of the sample, including both radioactive and non-radioactive elements of the sample. Attenuation corrections then convert the in-vacuo efficiency values to actual sample efficiency values, corrected for attenuation by the sample and any absorbers, and the intervening air between the sample and the detector, for subsequent use by the gamma spectroscopy software to report sample activity.

For Ge detectors, even those detectors with the same model number have different internal dimensions, and therefore a different efficiency response. And since those users expect very accurate results, each individual detector is extensively measured with multiple traceable sources in multiple geometries to create the exact MCNP [6] model which is then used to create the detector-specific Characterization file.

Scintillation detectors are manufactured to a rather consistent physical size, e.g. 3”diameter x 3” long. Therefore we can create a single [generic] file and use it for all detectors of that type. The GR1 device is manufactured to a physical size, like the scintillation detectors; i.e. 10mm x 10mm x 10mm. However, like the Ge detectors, not all of the physical CZT material is actively collecting charge. Tests were therefore conducted to determine how closely the group of detectors matched each other in efficiency. Figure 10 shows those results for a batch of 35 detectors. The uncertainty at 2 standard deviations of the group was 16%. A set of measurements are performed at the detector factory and only detectors within 10% of the reference value are used, however this measurement method has a small uncertainty. Therefore, even if starting with a Perfect Generic Characterization, any specific detector used with that Generic characterization could have a bias as much as 10% plus perhaps another 2% due to the uncertainty of the factory measurement process.

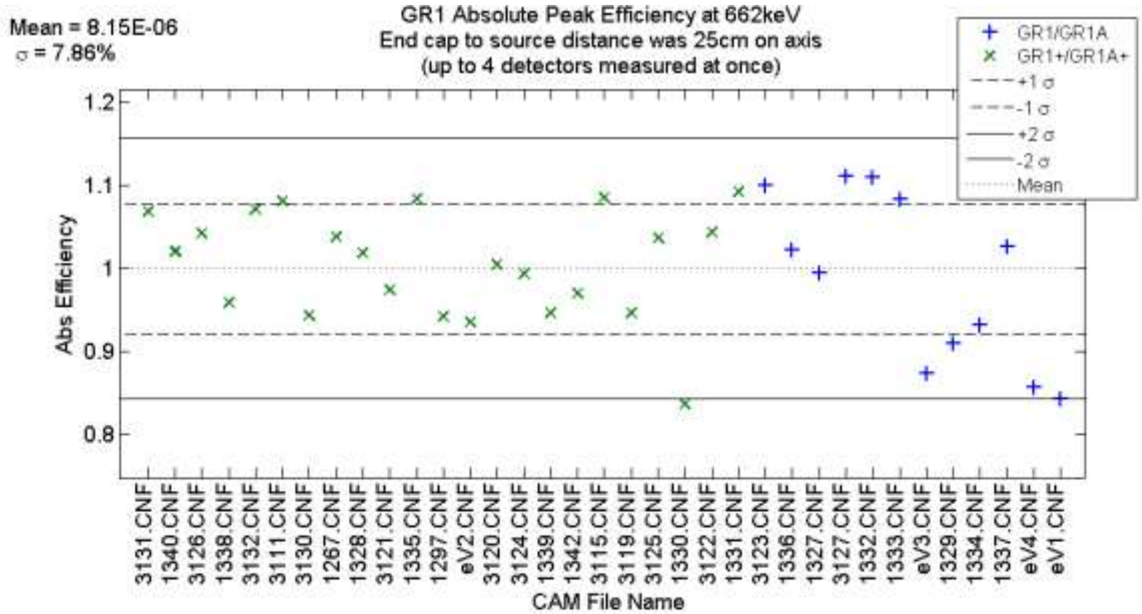
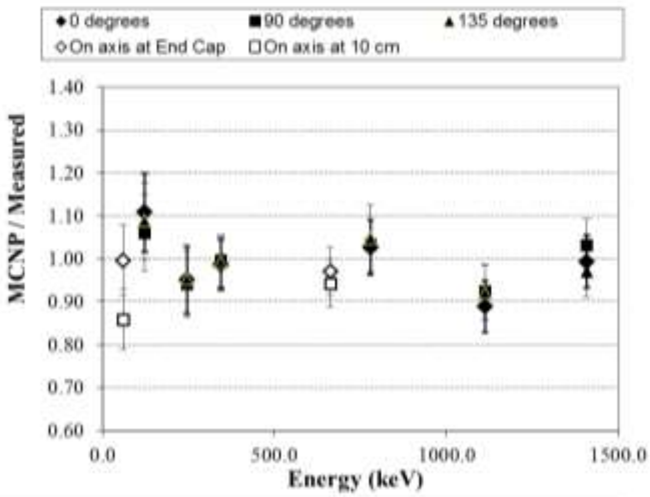


