Performance of an HPGe-based and NaI-based Radionuclide Identifier (RIID) in the Identification of Radioactive Materials

Ronald M. Keyser, Daniel L. Upp, Timothy R. Twomey

ORTEC
801 South Illinois Avenue
Oak Ridge, TN, 37831 USA
Ron.keyser@ortec-online.com, dan.upp@ortec-online.com, tim.twomey@ortec-online.com

Abstract

The process for detection and interdiction of illicit trafficking of radioactive and nuclear materials relies on Portal Monitors or hand-held instruments to first detect, then identify any radioactive material located in the shipment. The high number of medical, industrial and Naturally Occurring Radioactive Materials (NORM) in legitimate transit gives rise to frequent innocent alarms, that is, alarms on non-threatening nuclides. In order to allow these shipments to pass and the illicit material to be stopped, the nuclides must be accurately and rapidly identified. The RIID (Radionuclide Identifier) is used to identify the nuclides in the shipment as the second step in the interdiction process. Recent emphasis in the design and testing of RIIDs has been on accurate identification of nuclides in order to reduce the false positive rate and the innocent alarm rate. In previous work, the search mode of an HPGe-based RIID was compared with a NaI-based RIID for neutron and gamma-ray sources. In this work, the performance of the same two instruments in the identification of radionuclides is compared. The ANSI N42.34 requirements are the basis for the tests. Previous work also showed the performance of a HPGe-based RIID with mixtures of nuclides. Some of the single nuclides and certain mixtures of nuclides for both shielded and unshielded sources in the standard were used. Due to the short halflives of the medical isotopes, they were not used in these tests.

Results comparing the performance of both systems, with the standard and with each other will be given. The results show the HPGe system provides the correct identification more rapidly and on less spectral data than the NaI system and that it easily exceeds the ANSI N42.34 requirement to identify the nuclides in the shipment accurately and quickly.

Introduction

The Homeland Security defense against illicit nuclear trafficking relies on the ability to detect and identify any radionuclides passing through control points. For any identification system to be useful, it must make rapid determinations, have a low number of false positives (reporting a nuclide that is not present) and an even lower number of false negatives (not reporting a nuclide that is present). The popular press [1] has reported on the inability of many instruments to correctly perform the identification. The correct identification of the nuclide is important for single nuclides in order to identify the innocent alarms due to medical isotopes and allow passage. But the correct identification is even more important for mixtures of nuclides. That is,

the identification system must be able to report the presence of certain nuclides in every case and especially in the case where there are multiple nuclides in the sample (mixtures).

The ANSI N42.34 [2] standard and the IAEA draft specification3 give test procedures to verify the performance of a RIID for several different cases. The tests reported here are based on paragraph 8.7 of ANSI N42.34. In this test, the RIID must be able to identify all the components of the mixture of a single nuclide and a background of natural thorium within the time of 60 seconds. The tests include correct identification for both unshielded and shielded (5 mm steel) geometries. Thorium and its decay products account for about half of the of the false alarms at analysis stations.

Prior work [4, 5, 6, 7, 8] showed that high resolution gamma-ray detectors have the same or greater sensitivity than the most common size of low resolution detectors and that the HPGe detector systems can correctly perform the identification, even for mixtures, in less time than the requirements in the standard. This work compares the time for correct analysis of nuclides in the presence of thorium for the HPGe, high resolution RIID with a scintillator based RIID.

Experimental Configuration

The two RIIDs compared in the tests were described in detail earlier [4]. The tests were conducted using the two instruments sequentially. The sources were placed in front of the instrument being tested at a distance from the front face of the housing (not necessarily the detector) so that the dose displayed by the instrument's internal dose meter was 50 : R/h from each source for a total of 100 : R/h. This dose requirement meant that the distance from the RIID to the source was different for each source. The source was aligned with the active center of the detector as defined by the manufacturer. The sources were held in place with low mass and low atomic number materials to reduce scatter. The depleted uranium (DU) sample was positioned so that the maximum surface area faced the detector. When DU was used, the sources were positioned to minimize any shielding by the DU of the thorium source. The shield consisted of 5 mm stainless steel plates which completely covered the active detector face. The shields were positioned at the front of the RIID in all cases in order to obtain the required dose for the weaker sources.

The Detective EX continuously collects and analyzes the spectrum. Once a second the current analysis result is updated on the display. The running live and real time are also displayed. For each source, the identification was started with the source in place and the screen was continuously observed so that when the correct result was displayed for at least 10 seconds, the real time (representing the data collection time) could be recorded. The identification was repeated 10 times and the results shown are the average of the multiple analyses.

