Performance of a HPGe System for Surface and Container Measurements – 13582

Timothy R. Twomey* and Ronald M. Keyser**
*ORTEC – AMETEK, 801 South Illinois Avenue, Oak Ridge, TN 37830 USA
**Software & Information Services, 562 Bacon Springs Ln, Clinton, TN 37716 USA

ABSTRACT

The decommissioning of a nuclear facility or post-accident cleanup is an immense engineering effort requiring an array of specialist tools and techniques. The decommissioning and cleanup activities generate large quantities of low activity waste. For economic disposal, it is desirable to certify the waste as suitable for free release. Every container must be assayed to a sufficient degree of accuracy and sensitivity so that it may be certified to be or not to be suitable for "free release".

In a previous work, the performance of a highly-automated system for free release of large numbers of containers was presented in which the spectroscopy hardware comprised four ORTEC Interchangeable Detector Module (IDM) mechanically cooled HPGe spectrometers in conjunction with ORTEC ISOPlus waste assay software. It was shown that the system was capable of assaying large containers to free release levels in reasonable measurement times.

Not all operations have enough waste to justify an automated system or rapid assay results may be required, perhaps in a remote location. To meet this need, a new mobile system has been developed for the assay of smaller objects (drums, boxes, and surfaces) *In-Situ.* The system incorporates the latest generation IDM-200 and ISOPlus software and a new variant of the ISOCart hardware.

This paper will describe the system and performance.

Keywords: Waste assay, In Situ, HPGe, Germanium detectors, MDA, MDC, Free release

INTRODUCTION

Large amounts of waste are produced in cleanup of accidents and during dismantling and decommissioning activities of unneeded nuclear facilities. While some of this waste contains radioactive material, which is controlled by regulatory bodies, much of the waste has no nuclear material present, but this must be demonstrated prior to disposal. Waste with nuclear material levels below regulatory limits can be disposed of in ordinary waste streams as "below clearance limit" (CL) or "free release" material.

For free release, the contents of a waste container must be measured and certified to be below the specific activity limits (Bq/g) prescribed in the regulations. There is a much higher cost to dispose of waste which cannot be certified as free release. Manual systems for container assay using

germanium detectors (both liquid nitrogen and mechanical coolers) and similar software was described in Refs. (1, 2). An automated system using the IDM and ISOPlus software was described in Ref. (3) and demonstrated that containers could be measured to a Minimum Detectable Concentration (MDC) level suitable for free release in reasonable measurement times.

This paper describes the development of a transportable assay system, capable of measuring waste containers of any size and determining their eligibility for free release.

EQUIPMENT

The equipment consisted of an IDM 200 mounted on a movable cart, prototype collimator, a laptop for control and data collection, calibration sources, a 200 l drum, and a back shield of lead with an average thickness of 40 cm. The measurements were made in an ordinary building with concrete floors and ceiling in a room with gypsum-board walls. The waste container was a standard 200 l , steel-walled drum of 21.4 kg empty weight including removable lid. It was filled with mixed density waste comprising paper, printed circuit boards, electronic instrument chassis, and computer parts. It was loosely filled with a net weight of 83 kg, thereby constituting an average density of ~0.3 g/cc. The drum was mounted on a lift jack and positioned so that the midpoint of the drum is in line with detector center height.

The IDM 200 (and mechanically identical Detective 200), see Ref. (4), is a fully integrated spectroscopy system consisting of a HPGe detector (85 mm diameter by 30 mm deep), cooled by a miniature Stirling cycle cooler, DSP MCA, high voltage supply and high speed USB communication port. A "hardened", all metal-sealed detector cryostat eliminates any possibility of damage to the detector due to partial warm up. The system is designed for low power operation and can be mains powered or will run for several hours on an internal battery. The detector is shielded by 12.7 mm of steel up to the front surface of the detector cover. A 6.4 mm thick cylindrical lead collimator shield that extends from approximately the middle of the detector crystal to 25 cm in front of the front of the detector endcap was mounted on the steel shield. Figure 1 shows the prototype collimator in place on the unit. This collimator limits the field of view to the width (diameter) of the drum when the front edge of the collimator is 50 cm from the near surface of the drum.

