Abstract 236

Performance Characteristics of a Third Generation Portable Radionuclide Identifier

Ronald M. Keyser and Timothy R. Twomey
ORTEC, 801 South Illinois Avenue, Oak Ridge, TN 37830

ABSTRACT

The continuing need for a hand-held, portable radionuclide identifier for use in countering illicit nuclear trafficking and in positive identification of radioactive materials, benign or threat, has fostered the development of a next generation of instruments. Changes from the existing instrument have been made in response to the evolving needs of various users of the previous identifiers, but without reducing any performance with regard to ANSI N42.34. To address the requirements of front-line operators, the instrument was made significantly lighter and smaller, but the same HPGe gamma-ray detector crystal size has been retained, meaning previous performance data is still valid. In order to increase the ruggedness of the instrument the previous COTS PDA has been replaced with a custom, built-in processor. The instrument housing is now waterproof, with all connector apertures being sealed with plugs. The instrument capability has been improved by expanding the library to include nuclides recently adopted in medical procedures and encountered by reach-back teams, as well as other nuclides of interest identified during the millions of operating hours logged by the existing germanium-based identifiers. Battery lifetime was increased by using newer battery technology, new electronics for cooler controls and signal processing. The overall system has been further reduced in size and complexity by incorporating the battery charger internal to the instrument itself. The Detective family has already undergone extensive testing and the new instrument, the Micro-Detective, was subjected to some of the same tests. The results of testing with common gamma-ray sources and neutron sources is shown and compared with the results of previous instruments, showing compliance with ANSI N42.34.

Keywords: radioisotope; integrated systems; germanium detectors; HPGe; illicit trafficking; monitoring

INTRODUCTION

The Detective Family of Handheld Radionuclide Identifiers has been used by many workers to detect and identify radionuclides in many different scenarios. The performance has been described in previous works [1, 2, 3, 4, 5, 6] and is described by others [7] as producing the most accurate results. Various users have requested the instrument be changed to be lighter with a longer battery life and improved analysis features. The new version, the Micro-Detective, was designed to meet these needs. The Micro-Detective, shown in Fig. 1, is 50% smaller in volume and 40% lighter than the Detective-EX. The gamma ray detector is the same size. The neutron detector is ¼ the previous size.

The operational time was increased by using new battery technology, a new, lower power cooler, and new electronics: both signal and control. The battery charger was a separate unit and it is now included inside the case.

The analysis software has been improved in three ways: the SNM search mode was added; the nuclide list was expanded to include the new medical nuclides and other gamma rays associated with SNM; and additional nuclide and gamma ray reporting was added for the expert user.

Equipment

The nuclide identification scheme uses a "peak quality factor" to measure the quality of a gamma-ray peak in the spectral data. That is, to determine if the spectrum peak can be considered to be a “real peak” from the nuclide of interest. This quality factor, Q, is defined as:

$$Q = \frac{N}{\sigma_N}$$

where:

N = the net counts (background subtracted) in the full energy gamma ray peak
σ_N = the uncertainty of N

SNM Search Mode

In SNM Search mode, the value of Q for several different gamma ray energies associated with SNM are computed every few seconds. Q^2 is plotted on the display bar graph. The Q value is compared continuously against a user-definable threshold. The SNM warning message is displayed when the threshold is exceeded. The operation is similar to a rate meter or dose meter, but is specific to the gamma ray energies linked to SNM. When SNM is indicated, the identification mode is used to confirm the presence of SNM. Other criteria, including multiple energies are used in the identification process.

Nuclide List

The list of nuclides in the original instruments was developed in 2002 and did not include the medical isotopes approved for use (or expected to be approved) in the years between then and 2007. All of these isotopes can cause alarms and many can be used to mask nuclides of interest. The list of nuclides is shown in Table 1. This list will also be available in some other models and as upgrades. The SNM classifications given by ANSI N42.34 [8] and the IAEA [9] are also included in the analysis results.

