

An Improved Handheld Radioisotope Identifier (RID) for both Locating and Identifying Radioactive Materials

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Abstract

The two initial steps in any program designed to interdict illicit trafficking of radioactive and nuclear materials are location and identification. Many handheld radioisotope identifiers (RIDs) have been introduced with the claim to perform both of these tasks for gamma-emitting sources, yet only a few claim to do location of neutron sources and still fewer perform well as identification tools due to the low resolution gamma-ray detectors employed. An HPGe-based RID (Detective) has been shown to give superior performance in the identification of radionuclides in static conditions, that is, once the source has been located, according to the test processes given in ANSI 42.34. It has been generally thought that large systems, such as the NaI-based NAI-SS system or a plastic scintillator-based portal monitor would be used for the location even though the RID specifications include a search mode. This work tested the Detective-EX in its search mode for both gamma and neutron emitting sources and compared the results to an NaI-based RID. The tests were done using single nuclide sources (^{137}Cs , ^{60}Co), and a neutron source (^{252}Cf) in shielded and unshielded situations. The systems were moved past the sources at specified distances to simulate the actual search operation at an inspection station.

Keywords: nuclide identifier, germanium detector, search mode, neutron detector

Introduction

The Detective EX is a handheld radioisotope identifier (RID) based on a high purity germanium detector (HPGe) for the gamma ray detection and on moderated ^3He tubes for neutron detection. 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 materials by masking it with other, innocent, radioactive materials. HPGe is the only detector material available today which offers both high resolution and adequate detection efficiency in a single detector.

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 to these tests, it was generally assumed that the high resolution detectors would not perform well in the search mode. In the data presented below, it is shown that high resolution gamma-ray detectors have the same or better gross efficiency (sensitivity) than the most common size of low resolution detectors. Previous work^{1,2,3} has shown the ability of the HPGe detector systems to correctly perform the identification, even for mixtures, exceeding the requirements of the standard.

Experimental Configuration

The systems tested were the high-resolution ORTEC Detective EX (HPGe and ^3He) and a low resolution system based on sodium iodide (NaI) and lithium glass (LiG) detectors from another vendor. Both systems have compensated GM tubes for high gamma dose rate warnings.

The HPGe detector is a 50 x 30 mm detector cooled by a battery-operated Stirling cooler. The neutron detector consists of 4 ^3He tubes of 10 cm by 1 cm active volume. The gas pressure is 20

atmospheres. The tubes are inside a 22 mm by 15 cm by 10 cm HDPE moderator. The gamma-ray data are processed by a DSP-based MCA with a special filter for elimination of microphonic noise. The data collection is controlled by an internal PDA with a color, touch-screen display and the spectra are stored on removable media.

The NaI detector is a 1.5 x 2 inch detector with integral photomultiplier tube. The neutron detector is a LiG detector with integral photomultiplier tube. The signal processing is done with analog electronics. The data collection is controlled by a control panel and display. The data are stored internally for later download to a PC.

The two units were placed side-by-side for these tests as shown in Figs. 1 and 2. The offset of the two detectors accounts for the displacement of the maximum sensitivity in the results below. The instruments were placed on a laboratory bench and the sources were moved past the detectors to simulate the search mode.

The sources were moved one at a time in front of the detectors in one of two modes. The “horizontal” mode was from left to right in front of the detectors so that the source moved from out of view on one side to out of view on the other side. The gamma-ray sources were held at the centerline of the detectors for all tests. The neutron source was used both in the shielded (moderated) and unshielded mode. For the moderated mode, the source was moved on the laboratory floor and in the unshielded mode, the source was at the level of the detectors.

In both units, the search mode data were collected and stored in 1-second time slices. The source was positioned successively at discrete points each for 30 seconds. Ten data points were averaged for each position.



Fig. 1. Front view of two systems.