Figure 1 IDM 200 with Prototype Collimator

The Field of View is calculated by the software from the operator entered detector-drum distance, detector diameter, collimator material, and collimator size. The calculation was verified by measuring the field of view using a multi-nuclide gamma-ray point source. The source was moved in front of the detector with collimator at a distance of 30 cm from the end of the collimator (55 cm from detector). The peak area vs horizontal position is shown in Fig. 2. The FOV was calculated as the FWHM for the peak area vs position to be 33 cm. The calculated FOV was 34 cm. The detector was energy and efficiency calibrated using a NIST-traceable mixed gamma ray source ranging from 59 keV to 1.8 MeV placed at 30 cm from the detector front face on the detector axis. Both the resolution and efficiency are in the MDA formula. Figure 3 shows the detector resolution as a function of energy for this detector. Figure 4 shows the efficiency vs energy curve for this detector.

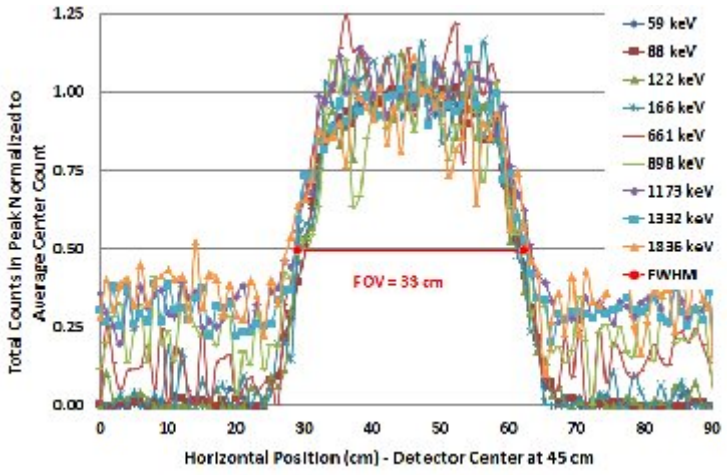

Figure 3 Normalized Count Rate vs Horizontal Position in Front of Detective 200 with Lead Collimator

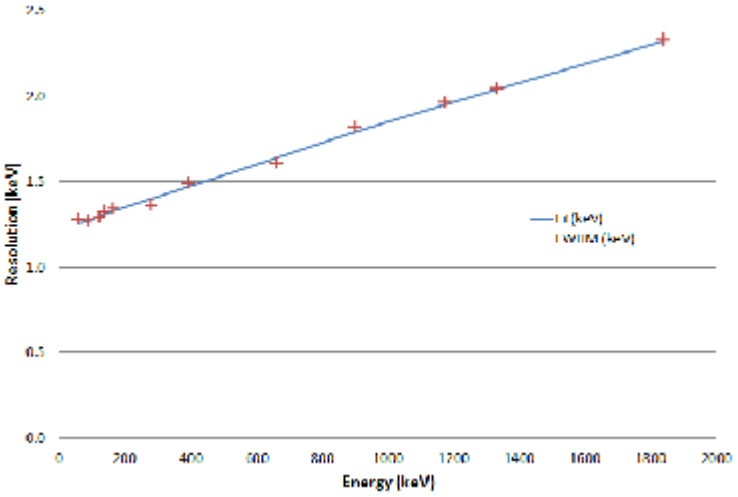

Figure 2 Resolution vs Energy

The ISOPlus software calculates the total efficiency of a volume source from a point source calibration. It also calculates the absorption correction based on the density of the contents (from the entered weight and volume) and type of material in the drum, assuming that, on average, the material and distribution of activity is homogeneous within the detector's field of view. To meet this assumption of homogeneous sample material, the drum can be rotated either by using a turntable or manually to multiple positions during the total count time. Multiple detectors can also be used and the spectra combined to obtain the final result.

The detector placement relative to the drum is shown in Fig. 5.