Table 1. Nuclides Identified in MicroDetective

^{241}Am	^{64}Cu	^{131}I	^{103}Pd	^{232}Th
^{211}At	^{152}Eu	^{111}In	^{210}Po	^{200}Tl
^{198}Au	^{155}Eu	^{192}Ir	^{239}Pu	^{201}Tl
^{133}Ba	^{156}Eu	^{194}Ir	^{226}Ra	^{202}Tl
^{207}Bi	^{59}Fe	^{40}K	^{188}Re	^{204}Tl
^{76}Br	^{64}Ga	^{140}La	^{75}Se	^{208}Tl
^{109}Cd	^{67}Ga	^{172}Lu	^{153}Sm	^{233}U
$^{252\text{-}249}$Cf	^{153}Gd	^{177}Lu	^{113}Sn	^{235}U
^{56}Co	^{159}Gd	^{99}Mo	^{82}SR-RB	^{238}U
^{57}Co	^{166}Ho	^{99M} Mo-Tc	^{90}Sr-Y	^{188}W
^{60}Co	^{166m} Ho	^{22}Na	^{182}Ta	^{131M} Xe
^{51}Cr	^{123}I	^{237}Np	^{99M} Tc	^{133}Xe
^{137}CS	^{125}I	^{233}Pa	^{228}Th	^{135}Xe
^{88}Y				

Hardware

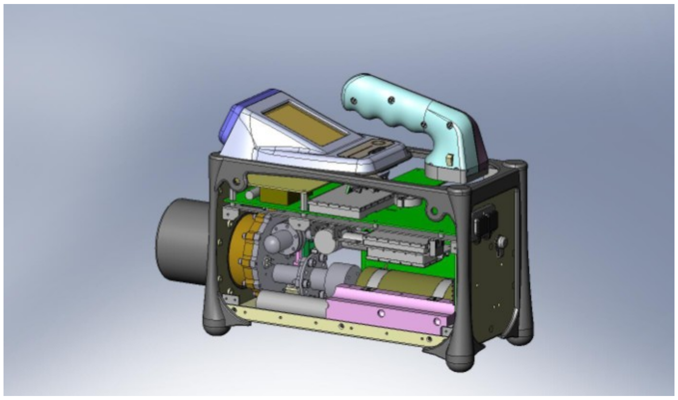

Figure 1 Cutaway View of Micro-Detective

The Micro-Detective side view is shown in Fig. 1. Compared to previous models, the housing is the same width, but shorter and narrower. The handle can be removed to reduce the overall height by about 3 cm. The PDA has been replaced by an imbedded single-board computer; the high resolution, color display with touch screen is of the high-intensity, daylight-readable type. All of the interaction (except power on) is through the touch screen and soft buttons. In the figure, the battery has been removed to show the cooler and detector mount. The rubber bumpers have been extended to include the top corners and side edges. The HPGe detector crystal is nominally 50 mm diameter by 30 mm deep, mounted in the same way as the previous models.

The neutron detector is located in the lower rear corner. It is a single ^{3}He tube: 0.5 inch diameter, 4 inch active length, 20 ATM fill pressure, surrounded by HDPE moderator. The outdoor background as measured with this instrument in Oak Ridge is about 0.02 n/s.

Removable storage media, compact flash and secure digital cards, can be accessed under the sealed cover above the touch screen. An internal GPS is provided. Wireless communication is available using IEEE 802.11g. Standard Windows functions are used to communicate with PCs on the network.

The current model is highly splash proof. The next model will be completely water-tight and will operate while submersed in water. The rear panel contains the 12-17 V dc power, USB, and the audio output connectors. The USB can be used to control the unit from any ORTEC Connections program or “ActiveSync” using standard Windows programs.

