

Operational Experience with a Secondary Spectroscopic Vehicle Portal Monitor Using High Purity Germanium Detectors

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ABSTRACT

Portal monitors, container scanners, and mobile search systems, constructed with high purity germanium (HPGe) detectors, are currently being installed at locations world-wide. This reflects a general desire for improved performance and for a reduction in the time to make a good decision making in interdiction cases.

A COTS integrated gamma-ray spectrometer, (the IDM) incorporating a mechanically cooled HPGe detector, digital signal processing electronics, MCA, and communications hardware has been developed at ORTEC to meet the detection and environmental needs of these systems. Specially developed software allows these spectrometers to be configured in a variety of portal monitoring applications.

An Advanced Spectroscopic Portal Monitor (ASP) for secondary inspection of motor vehicles has been constructed and installed at the Anthony, New Mexico Port of Entry (POE). The POE is operated by the New Mexico Department of Public Safety Motor Transportation Police Division, and has been fully operational since November 2009. The instrument operates as a secondary screen to automatically resolve alarms which occur as all commercial transport vehicles pass through the primary plastic scintillator (PVT) portal on the site. The ASP provides automated, unambiguous nuclide identifications, for both innocent and threat categories. The dual pillar monitor incorporates a total of 8 IDMs, four per side.

The automatic nuclide identification software is derived from algorithms developed for the ORTEC Detective hand-held nuclide identifiers. The system is mounted in environmentally hardened enclosures. The system meets the identification requirements of ANSI N42.38.

This paper describes the radiological design features of the monitor, operational experience, and performance data.

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

INTRODUCTION

The monitoring of cross border traffic in order to prevent the illicit trafficking of nuclear materials is of key importance in efforts to prevent nuclear terrorism. It is by now well understood that streams of commercial freight can often contain innocent radioactive material which cannot be determined a-priori to be innocent. It is highly important that the flow of commerce be unimpeded while these determinations are made. At the same time since the objective is to intercept illicit material, false positives may not be avoided at the expense of passing false negatives, which can have catastrophic consequences. In short, an effective freight portal monitor must embody the ability to rapidly identify unequivocally any radioactive sources present in a vehicle so that the innocent vehicle can be on its way while the illicitly trafficked material is intercepted rapidly and reliably.

It was decided in 2008 by New Mexico Motor Transportation Police to develop a PRND¹ capability at the Anthony port of entry, which would allow the screening of highway I-10 westbound commercial vehicle traffic from El Paso, TX and the Santa Teresa New Mexico-Mexico border crossing.

The Agency's PRND program general objectives were to improve screening for nuclear and radiological materials entering New Mexico, preventing trafficking of threat materials across the Mexico-United States border, to ensure the legal and safe transportation of radiological materials (to include proper packaging and labeling), and to identify radiological materials transported in commerce, including NORM and TENORM.

It was considered of high importance that the flow of commerce should not be impeded at a facility with high traffic volumes, while, at the same time, the system should provide accurate identification of all types of radiological sources in transit; threat, innocent, shielded, unshielded and/or mixed. In order that the traffic flow requirement be met, false IDs and innocent alarms were to be kept at a minimum consistent with no loss of sensitivity.

A primary RPM is installed at Anthony and is an SAIC Exploranium AT-980 with 4 PVT detectors for gamma detection and 2 ³He tubes for neutron detection. This is an operator-friendly system that meets ANSI N42.35 and does not require previous radioactive monitoring experience.

During the summer of 2009, the SAIC AT-980 primary RPM went into operation at the Anthony POE. Prior to the installation of the ORTEC Detective-ASP HPGc RPM, POE personnel relied on handheld radioisotope identification devices. This proved very time consuming and impractical given the level of traffic and available personnel.

The ORTEC Detective-ASP was installed and brought into operation in the fall of 2009.

¹ PRND: Preventive Radiological Nuclear Detection

ORTEC DETECTIVE ASP SYSTEM DESCRIPTION

The ORTEC Detective-ASP HPGe portal monitor is of modular design, based around Interchangeable Detector Modules or IDMs . In the case of the installation at Anthony NM, 4 IDMs are mounted on either side of the traffic lane. Figure 1 shows the Anthony POE New Mexico installation.