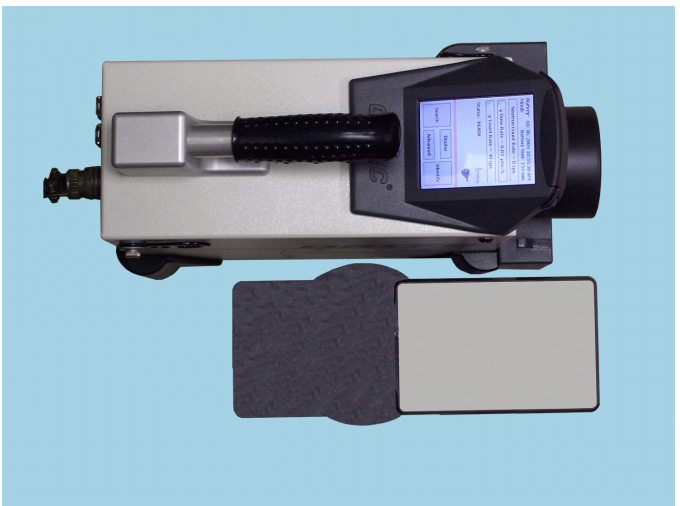


Fig. 2. Top view of two systems.

The second mode was the “vertical” mode where the sources were moved directly away from the instruments on a line centered between the units from minimum distance to 2 meters distance. These two modes are shown in Fig. 3.

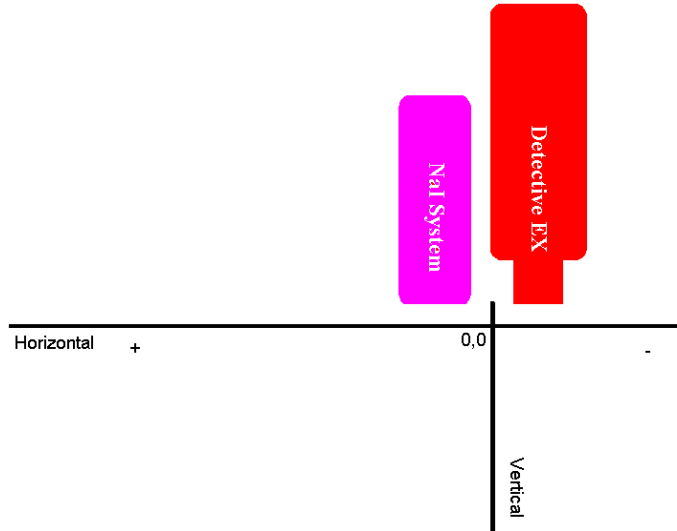


Fig. 3. Directions of Source Movement.

The ^{137}Cs source was a nominal 36 kBq source when the data were collected. The ^{60}Co source was a nominal 1 MBq and the neutron source was a ^{252}Cf source 38 MBq. The neutron source is stored in a 50 cm cube of HDPE and this was used as the moderated source, as shown in Fig. 4.

The minimum distance between the gamma-ray sources and the detectors was 2 cm. For the unmoderated neutron source the minimum distance was 50 cm. At this distance for the neutron source, the overdose alarms on both units were triggered. In all cases it was determined that the systems were operating in the normal (non-overload) condition.

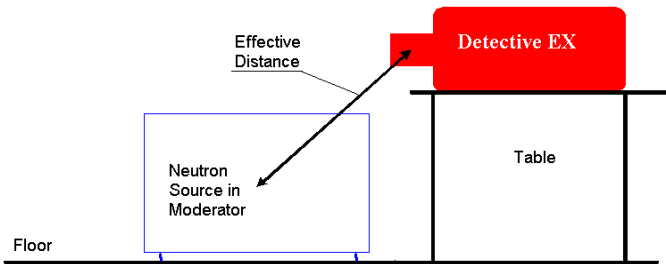


Fig. 4. Distance from Moderated Neutron Source to Detector.

Results

^{60}Co

The gross count rate for ^{60}Co for the minimum distance between source and detector is shown in Fig. 5. Note the offset in the maximum position is due to the distance between the detection centers of the two devices. The HPGe detector shows a higher count rate (efficiency) than the NaI system. The NaI system has a wider angle of acceptance, indicated by the wider peak in the data.