Figure 10 Normalized Peak efficiency for a point source of Cs-137 at 25cm for a batch of 35 detectors.

To create the Generic Characterization, a "representative" detector was used. The normal procedure as used for HPGe detectors was followed for this detector, although the fixture positioning the sources had to be modified due to the small size and shape of the detector:

- NIST-traceable multi-energy point sources were measured at 0, 90, and 135deg from the axis of the detector
- NIST-traceable multi-energy disc source was measured on axis at 0 and 10cm
- A MCNP model of the detector was created; the parameters were adjusted by best fit based upon comparison to the 22 energy and space data points.
  - o See Figure 11a for the MCNP:Measured efficiency comparison
- The average MCNP:Measured efficiency ratio was 0.99 with 0.06 sd.
- The MCNP model was used to create the Detector Characterization file
- That Characterization file was used with ISOCS to create the efficiencies for each of the 22 points.
  - o See Figure 11b for the ISOCS:Measured efficiency comparison
- The average ISOCS:Measured efficiency ratio was 0.95 with 0.06 sd.



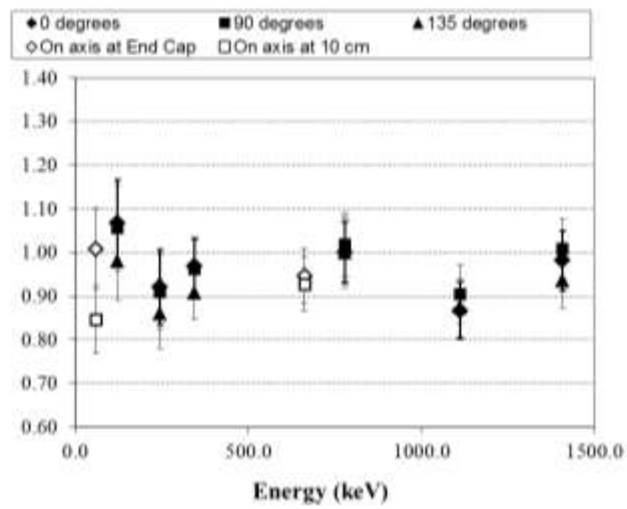


Figure 11 Figure 11a [left] shows the MCNP:Measured efficiency ratio; figure 11b [right] shows the ISOCS:Measured efficiency ratio

The claimed accuracy of the ISOCS Generic Characterization is 20% at 1 standard deviation for the 30-100 keV energy range and 18% for the 100-3000 keV range. This is consistent with claimed accuracy of scintillation detector Generic Characterizations. Higher activity sources are on order, which should allow lower uncertainty. We expect in the future to be able to reduce the uncertainty to 15% and 12% for the Generic Characterization, and to 8% and 5% uncertainty for Detector-specific Characterizations.

THE TUNGSTEN SHIELD AND COLLIMATOR SET

The final step to turn the GR1 into a easily portable in-situ measurement tool was a shield. The GR1 is very small [25x25x76mm with connecting cable], in comparison to a scintillation detector and MCA [nominally 60mm diameter x 250mm] and the Ge detector head [nominally 70mm diameter x 150mm long]. That means the shield can be much less weight for the equivalent amount of shielding. The goal here is a device that is easy to be carried and used by one person.

A shield set has two purposes: 1] to reduce the background from other sources of radioactivity, and 2] to make it easier to quantify the object of interest.

Reducing the background is accomplished by shielding the sides and back of the detector. Most photons from the source do not first interact with the detector; they are emitted in all directions, and scatter around before some of them hit the detector. This scattered radiation hits the detector mostly from the sides and back. Furthermore, because the gammas are scattered, most are considerably lower energy. This makes them easier to shield than the higher energy primary photons they originally were. A typical scattered radiation environment in a nuclear power plant is 200-300 keV. The attenuation factor for common shield materials at that energy is nominally 10x higher than at the typical primary energy of 700 keV. Therefore shielding is added around all 4 sides and the back of the GR1.