Figure 1 Installed HPGe Portal at Anthony, New Mexico

An IDM is shown in Fig.2. Each IDM is a fully integrated gamma spectrometry subsystem consisting of an 85 mm diameter x 30 mm deep HPGe crystal. A complete description is given in [1]. The MCA uses the 1460 keV peak of ^{40}K for gain stabilization. The large diameter detector is optimized for energies from 100 keV to 400 keV with sufficient response up to 3 MeV, which is the necessary energy range for detection of SNM.

The IDM includes steel shielding (the black ring around the detector end cap in Fig. 2). It extends from just behind the detector crystal for a distance of 10 cm. It is 12 mm thick for 4 cm and 25 mm thick for the remaining length.

IDM Mounting

Anthony, New Mexico is situated south of Las Cruces near the New Mexico–Texas state line in the Upper Mesilla Valley. The average annual high temperature is approximately 36°C in the summer months of June/July, falling to an average low of -1°C in December/January. Record highs of 45°C and lows of -21°C have been recorded.

For this reason, the 8 IDMs were mounted in environmentally controlled cabinets. The cabinets and shielding define the detection zone to be from 0.1 m to 2 m above the ground and are positioned 5 m apart. Four IDMs are mounted on each side of the detection zone at vertical positions of 0.25, 0.75, 1.25, and 1.75 m above ground level. Each cabinet includes an HVAC system and controller to maintain temperature inside the cabinet at a satisfactory level as well as a UPS power backup

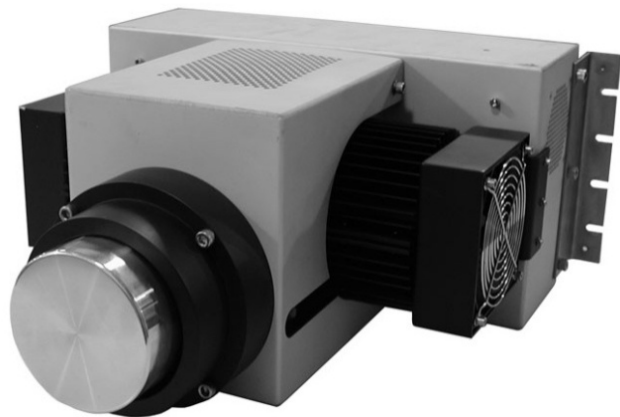


Figure 2 Interchangeable Detector Module (IDM)

supply. The front of each cabinet has a plastic window the entire vertical distance to minimize the attenuation of gamma rays to the detector. The detectors and electronics are controlled by computers mounted with the IDMs and communicate with the control computer by Ethernet.

Shielding

To reduce the general background and radiation from adjacent vehicles, side shields were added to the existing back shield as shown in Fig. 3. The additional shielding is 2.5 cm of steel as a vertical side shield from the bottom of the mounting rack to the 2 m height. The side shield extends from the steel shield outer diameter to 13 cm in front of the detector end-cap. The Field of View (FOV) is the area in front of the detectors where a source of gamma rays (NORM or other source) could contribute to the spectrum. The side shields limit the horizontal FOV to about 120° for low-energy gamma rays.

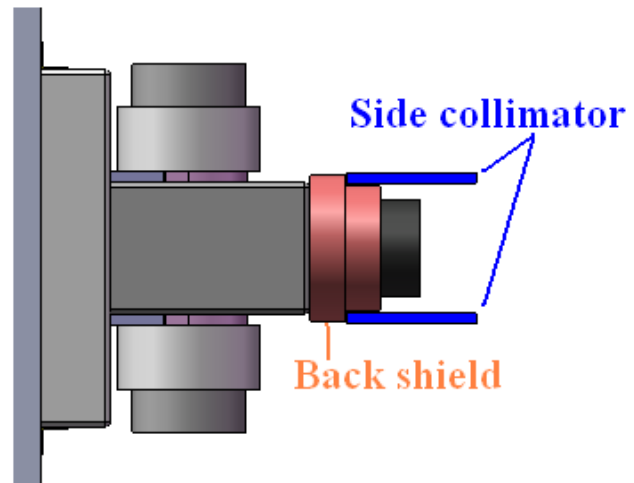


Figure 3 Schematic of IDM showing shielding

Vehicle occupancies are determined by magnetic sensors in the roadway.