The scintillator-based RIID operates by collecting a spectrum for a fixed time, storing the spectrum, analyzing the spectrum and displaying the result. For this test, the collection time was set to the minimum time and the manual time extension mode was used to extend the time of the spectrum collection until a result was observed. The recorded times are only for the spectrum collection and do not include the extra time for processing.

The peak confidence level on the peak areas for the peak to be recognized as present in the spectrum was set to 5 sigma for both instruments. This level ensures a low level of false positives. The background dose is about 5 : Sv/h.

For either instrument, if the correct analysis was not observed in 180 seconds, the process was stopped and the result recorded as a failure. The maximum counting time is given in ANSI N42.34 and IAEA draft TECDOC as 60 seconds for unshielded and shielded sources.

Some of the sources were point sources and some were extended sources. The list of sources is shown in Table I.

Table I Sources used			
Source	Nominal activity	Form	Correct report
Co 60	1 uCi	Point source	Co 60
Ba 133	1 uCi	Point source	Ba 133
Am241	1 mCi	Point source	Am 241
Cs 137	1 uCi	Point source	Cs 137
Depleted uranium	18 g	Thin plate	Depleted uranium or high uranium content
Thorium	200 g natural thorium	Bulk powder, about 20 mm x 15 mm diameter	NORM - Th, Th 232, Th 228, or Ra 226

Example spectra

As soon as the correct analysis was observed in the Detective EX, the spectrum was manually saved. An example spectrum of unshielded thorium with ^{137}Cs is shown in Fig. 1 and for shielded in Fig. 2. In these spectra, note the relatively low number of counts needed to make the identification. The energy range of the stored spectrum is 0 to 3 MeV, but only 0 to 2.7 MeV is shown in the figures.
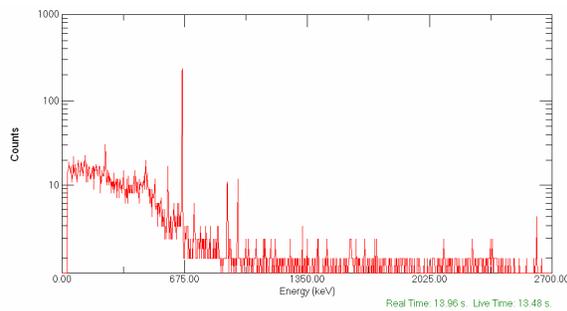
Figure 1. Short time spectrum of unshielded thorium and ^{137}Cs from HPGe detector.
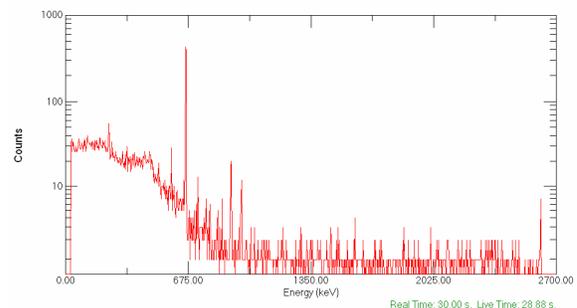
Figure 2. Short time spectrum of shielded thorium and ^{137}Cs from HPGe detector.

The DU and thorium combination is shown in Figs. 3 and 4. In this spectrum, note the closely spaced gamma-ray peaks in the spectrum, which are easily separated by the HPGe detector.
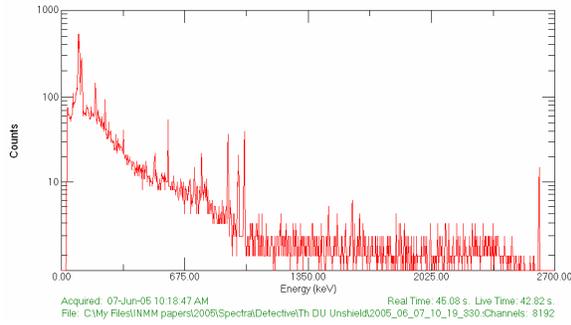
Figure 3. Short time spectrum of unshielded thorium and depleted uranium from HPGe detector.
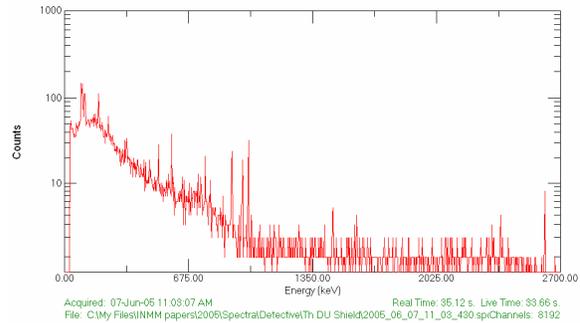
Figure 4. Short time spectrum of shielded thorium and depleted uranium from HPGe detector.

