Illicit Trafficking, Sub/cross-national threats, Poster presentation

A Comparison of an HPGe-based and NaI-based Radionuclide Identifier (RID) for Radioactive Materials

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Abstract:

The three steps in the interdiction process for illicit trafficking of radioactive and nuclear materials are detection, location and identification. Many handheld radioisotope identifiers (RIDs) have been introduced with the claim to the latter two tasks for gamma-emitting sources. Recent emphasis has been on identification in order to reduce the false positive rate. Previous work compared the search mode of an HPGe-based and a NaI-based RID for neutron and gamma-ray sources. In the present work, the performance of the same two instruments in the identification of radionuclides is compared. The requirements for the identification are given in ANSI N42.34 and related standards. The tests in the standard are for single nuclides and certain mixtures of nuclides for both shielded and unshielded sources. The two systems have been compared under the standard test conditions for a variety of the sources and configurations specified.

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.

Keywords: radioisotope; identifiers; germanium detectors; HPGe; illicit trafficking

1. Introduction

The Detective EX is a handheld radioisotope identifier (RID) based on a high purity germanium detector (HPGe) and moderated ^{3}He tubes for the gamma ray and neutron detection respectively. The size of the HPGe and neutron detectors was based on the efficiency requirements of ANSI N42.34 for the detection of differing amounts of material and on the ability to correctly identify the various nuclides in mixtures. The mixtures specified in the standard are those which could be used to hide prohibited material by masking it with other, innocent, radioactive materials. HPGe is arguably the only material available today which has both the necessary high resolution and adequate detection efficiency in a single detector. The neutron detectors were not used for these identifications.

Because of the relatively small size of the HPGe detector (about 12% relative efficiency), there is a widely held misconception that accurate nuclide identification will require a long counting time in order to obtain the necessary spectrum counts. However, these results show that the improved resolution of the HPGe more than compensates for the fewer overall counts than in the scintillator spectrum.

In the expected mode of operation of the RIDs, the location of the source is determined in the “search mode” and then the identification of the nuclides is determined in the identify mode. Prior work [1,2,3,4]

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 for the HPGe, high resolution RID with a scintillator based RID.

2. Experimental Configuration

The two RIDs were described earlier [1] and are shown in Fig. 1. The tests were conducted using the two instruments sequentially. The sources were placed in front of the instrument being tested at 10 cm from the front face of the housing (not necessarily the detector) and aligned with the active center of the detector as defined by the manufacturer. The sources were positioned with low mass and low atomic number materials to reduce scatter. The DU samples were positioned so that the maximum surface area was facing the detector. When the point sources were used with the DU, the point sources were positioned beside the DU to eliminate any shielding by the DU. The average dose, as recorded by the instruments, was about 50 ：Sv/h above background, consistent with the ANSI N42.34 [5] requirements.

Figure 1. The Detective and scintillator-based RIDs.

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, the real time (representing the data collection time) could be recorded. The identification was repeated and the results shown are the average of the multiple analyses.

The scintillator-based RID 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, typically about 25 seconds

Both instruments were operated at the same confidence level on the peak areas for the peak to be recognized as present in the spectrum. This level was set such that the uncertainty of the net peak area was less than 5 sigma for most peaks. This level ensures a low level of false positives.

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 not given in ANSI N42.34, but is listed in the IAEA draft TECDOC [6] as 60 seconds for unshielded sources.

Some of the sources were point sources and some were extended sources. The list of sources is shown in Table 1.

Source	Nominal activity	Form	Correct report
Cs 137	1 uCi	Point source	Cs 137
Co 60	1 uCi	Point source	Co 60
Ba 133	1 uCi	Point source	Ba 133
Depleted uranium	98 g	Bar (5 x 5 x 30)	Depleted uranium
Depleted uranium	18 g	Thin plate	Depleted uranium

Mixed 1888	0.5 uCi each	Point source	Am241, Cs137, Co60, Cd109
Thorium	200 g natural thorium	Bulk powder, about 20 mm x 15 mm diameter	Th 232, Th 228, or Ra 226
Natural Uranium	Unknown	Uranium in glass	Uranium
Natural Uranium	5000 bq	Compressed powder, 5 mm x 40 mm diameter	Uranium

2.1. Example spectra

As soon as the correct analysis was observed in the Detective, the spectrum was manually saved. An example spectrum for identifying ^{60}Co is shown in Fig. 2. In this spectrum, note the relatively low number of counts needed to make the identification.