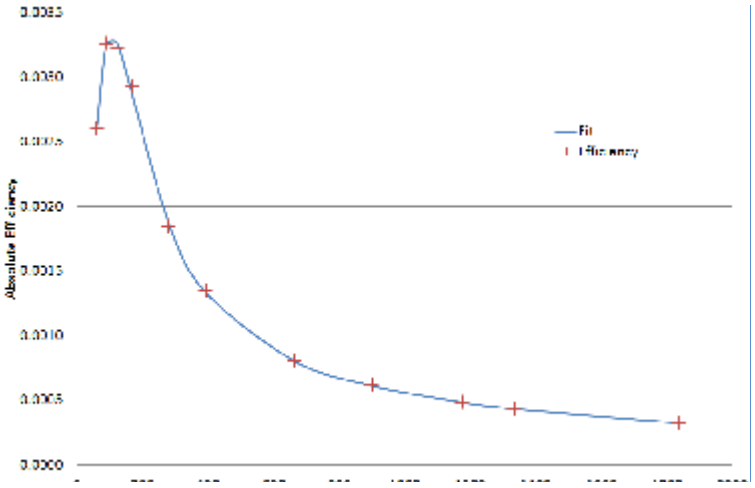

Figure 4 Efficiency vs Energy for Point Source at 30 cm

Nuclides and MDC

The MDCs were calculated for ^{54}Mn, ^{60}Co, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{241}Am. These same nuclides used in Ref. (3) so that a comparison could be made to the previous results. The MDC method selected was the NuReg 4.16 Method as defined in Ref. (5). The background width was selected as 2.5 FWHM. This width was selected to be able to compatible with previous calculations. A smaller width, as given in ISO 11929 (Ref. 6) would give smaller (better) values.

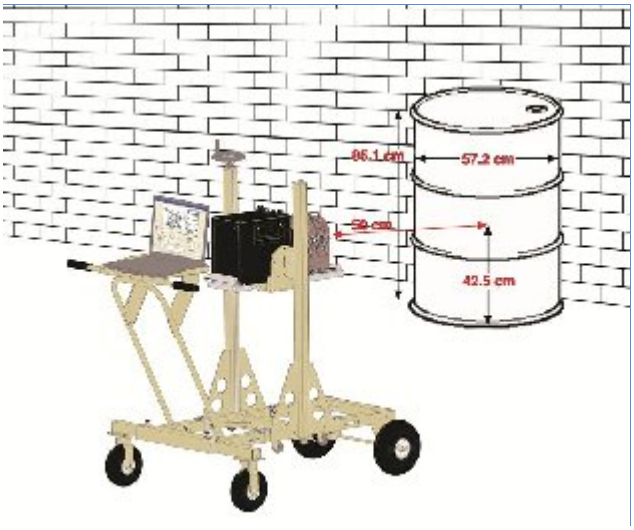

Figure 5 Detector and Drum Arrangement

Spectra

The system was operated in automatic mode to collect spectra over a two-day period. The collection times were 3600, 7200, 10000, 20000, 30000, 40000, 50000, and 60000 seconds. In addition, 36 spectra were collected for 1 hour each to measure the distribution of the results.

RESULTS

Background

Figure 6 shows a 50000 s background spectrum with the drum in front of the back shield. This is a typical background for rooms in concrete buildings.

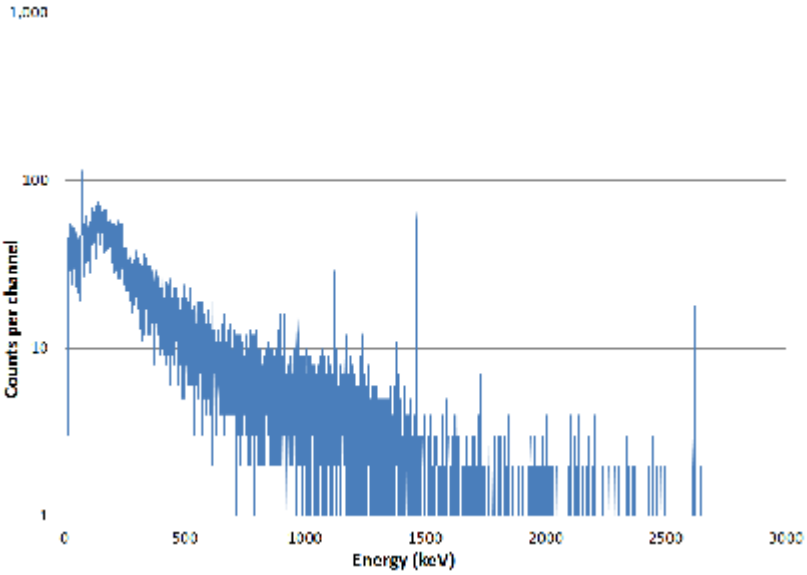

Figure 6 Long Time Background with Drum

Minimum Detectable Concentration

The MDC was calculated for the listed nuclides for each of the spectra of different counting times. The MDCs vs counting time for some of the nuclides are shown in Fig. 7. It shows the typical reduction with the square root of the time.