The corresponding spectra for the scintillator system are shown in Figs. 5, 6, 7, and 8.
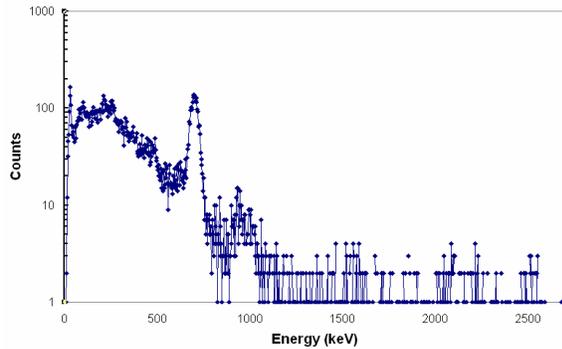
Figure 5. Short time spectrum of unshielded thorium and ^{137}Cs from scintillator detector.
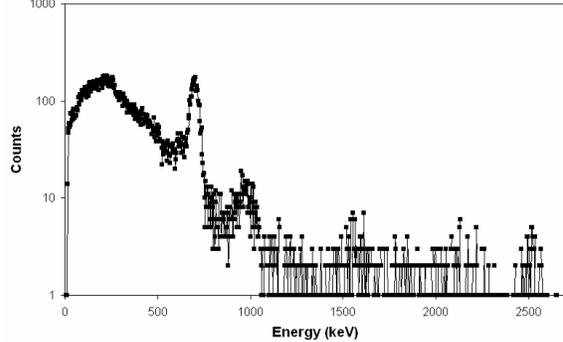
Figure 6. Short time spectrum of shielded thorium and ^{137}Cs from scintillator detector.

The scintillator spectrum does not separate the gamma-ray lines, making the identification difficult.
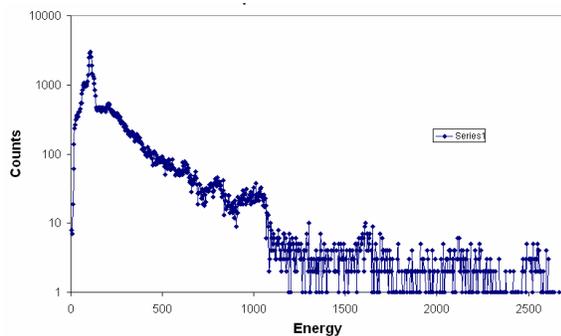
Figure 7. Short time spectrum of unshielded thorium and depleted uranium from scintillator detector.
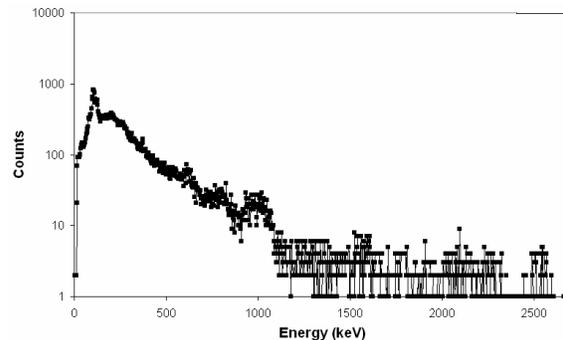
Figure 8. Short time spectrum of shielded thorium and depleted uranium from scintillator detector.

Results

The HPGe RIID was able to identify the added nuclide or DU in the presence of natural thorium in less than the 1 minute requirement of ANSI N42.34, and in some cases less than 30 seconds as shown in Fig. 9. The time to identify increases when the source is shielded, but remains lower than the requirement.
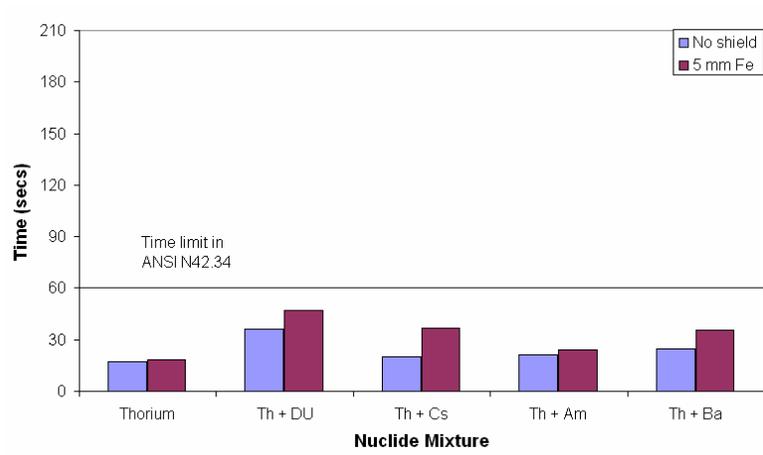
Figure 9. Time to identify both nuclide and NORM-Th by HPGe RIID.