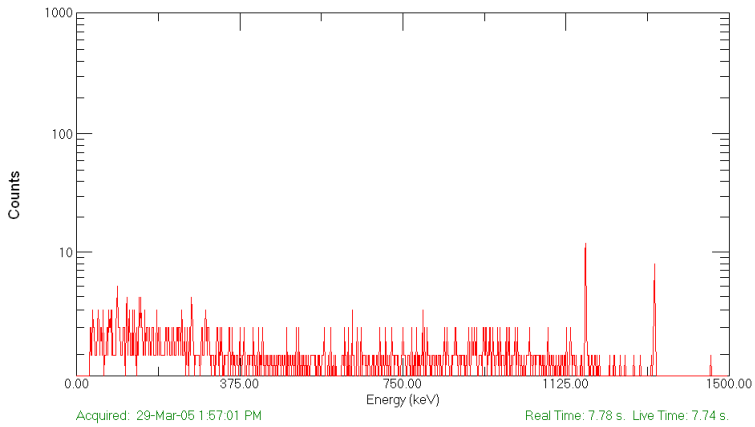

Figure 2. Short time spectrum of ^{60}Co from HPGe detector.

The DU and ^{133}Ba combination is shown in Fig. 3. In this spectrum, note the closely spaced gamma-ray peaks in the spectrum, which are easily separated by the HPGe detector.

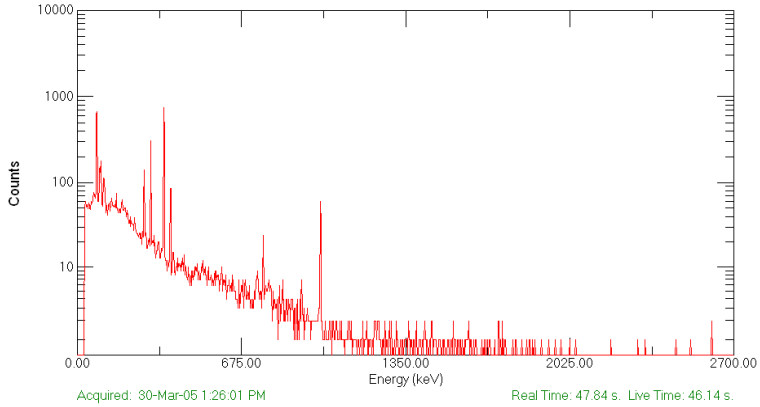

Figure 3. HPGe Spectrum of depleted uranium and ^{133}Ba.

The corresponding spectra for the scintillator system are shown in Figs. 4 and 5.

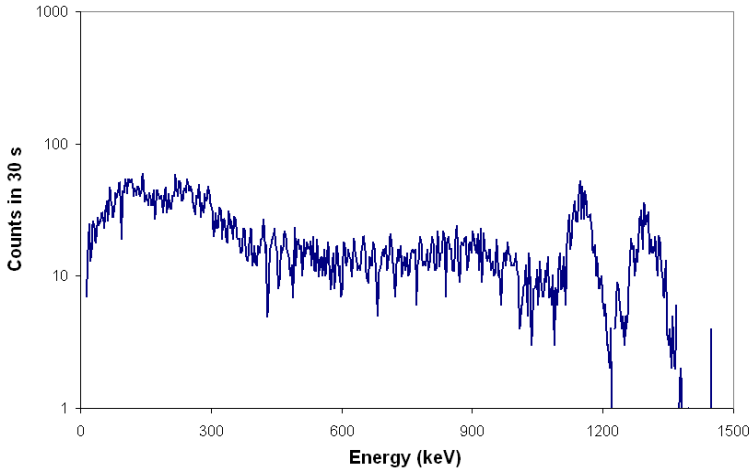

Figure 4. Scintillator spectrum of ^{60}Co.

The scintillator spectrum does not show the separation of the gamma-ray lines, making the identification difficult.

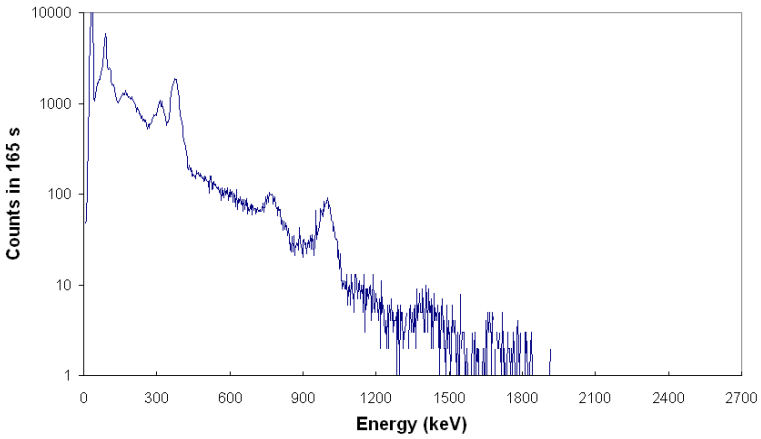

Figure 5. Scintillator spectrum of depleted uranium and ^{133}Ba.