If front shielding is added, that can also make the nuclide quantification easier by more precisely defining the field of view of the detector, and therefore knowing better what parts of a large object are being measured. If a big object [large wall surface, large box, large ground area] or a long object [pipe] is being measured, having a collimated view of a part of the object can simplify the calibration. The calibration process need only to consider the parts of the object within the field of view. This also allows infinite field calibration methods [also supported by ISOCS efficiency calibration software] to be used, as even further simplification. Therefore, several different front collimators were added to the GR1 shield set.

Several different materials were considered. Steel is the lowest cost shield material, and steel shields are easy to build. Lead is another very common material due to the high density and Z, but it is soft and somewhat toxic so must be protected and structurally supported. Tungsten is the most expensive material considered, but also the highest density, and tungsten alloy shields are easy to build. Tables 1 and 2 show what we considered in the shield design. Table 1 compares the transmission factor and weight for steel, lead, and tungsten. For shields of equivalent effectiveness, tungsten weighs less than lead and considerably less than steel. A completed shield of this size in tungsten doesn't cost much more than steel or lead, since the cost is dominated by the labor, not materials.

Table 1 Shield characteristics considered for GR1 shield

1m dia source at 1m	Fe	Pb	W
Density - g/cc	7.8	11.4	17.0
Transmission factor / cm at 700keV	0.56	0.31	0.21
Transmission factor / cm at 1332keV	0.65	0.52	0.39
Thickness [cm] x10 att'n at 700 keV	3.93	1.97	1.46
Weight [kg] x10 att'n at 700 keV	13.2	5.3	5.1
Thickness [cm] x10 att'n at 1332 keV	5.37	3.50	2.45
Weight [kg] x10 att'n at 1332 keV	25.8	15.1	12.0

Table 2 compares the effectiveness of different thicknesses of tungsten. The shield design chosen here is 2cm tungsten. This provides a factor of 23 attenuation at 700 keV, and approximately a factor of 50,000 at 300 keV. The shield weighs 8.4 kg [18.6 lbs] with the maximum collimation. For special situations, e.g. multiple radioactive objects nearby where the advantage of distance cannot be used to reduce the impact of the unwanted item, thicker shields can be built. A 3cm thick shield with x17 attenuation at 1332 keV would weigh 17.5 kg [38 lbs], and a 4cm thick shield with x43 attenuation at 1332 keV would weigh 28.3 kg [67 lbs]. These can be easily made, if the situation warrants it. However we wanted the base device to be easily for a technician to carry and set up, therefore the 2cm thickness decision.

Table 2 Attenuation factor and weight of selected 2cm thick shield, and other optional thickness W shields

	attenuation factor				weight	
thickness cm	300 keV	500 keV	700 keV	1332 keV	kg	lbs
2	4.9E+04	104	23	6.6	8.4	18.6
3	1.1E+07	1056	113	17	17.5	38.4
4	2.4E+09	10750	544	43	28.3	67.2

The shield design has also followed the flexibility methods successfully used in the ISOCS Ge shield as shown in Figure 1. There are several end pieces that can be optionally used to provide varying degrees of collimation. Figure 12 shows the primary shield, the 3 removable collimator inserts, the removable collimator ring, and the GR1 detector. A vintage Canberra spectrum coffee mug [not part of the package] is also shown for size comparison.

Figure 12 The GR1 detector, and tungsten shield and collimator set

The shield can be used in 4 different configurations

1. 180 degree FOV as shown in the assembly on the upper left. The detector is inside, just behind the thin aluminum plate. The W shielding is only on the sides and back of the detector
2. 35mm collimator where the square front plate with the 35mm hole is attached to the shield assembly
3. 8mm collimator where the plug at the upper right in Fig 13 is inserted into the 35mm diameter hole
4. 2mm collimator where the plug in the middle is inserted into the 35mm hole
5. 0mm collimator where the plug on the lower left is inserted. This configuration allows the user to know the contribution from objects outside the expected field of view where their gammas penetrate the shielding.