The MDCs for the IDM 200 are compared to the previous work for several counting times in Table I. It should be noted that different containers were used.

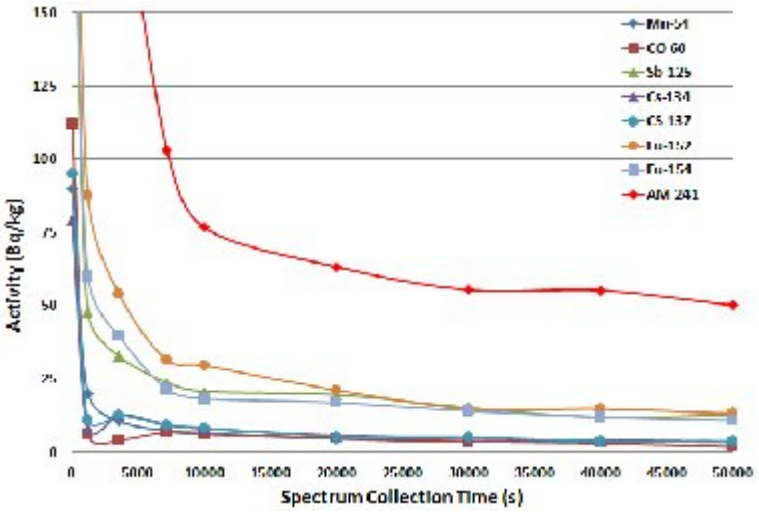

Figure 7 MDC vs Collection Time

RESULTS

The results show that the single detector system using the IDM 200 can be used in the field on medium size containers to give results below the required limit in a count time of one to two hours for most nuclides of interest. Only low-density samples were counted. The attenuation correction is based on the measured density and the operator entered type of content. The Sogin results are based on a single detector spectrum (one of the four detectors in the automated system) and show a lower level in a shorter time due to the significantly thicker collimator (10 cm vs 4 mm) and larger volume (1000 l vs 200 l). The clearance levels are taken from Refs. 7, 8, and 9. These results show that the clearance level MDCs can be met in 10,000 s or less for the measurement configuration used. The achieved MDCs are generally higher than those achieve with a single detector in the SOGIN system. This is attributable to the much deeper collimation chosen in the present system, which lowers the background, but also the

absolute detection efficiency for extended sources. A thicker side wall but less deep collimator would further reduce background due to radiation from the side of the system, while inproving the absolute efficiency. It is suited for small numbers of containers or containers in remote locations where the use of a larger system is impractical.

Table I MDCs (Bq/g) for Waste Density ~ 0.3 to 0.4 g/cc

Nuclide	3600 s	7200 s	10000 s	Representative Clearance level (Refs. 7, 8, 9)	Sogin System (2400 s)
^{54}Mn	0.011	0.0072	0.0065	1.0, 0.1, 0.1	0.0030
^{60}Co	0.004	0.0067	0.0060	1.0, 0.1, 0.1	0.0019
^{125}Sb	0.033	0.0237	0.0207	10.0, 1.0, 1.0	0.0102
^{134}Cs	0.013	0.0093	0.0079	1.0, 0.1, 0.1	0.0032
^{137}Cs	0.013	0.0091	0.0082	1.0, 1.0, 1.0	0.0037
^{152}Eu	0.054	0.0312	0.0295	1.0, 0.1, 0.1	0.0131
^{154}Eu	0.039	0.0214	0.0182	1.0, 0.1, 0.1	0.0080
^{241}Am	0.194	0.1030	0.0767	1.0, 0.1, 0.1	0.0655

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