SOFTWARE SPECTRUM ANALYSIS

Peak Quality Factor

The identification of a nuclide is based on the presence in the spectrum of selected intense gamma rays from that nuclide. The gamma rays used for each nuclide are given in a table stored in the analysis software. The gamma rays in the table are derived from those given in several sources [2, 3, 4, and 5]. The peak is present in the spectrum if a measured parameter of the peak is above a threshold. The peak parameter used is the peak quality factor (Q) and is defined as the net peak area divided by the uncertainty in the net peak value [6]. The Q value depends on the peak signal and the background under the peak. The threshold is based on the desired false positive rate and false negative rate [7]. There is a threshold specified for each gamma ray in the analysis table. The identification is based on the full energy gamma ray signal and not on gross counting.

The background is determined dynamically from the same spectrum as the gamma ray net peak area is determined, so there is no stored background or background history used in the analysis. This avoids the problem of background suppression by high density shipments and variations in the background by natural causes, such as the weather.

Multiple detectors can be used to improve the detection ability by calculating the gross and net area for each peak in each detector spectrum and combining these gross and net values into a composite Q value. Combining detector responses in this manner and not by summing spectra avoids the problem of differing energy responses and differing peak widths (resolution) of the different detectors. This gives the Q for the portal of up to 8 times the efficiency of a single IDM.

In addition, different groupings of detector responses can be combined and the grouping with the best signal-to-noise ratio is used for the identification.

Figure 4 (test data) shows the individual net count responses from 8 IDMs for the situation of 88 μCi ^{133}Ba with NORM and shielded by 2.5 cm of steel as a function of time. Also shown is the aggregate or sum of the responses and the time of the end of the occupancy. There are 4 occupancies shown over the total time of 9 minutes. The source signal is clearly visible in the sum, but not in any one detector signal.

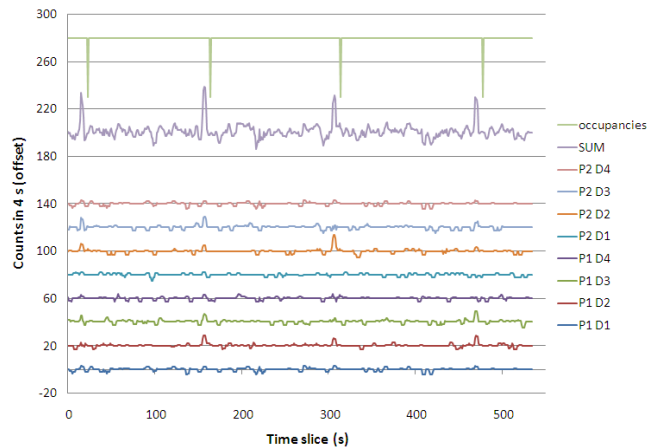


Figure 4 Contributions from Individual IDMs and the Composite Signal for ^{133}Ba (88 μCi) with 2.5 cm Steel Shielding

ANTHONY POE CONCEPT OF OPERATIONS (CONOPS)

Previous POE operational experience had shown that manual adjudication of primary RPM alarms by the use of the available hand-held RIIDs was impractical. Prior to the installation of the ORTEC Detective-ASP RPM, POE personnel relied on hand-held radioisotope identification devices (Canberra Inspector 1000s based on $\text{NaI}(\text{Tl})$ and LaBr_3) for alarm adjudication. This proved very time consuming requiring one or two additional port personnel to attend to the alarming vehicle, start up the hand held RIID, locate the radioactive material, count long enough to obtain a usable spectrum, conduct a CVSA² safety inspection and manually enter the alarm data into a report.

Because of minimal staffing levels and safety considerations (especially during the evening hours of operation), very few primary RPM alarms were adjudicated in this manner and were primarily limited to neutron alarms. Another consideration that prevented POE personnel from adjudicating these alarms was the unreasonable length of time of vehicle detention required to locate, identify, and document the alarming material using a handheld RIID, in addition to the number of personnel required to safely conduct the secondary evaluation and inspection.