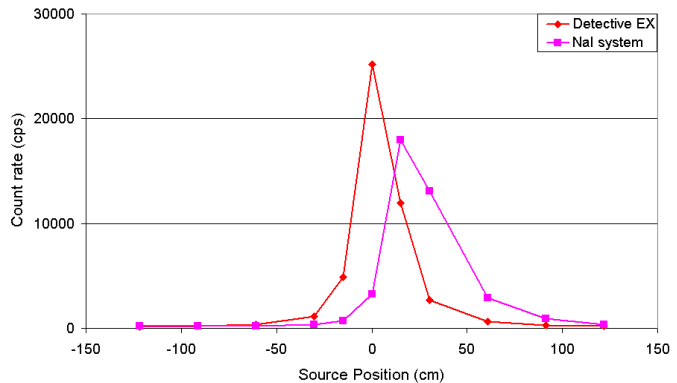


Fig. 5. Sensitivity to ^{60}Co for Detective EX and NaI System vs Horizontal Position at Minimum Offset.

The gross count rate for ^{60}Co for the case with the source at a distance of 60 cm is shown in Fig. 6. The results are similar to those in Fig. 5. The HPGe has higher sensitivity at the maximum point and the NaI has a wider angle of acceptance.

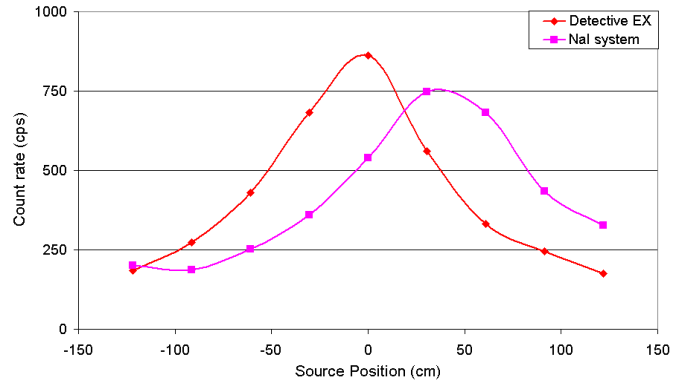


Fig. 6. Sensitivity to ^{60}Co for Detective EX and NaI System vs Horizontal Position with 60 cm Offset.

The result of the scan along the vertical direction, out from the front of the instruments, is shown in Fig. 7. The HPGe system again shows higher sensitivity up to about half a meter.

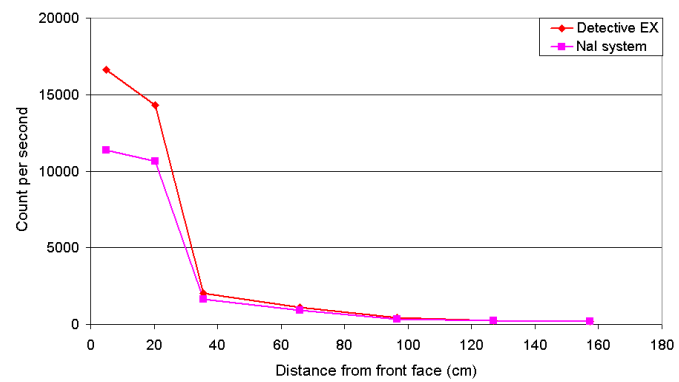


Fig. 7. Sensitivity to ^{60}Co for Detective EX and NaI System on Distance from Front Face.

^{137}Cs

The ^{137}Cs result for the minimum distance horizontal scan is shown in Fig. 8. The HPGe system is similar to the ^{60}Co result, but the difference in sensitivity is greater in this case. The angle of acceptance is the same in both detectors for this case.

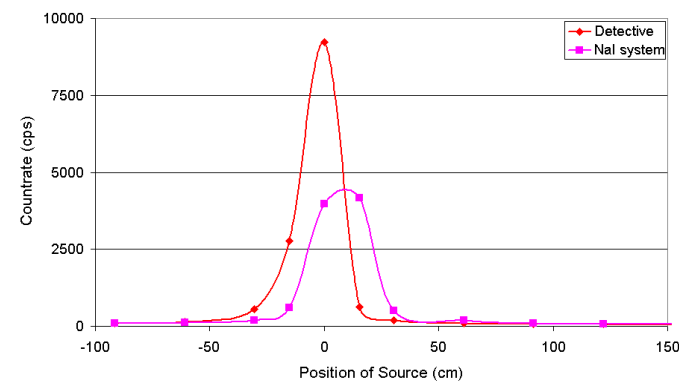


Fig. 8. Sensitivity to ^{137}Cs for Detective EX and NaI System vs Horizontal Position at Minimum Offset.