3. Results

3.1 Single nuclides

For the single nuclide cases, both RIDs were able to correctly identify the nuclide, however the Detective determined the result in less time than the scintillator-based system.

3.2 DU and DU with other nuclides

The HPGe RID was able to identify DU as "depleted uranium" both alone and with other nuclides in less than 1 minute, and in some cases less than a few seconds. The time to identify increases as the number of gamma-ray lines in the spectrum increases, but remains at or near the 60 second requirement except for the DU and mixed nuclide standard. The DU plus mixed 1888 standard is identified in about 100 seconds as DU plus the 4 nuclides shown in Table 1.

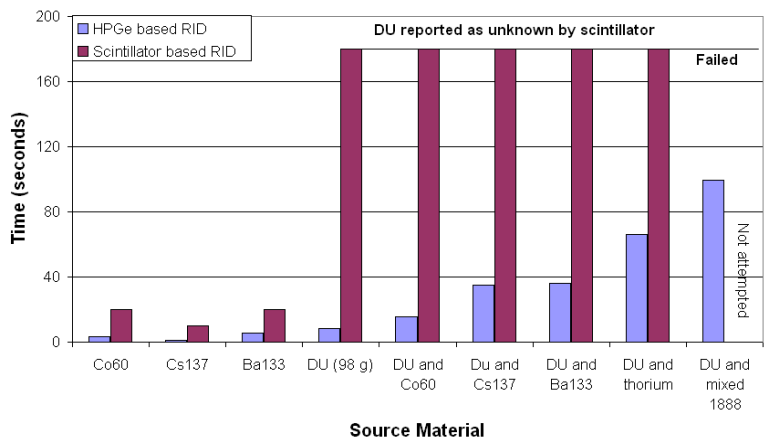

Figure 6. Comparison of time to identify single nuclides alone and with DU by HPGe and Scintillator RIDs.

The scintillator RID reported "unknown" in all cases where DU was the sample. For the mixtures with the ^{60}Co ^{133}Ba and natural thorium, the addin nuclide was reported with no DU reported. For the mixture of ^{137}Cs and DU, the scintillator RID only reported ^{137}Cs.

These results are shown in Fig. 6.

3.3 Other nuclides and combinations

Several other combinations of nuclides were tested. The results are shown in Fig. 7. The HPGe RID is able to identify the material in less than 130 seconds in all cases and generally less than 40 seconds. The background test was done in a room with concrete floors, walls and ceiling and the expected result was ^{40}K. The background dose is about 5 : Sv/h.

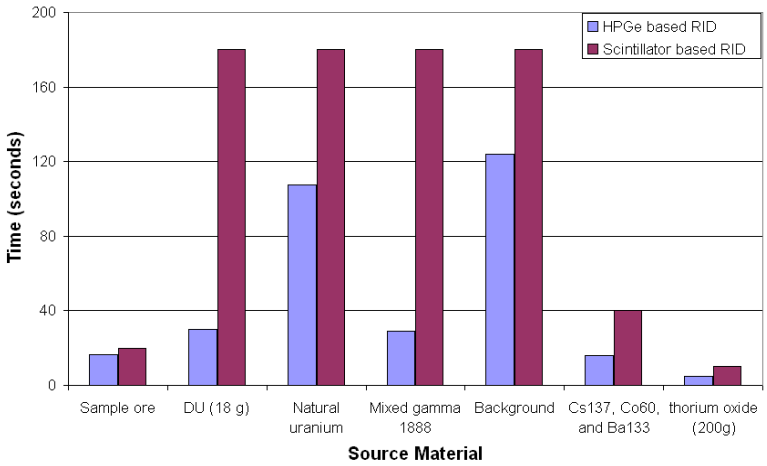

Figure 7. Comparison of time to identify multiple nuclide mixtures, uranium, and natural material by HPGe and Scintillator RIDs.

The scintillator RID reported “unknown” for the small DU sample and for the natural uranium sample. For the mixed gamma, only ^{241}Am and ^{60}Co were reported with ^{109}Cd and ^{137}Cs missing. For the background case, no nuclides were reported. For the thorium ore, any of the possible components (e.g., ^{232}Th, ^{228}Th, or ^{226}Ra) were accepted as the correct result, since the different requirements can dictate which result is displayed.

4. Conclusions

The results show that the HPGe-based RID can correctly analyze single nuclide samples and mixtures of materials in less time than a RID based on scintillation detectors. More importantly, the depleted uranium sample was correctly identified by the HPGe and not identified as DU by the scintillator, both in mixtures and even when DU was the only material present. This is possible because of the greatly improved resolution of HPGe compared to scintillators, which greatly improves the signal-to-noise ratio. Further work will concentrate on more complex mixtures.

4. References

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