Tested Nuclides

The nuclides used in the testing are shown in Table 2. These are commonly available nuclides (also used in previous testing), but do demonstrate the identification time and peak separation ability. The sources were placed at a distance to give the 500 nSv/h dose as prescribed in ANSI N42.34 both with and without the shield. The shield

Table 2. Nuclides Used in the Test

Single	Mixtures
^{133}Ba	DU and ^{133}Ba
^{60}Co	DU and ^{137}Cs
^{137}Cs	Thorium oxide and ^{137}Cs
DU	Thorium oxide and ^{133}Ba
Thorium oxide	Thorium oxide and ^{60}Co
	Thorium oxide, ^{133}Ba, and ^{137}Cs

was 5 mm stainless steel positioned near the source. The dose was measured with a separate, handheld dose meter.

The detector efficiency was measured according to IEEE 325 at 25 cm from endcap using a NIST traceable mixed gamma ray source with energies from 59 to 1836 keV. To simulate the efficiency in the detector-sample geometry most likely to be used in the field, a NIST traceable mixed gamma ray, 10 cm diameter filter paper source was used at 10 cm from endcap.

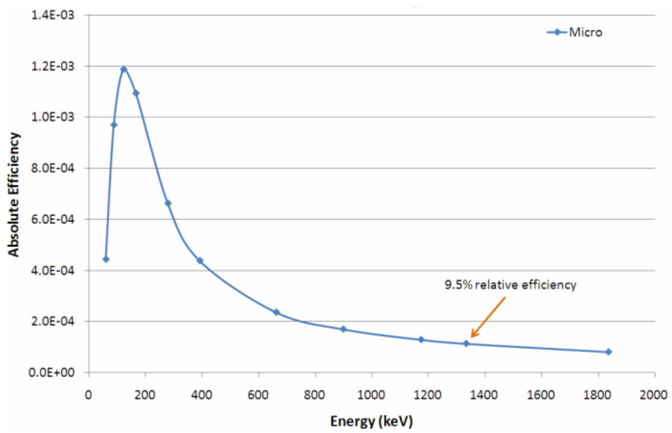

Figure 2. Absolute Efficiency for Point Source at 25 cm from Endcap

RESULTS

The absolute efficiency for a point source at 25 cm is shown in Fig. 2. It shows the normal response for a p-type detector. The IEEE relative efficiency at 1332 keV is about 9.5%.

The 10 cm filter paper efficiency is shown in Fig. 3. The efficiency shows the same general shape, but this geometry is nearly 4 times as efficient. The plot above 1365 is straight line extended from 1365 to 2000 keV.

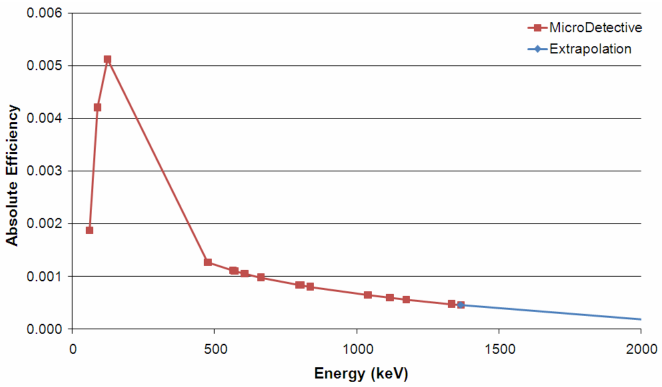

Figure 3. Absolute Efficiency for 10 cm Disk at 10 cm

The nuclide identification times for the single nuclides are shown in Fig. 4. These are similar to the times reported in earlier work. These times are also much lower than the maximum data collection time required by ANSI N42.34. Also the flux on the detector is specified as the dose, which can include a significant fraction of low energy photons that are not useful in the identification of the nuclide. Thus the time to identify high uranium concentration or depleted uranium is lower in the shielded case than in the unshielded case.