The scintillator RIID was unable to identify thorium alone (NORM-Th) in less than 60 seconds and only reported the result as "unknown" nuclide for depleted uranium, ^{137}Cs and ^{241}Am. For the case of thorium and ^{133}Ba, the correct result was obtained by collecting the spectrum for 120 seconds. For the cases of unshielded ^{241}Am or ^{133}Ba, the individual nuclide was identified in a short time; ^{241}Am taking the longer of the two. NORM - Th was not identified within the 60 seconds.
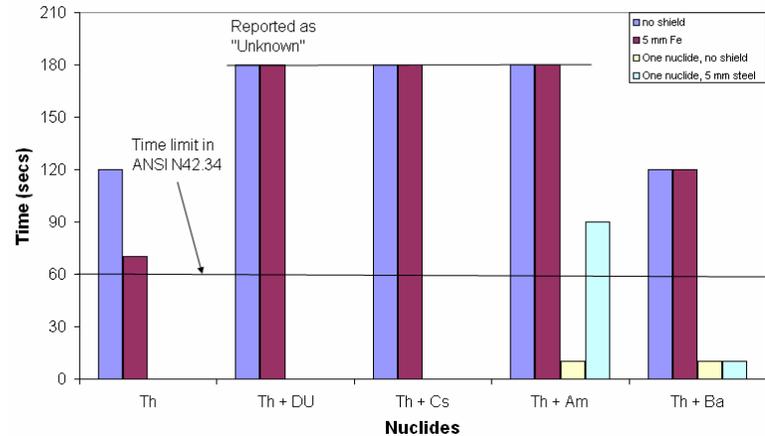
Figure 10. Time to identify both nuclide and NORM-Th by Scintillator RIID.

Conclusions

The results show that the HPGe-based RIID can correctly analyze single nuclides in the presence of thorium in less time than required by ANSI N42.34 than can a RIID based on scintillation detectors. More importantly, several relatively simple combinations of nuclides correctly identified by the HPGe were not identified by the scintillator. This is attributable to the vastly superior resolution of HPGe compared to scintillators, which greatly improves the signal-to-noise ratio. Further work will concentrate on producing more detailed identification for other types of shielded sources and combinations of sources.

References

1.   See, for example, S. Highman and R. O'Harrow, Jr., "Securing the Homeland", Washington Post National Edition, 30 May 2005

2.   American National Standards Institute, "Performance Criteria for Hand-held Instruments for the Detection and Identification of Radionuclides," ANSI N42.34, January, 2004

3.   Co-ordinated Research Project: "Improvement of Technical Measures to Detect and Respond to Illicit Trafficking of Nuclear and other Radioactive Materials," Technical / Functional Specifications for Border Radiation Monitoring Equipment

4.   R. M. Keyser, T. R. Twomey, and D. L. Upp, "An Improved Handheld Radioisotope Identifier (RIID) for both Locating and Identifying Radioactive Materials," HPS Midyear Meeting, January 2005

5.   R. M. Keyser, T. R. Twomey, and D. L. Upp, "Performance of Light-Weight, Battery-Operated, High Purity Germanium Detectors for Field Use," INMM Annual Meeting, July 2003

6.   T. R. Twomey and R. M. Keyser, "Hand-Held Radio Isotope Identifiers for Detection and Identification of Illicit Nuclear Materials Trafficking: Pushing the Performance Envelope," World Customs Organization Conference, London, Sept. 2004

7.   R. M. Keyser and T. R. Twomey, "Performance of a Portable HPGe-Based Nuclide Identifier on Multiple Nuclide Mixtures," INMM Annual Meeting, July 2004

8.   R. M. Keyser, T. R. Twomey, and D. L. Upp, "A Comparison of an HPGe-based and NaI-based Radionuclide Identifier (RIID) for Radioactive Materials," ESARDA Annual Meeting, May 2005