The ^{137}Cs result, with background subtraction, for the 60 cm distance horizontal scan is shown in

Fig. 9. In this case, the count rate from the source is not much higher than the background. The background count rate, averaged over 200 seconds, was 47 cps for the Detective EX and 54 cps for the NaI system.

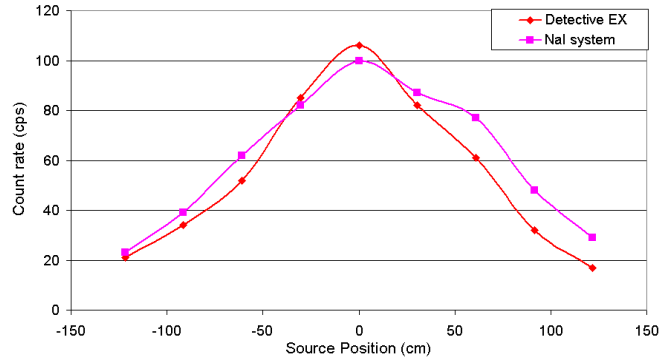


Fig. 9. Sensitivity to ^{137}Cs for Detective EX and NaI System vs Horizontal Distance and 60 cm Offset.

The result of the vertical scan is shown in Fig. 10. The HPGGe system again shows higher sensitivity up to about half a meter.

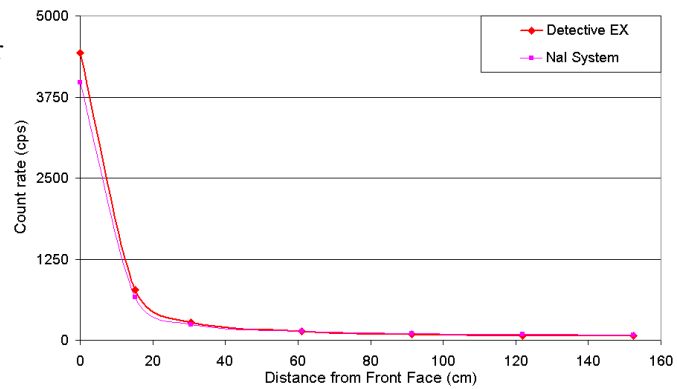


Fig. 10. Sensitivity to ^{137}Cs for Detective EX and NaI System on Distance from Front Face.

^{252}Cf

The ^{252}Cf horizontal scan for the moderated source is shown in Fig. 11. The neutron data are complicated by the room return, which is the case for many neutron measurements. The concrete floor will reflect many neutrons into the detector. In these measurements, the nearby materials, including people, were held as constant as possible to minimize the changes in neutron reflections during the measurements. Note that the neutron detector in the Detective EX is nearly 50 times more efficient than the neutron detector in the NaI system.

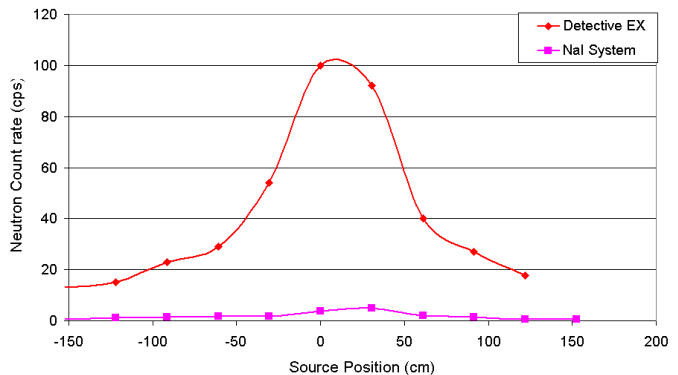


Fig. 11. Sensitivity to Moderated Neutrons for Detective EX and NaI System vs Horizontal Distance.