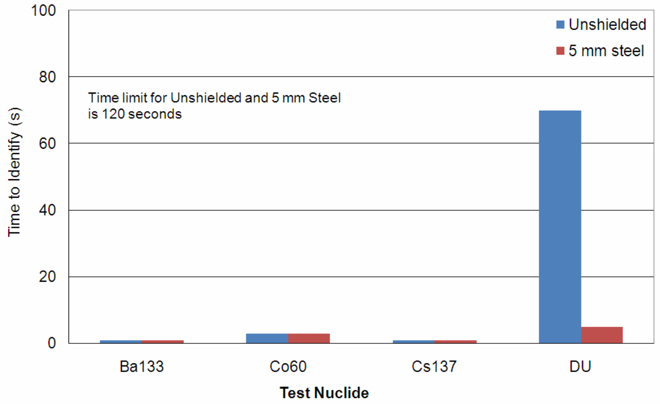

Figure 4. Time to Identify at Dose Rate of 500 nSv/h

The nuclide identification times for mixtures of depleted uranium with ^{133}Ba and ^{137}Cs are shown in Fig. 5. The masking nuclides in these cases are increasing the background in the low-energy region, lowering the peak quality factor because of the increase in the uncertainty of the net peak area. Note the identification times are again lower for the shielded case.

While natural thorium is not a threat nuclide, it is a component of many natural materials and could be a masking nuclide. The nuclide identification time for natural thorium oxide in combination with other nuclides is shown in Fig. 6. These times are again well below the ANSI specified time limit.

Neutron sensitivity

The neutron sensitivity was measured with an un-moderated ^{252}Cf source at 1 meter from the front and bottom of the HPGe detector as shown in Fig. 7. The efficiencies of several units [4] are shown in Table 3.

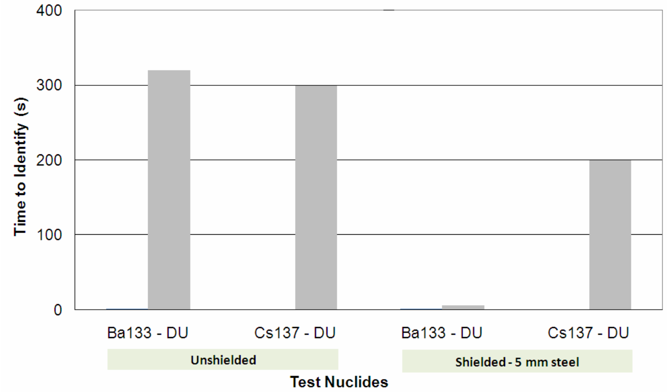

Figure 5. Time to Identify Uranium Mixture Components at a Dose Rate of 500 nSv/h Each

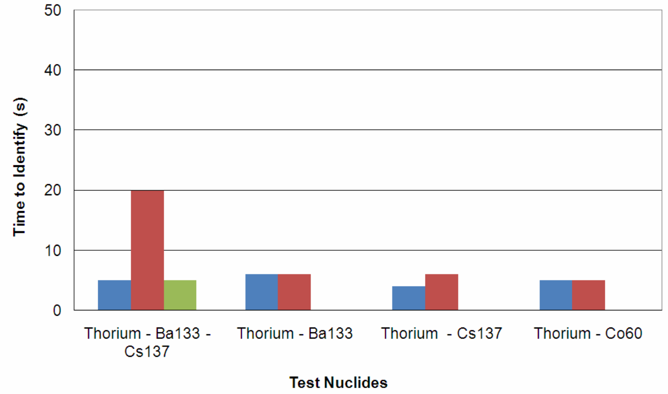

Figure 6. Time to Identify Thorium Mixture Components at a Dose Rate of 500 nSv/h Each