The detector, shield set, and ISOCS efficiency calibrations can also be used to assay samples in the field, as illustrated in Figure 13.

Figure 13 Sample assay example, close and far

The shield is also light enough for use on a sturdy camera tripod. Because of the weight of the shield, several types of tripods were evaluated and a heavy duty one made from carbon fiber was selected. It also has flip-tabs holding securing the leg extensions allowing easy and secure operation in the field, even with globes. For transport, a heavy duty Pelican waterproof case has been selected and fitted with custom foam compartments. These are shown in Figure 14.

Figure 14 Shield on tripod; transport/shipping case that can securely contain all items

VALIDATION TESTING OF THE GR1, SHIELD, AND ISOCS EFFICIENCY CALIBRATION SOFTWARE

Two series of tests were conducted. The first test compared the ISOCS efficiency to a reference efficiency from another mathematical code. The second test compared the ISOCS efficiency against measurements with sources.

The first test compared the ISOCS efficiency against the efficiency as computed by the MCNP software. That comparison is very useful as it allows nearly the same physical configuration to be modeled by both methods. The tungsten density and composition, shield dimensions, and source dimensions and construction can be exactly duplicated in both models. There is no loss of fidelity due to interpreting a gamma spectrum and extracting the correct peak area. There is no problem with background interference from other peaks. One difference in the models is in the detector. The real detector and housing is cubic in shape, whereas the detector in the ISOCS model is an equivalent area and volume cylinder, due to limitations in the software. The other difference is in the shield. The extreme flexibility of MCNP allows an exact model of the rectangular shield with circular holes to be created. However the ISOCS model was created as a rectangular shield with rectangular holes of equivalent area to the real circular holes.

Four different shapes were modeled in both software:

- A point source on axis at 25cm from the detector
- A 1 meter diameter thin disc at 5cm from the detector
- A 2 meter long 7cm diameter pipe at 5cm from the detector
- The same 2m long pipe, rotated 45 degrees to cross the shield diagonally

For each model, efficiency calibrations were performed with no shield, and with the shield in each of the 5 collimation modes. Graphs showing the ratio of the ISOCS efficiency vs. the MCNP efficiency are shown in Figure 15. The comparisons are generally within 10%. However, when the pipe is rotated 45 degrees, some of the comparisons approached 20%.

Three different source geometries were measured and compared to the ISOCS efficiency.

- A point source on axis at 25cm from the detector
- A line source 80cm long 1m from the detector
- A 200 liter drum filled with wood at 6cm
- A 200 liter drum filled with wood at 25cm

For each source geometry, measurements were made with as many collimator configurations as both time and source activity permitted. Graphs showing the ratio of the ISOCS efficiency to the measured source activity are presented in Figure 16.