In all the neutron scans, the gamma-ray flux was significant. In most cases, the gamma-ray flux was many times the flux of the ^{137}Cs and ^{60}Co scans.

The ^{252}Cf horizontal scan for the unmoderated source is shown in Fig. 12. In this case, the Detective EX is significantly more efficient than the NaI system. The unmoderated source was 50 cm minimum distance (position 0 on the graph) from the detector. Comparing Figs. 11 and 12 shows that the moderator in the Detective EX contributes to the sensitivity in the unmoderated neutron flux.

The vertical scan for the moderated source is shown in Fig. 13. The minimum distance was limited by the moderator and the placement of the source on the floor below the position of the detectors.

The vertical scan for the unmoderated source is shown in Fig. 14. In this case, the source was at the level of the detectors. The minimum distance was 1 meter because of the high dose alarm signal, which was based on the gamma-ray flux.

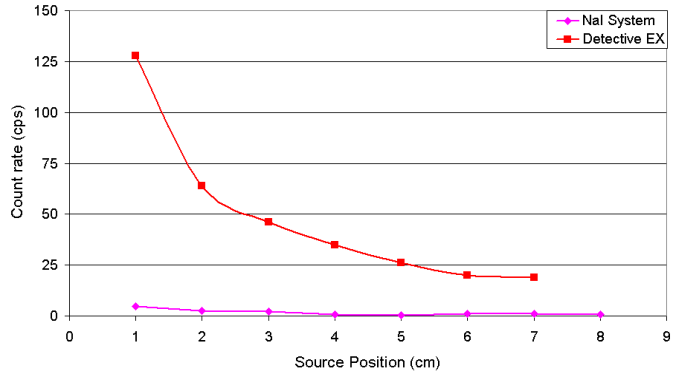


Fig. 12. Sensitivity to Moderated Neutrons for Detective EX and NaI System Distance from Front Face.

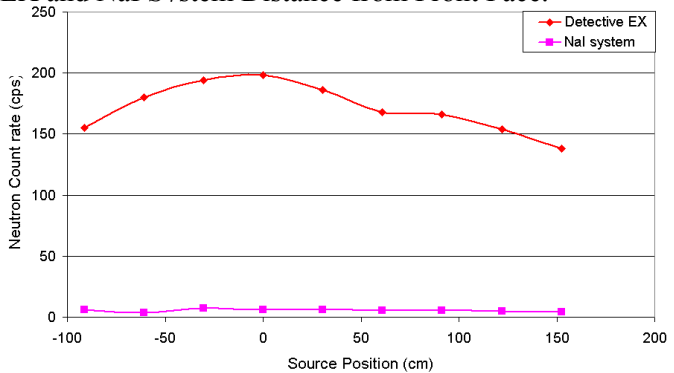


Fig. 13. Sensitivity to ^{252}Cf Neutrons for Detective EX and NaI System vs Horizontal Distance.

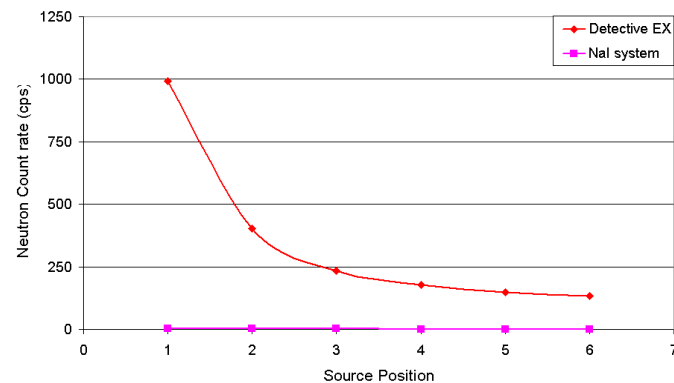


Fig. 14. Sensitivity to ^{252}Cf Neutrons for Detective EX and NaI System vs Distance from Front Face.

Conclusions

The results show that the HPGc detector of about 12% relative efficiency has higher sensitivity in the search mode than the 1.5 x 2 inch NaI detector commonly used in low-resolution RIIDs. The Detective EX also has a much more efficient neutron detector than commonly used neutron detectors based on lithium glass.

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