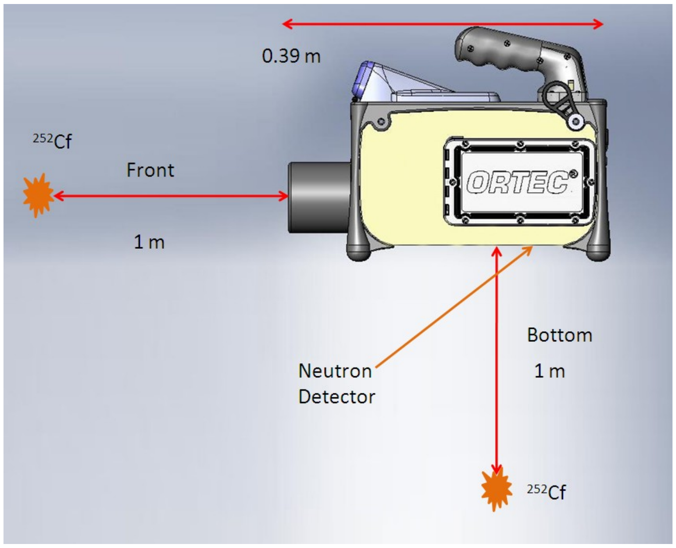

Figure 7. Neutron Source Placement for Sensitivity Measurement

Table 3. Neutron Efficiency for ^{252}Cf at 1 meter	
Micro-Detective (front)	2.0×10^{-5}
Micro-Detective (Bottom)	3.0×10^{-5}
Detective EX	2.2×10^{-4}
Popular NaI RID	4.0×10^{-7}

The geometry of the neutron detector is less than optimal for detection from the front as it is located at the rear of the unit (See Fig. 1) and oriented with an end facing the front. This design was necessary to reduce the size and weight of the unit. The efficiency from the bottom, where the tube is perpendicular to the flux and closer to the source, is a better way to compare with the Detective EX. The Detective EX neutron detector was determined to have higher efficiency than needed for the intended applications. The results show that even though the Micro-Detective has lower sensitivity for neutrons than the Detective-EX, it is still much more efficient than another commercial RID, tested previously [4].

CONCLUSION

The gamma ray detection and nuclide identification performance of the smaller and lighter RIID was shown to be very similar to the previous model. This is expected because the HPGe detector is the same size. The nuclide identification times are short and typically well below the ANSI time requirements. The neutron sensitivity is, as expected, lower, because a much smaller neutron detector was used in response to user requests. With enhanced analysis capabilities, a substantial reduction in size and weight, fewer components, and improved water resistance, the new generation instrument is a considerable advancement on the previous model.

REFERENCES

1. R. M. Keyser, T. R. Twomey, and D. L. Upp, “An Improved Handheld Radioisotope Identifier (RID) for both Locating and Identifying Radioactive Materials,” Proceeding of the HPS Mid Year Meeting, Jan 2005

2. R. M. Keyser, Timothy Twomey, and Daniel Upp, “Performance of Light-Weight, Battery-Operated, High Purity Germanium Detectors for Field Use,” Proceedings of the INMM Annual Meeting 2003

3. R. M. Keyser and T.R. Twomey, “Performance of a portable HPGe-based Nuclide Identifier on Multiple Nuclide Mixtures,” Proceedings of the INMM Annual Meeting 2004

4. Ronald M. Keyser, Daniel L. Upp, and Timothy R. Twomey, “A Comparison of an HPGe-based and NaI-based Radionuclide Identifier (RID) for Radioactive Materials,” Proceedings of the ESARDA Annual Meeting 2005

5. Ronald M. Keyser, Daniel L. Upp, and Timothy R. Twomey, “Performance of an Improved HPGe-based Radioisotope Identifier (RIID) in the Identification of SNM and SNM Mixtures,” Proceedings of the INMM Annual Meeting 2006

6. Ronald M. Keyser and Richard C. Hagenauer, “Performance of a Portable, Electromechanically-Cooled HPGe Detector for Site Characterization,” Proceedings of the MARC VII April, 2006

7. “Detecting nuclear and radiological materials,” RS policy document 07/08, The Royal Society, London, March 2008

8. “Performance Criteria for Hand-held Instruments for the Detection and Identification of Radionuclides,” American National Standard: ANSI N42.34-2003, National Committee on Radiation Instrumentation, N42, American National Standards Institute and The Institute of Electrical and Electronics Engineers, Inc.

9. “Technical and Functional Specifications for Border Monitoring Equipment, Technical Guidance,” IAEA Nuclear Security Series No. 1, STI/PUB/1240, International Atomic Energy Agency (2006a), Vienna, IAEA