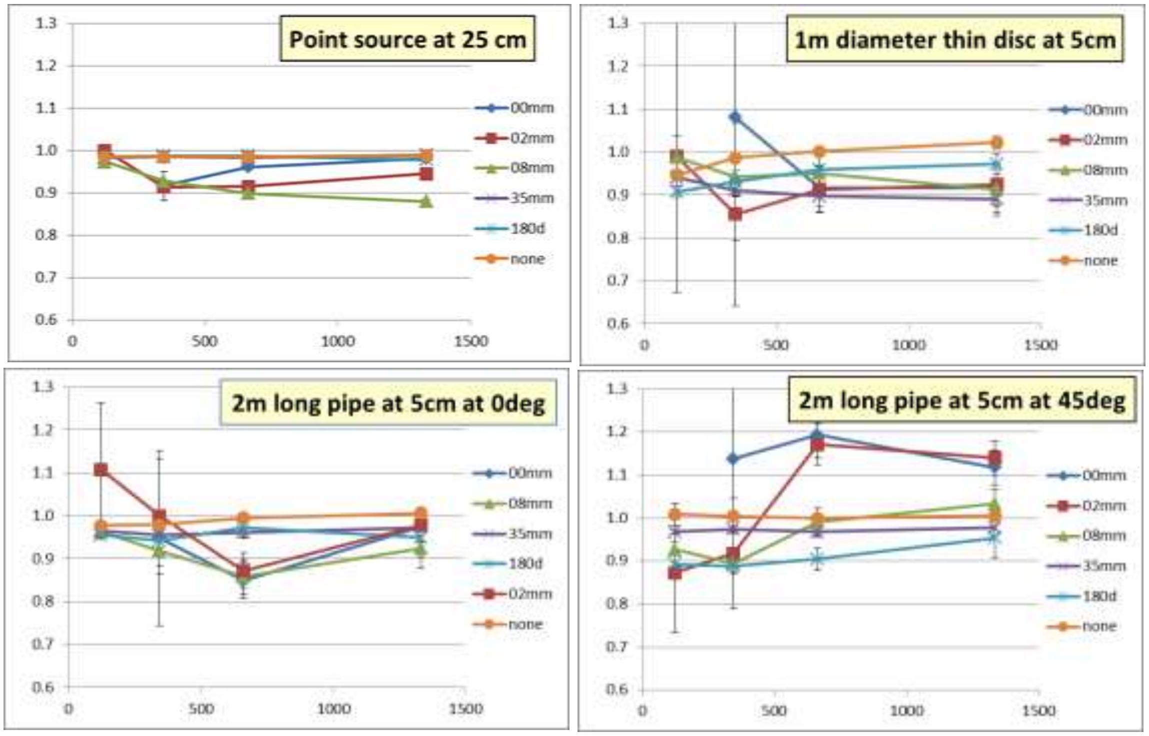
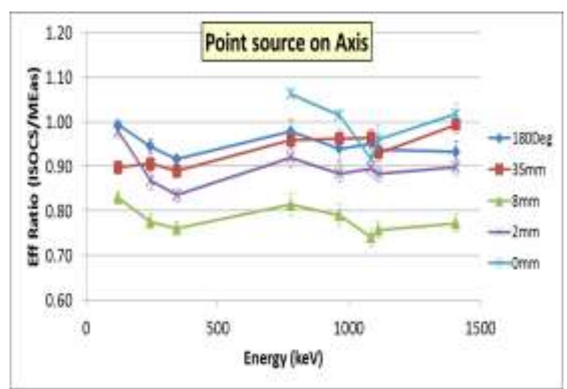


Figure 15 The ratio of ISOCS vs. MCNP efficiencies

For source-based efficiency calibrations, there is less control of the actual geometry, and therefore more uncertainty in the source-based efficiency. Consequently there is a larger average difference between the two efficiency values. But, in general, most all efficiency values at most all energies agree within 15-20% of each other. The biggest discrepancies occur at locations where the circular-rectangular approximations come into play.



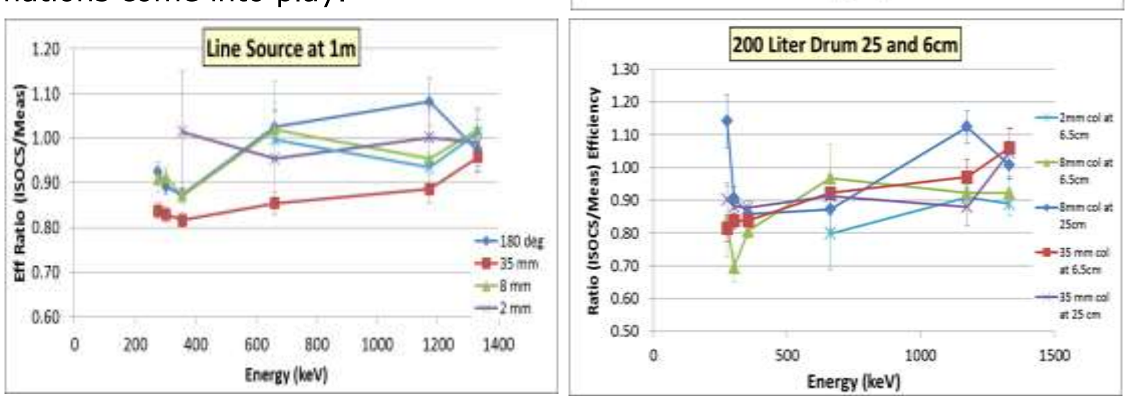


Figure 16 The ratio of ISOCS vs. Radioactive Source efficiencies

DETECTION LIMITS

The penalty to pay for having a small light-weight and portable detection system is sensitivity. Efficiency is roughly proportional to detector mass. Since CZT and Ge are approximately the same density, then efficiency is roughly proportional to detector volume. Background is also roughly proportional to detector mass and FWHM. Therefore MDA is roughly proportional to the square root of FWHM/volume. A typical Ge detector of 40% relative efficiency, the most popular size sold for the ISOCS detector-shield product, has a volume of approximately 180 cm3 and a FWHM of 0.3% at 662 keV. The CZT here has an active volume of approximately 0.8cm3 and a FWHM of 2%. Therefore one would expect the Ge to have a 40x higher MDA. If one is interested in having equal MDA performance, then the CZT system would need to have a counting time that is approximately 1600 times as long.

Table 3 shows some approximate MDAs for both CZT and a 40% HPGe detector under approximately the same conditions.

Table 3 Comparative MDAs between 40% Ge and GR1 CZT; progeny are assumed to be in equilibrium

		GR1 CZT; no shield [MB] or 180d shield					40% Ge detector			
Nuclide	Energy	100kg MB soil or hole in ground; 15min; Bq/kg	60kg MB water or hole in ground; 15min; Bq/kg	Detector 1m above infinite soil; 15min; Bq/kg	200 liter drum at 1 meter; 15min; Bq/kg	2m long pipe at 2m; 60min; kBq	Detector 1m above infinite soil; 15min; Bq/kg	200 liter drum at 1 meter; 15min; Bq/kg	2m long pipe at 2m; 60min; kBq	Ratio CZT to Ge MDA
Cs137	662	49	26	66	1349	118	1.1	45	2.5	46
Cs134	800	46	26	61	1285	115				
Co60	1332	56	46	77	1804	168	0.8	28	2.2	79
Eu152	122	140	17	146	2173	129				
Eu152	1408	275	252	381	9289	868	3.5	110	10	25
U238	94	1683	157	1279	21569	1186	95	1200	160	13
U238	1001	6674	4335	8933	195043	18080	110	3500	280	67
U235	185	64	10	71	1088	69	10	69	5.8	12
Am241	60	591	44	267	5988	296	36	3700	94	
Ra226	352	74	26	97	1694	129				
Ra226	609	82	39	109	2171	184				
Th232	238	63	13	74	1174	78				
Th232	911	170	91	226	4654	408				

The higher MDA of the small CZT does not make it an attractive candidate to precisely measure natural levels of radioactivity in soil. But it is a good candidate to measure other modestly radioactive items, such as those that might be in low level radioactive waste, or as might be encountered by technical responders to potential radiological emergencies, or as a local regulatory responder to a truck monitor alarm. For example, the regulatory food limit for Cs-137 is approximately 1000 Bq/kg in most of the world and 100 Bq/kg in Japan. Rice in Japan is commonly sold in 30 kg bags. If the unshielded detector is sandwiched between several bags, or the shielded detector is placed in contact with several bags, the estimated MDAs for a 15 minute measurement are 26 and 66 Bq/kg, respectively. This is somewhat under the very conservative Japan limit and comfortably under the limit in most other countries. Therefore this would be a very acceptable tool for quick assay in the field of bulk quantities of vegetables, grains, beef, etc. Or to prove that such food items are not of radiological concern.

CONCLUSIONS

These "large" volume CZT detectors have adequate resolution to allow measurements in quite complicated conditions, such as waste from NPPs. The GR1 works quite acceptably at doserates up to 1 mSv/hr [100 mR/hr] and 40-50 degrees C. The integrated MCA allows a very light weight shield [10 kg]. A flexible shield and collimation set, and tripod allows quick setup for a wide variety of in-situ measurement situations. No external power is needed as the detector is powered from the laptop. The efficiency is considerably lower than even a small Ge detector, and therefore the MDA is higher or the counting time is longer. But in return a device is available at approximately 1/3 the cost of a portable shielded Ge detector and that can be easily carried by a worker into a complicated work environment for measurements that would be quite difficult for the shielded Ge detector.

This is therefore a quite suitable device for those situations where the entry cost of a shielded Ge detector like the ISOCS system is too high, and where better quality spectroscopy than can be obtained from NaI systems is required. For uses that already have transportable shielded Ge systems, this is a low cost complementary device that can be more quickly deployed and is suitable for many situations, perhaps as a quick trial measurement, to see if the full shielded Ge system is needed.

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