When the ORTEC Detective HPGe ASP RPM went into operation, POE personnel attempted to run as many vehicles that alarmed the primary PVT RPM through the secondary HPGe RPM as possible using the following CONOPS:

Upon alarming the primary PVT RPM, POE personnel direct the vehicle into the secondary HPGe RPM where a stand-in count is performed for 300 seconds at the point of highest activity as determined by the primary PRM. The secondary HPGe RPM automatically stops counting after 300 seconds and alerts the operator whether or not threat material is present, in addition to identifying the radionuclide(s) detected and the confidence level of identification. The operator at this point may either direct the vehicle to one of the inspection bays for further inspection, or release the driver to continue on his way. The time

² CVSA: Commercial Vehicle Safety Alliance

taken for secondary screening is minimal and does not impede commerce. The only action required by the operator is to direct the vehicle into the secondary HPGe RPM, manually start the counting and then either direct the driver to exit the POE or proceed to an inspection bay for further examination. Some local vehicles that routinely alarm the primary RPM on a daily basis, such as propane trucks, are routed through the secondary RPM in a drive-through mode to insure that no other masking radionuclide is present. When conducting a secondary evaluation of a primary gamma/neutron alarm, what previously took up to 30-45 minutes with several POE personnel may now be accomplished in 5 minutes with only one POE employee.

HPGe spectra, reports, and photographs are stored on the main computer in the operator booth in addition to being transmitted to a server at NMDPS headquarters in Santa Fe every night. These data are also sent every 30 days to Sandia National Laboratories, California for statistical analysis.

OPERATIONAL EXPERIENCE

Approximately 1700 vehicles per day pass through the Anthony primary PVT RPM.

During the 219 days following 01/01/2010, 266 primary RPM alarms occurred of which approximately 135 were sent through the secondary HPGe RPM. The others were excluded from secondary inspection based on profiling, for example known suppliers of tiles or ceramic ware.

There were zero unresolved events at the secondary HPGe RPM; that is, there were no cases of unknowns or failure to identify. It is estimated that the use of the secondary RPM saves at least 1 hour per detected event. The secondary system does not impede the primary traffic flow at all, and in fact would be capable of processing much higher traffic levels without impacting the overall traffic flow. A single secondary HPGe RPM could support MULTIPLE primary PVT RPMS without slowing traffic flows.

HPGe RPM RELIABILITY

The amount of HPGe RPM downtime has been minimal and recovery only required a simple rebooting of the RPMs computers. Some issues have been encountered relating to malfunctioning cameras. This ongoing problem is still being investigated. The primary PVT RPM has also been very reliable with minimal downtime.

ALARM EXAMPLES

1. A high gamma ray count alarm on the primary PVT RPM alarm from a passenger bus resulted in the bus being directed to the secondary HPGe RPM. After a 300 second stand-in count; uranium, radium and thorium were detected at high confidence levels. The inspector asked the bus driver for permission to enter the bus to locate the source of radiation. Since the inspector already had an idea where the radiological source was located from the counting profile provided by the primary PVT RPM, the inspector, using a RadEye PRD,

located a backpack that alarmed the PRD. The passenger who owned the backpack said that he had found the backpack in a trash dumpster in Arizona and contained some rocks, vials containing powder, and some type of liquid metal in them. After determining that the gamma ray activity from the backpack was safe, the passenger voluntarily exited the bus and the backpack was removed for further evaluation. After the bus exited the secondary RPM, the backpack was placed in the secondary RPM by itself and counted for another 300 seconds. Background and source spectra were transmitted to the DNDO JAC (Joint Analysis Center) for analysis. JAC instructed POE personnel to survey and take photographs of each item within the backpack after the owner gave permission to remove the contents of the backpack. The glass vials did not contain liquid metal and appeared to contain some type of mineral, possibly gold ore. The backpack also had two (2) rocks that gave off high gamma count-rates. JAC determined that the contents of the backpack were not threat material and that the two (2) rocks were high-activity uranium ore.

2. A vehicle displaying a “7 Radioactive” placard alarmed the primary RPM and was sent to the secondary HPGe RPM for analysis. After 300 seconds of stand-in counting, the maximum gamma count rate was measured at 17,219 cps and provided the following IDs: elevated uranium, U-238, U-235, U-natural, and depleted uranium. The shipping papers indicated that cargo contained radioactive material, type A package, fissile, 7, UN3327 (unirradiated uranium dioxide nuclear reactor fuel assemblies-physical form solid), U (enriched 20% or less).
3. Other gamma alarms adjudicated by the HPGe RPM include medical isotopes, such as thallium and iodine, detected in drivers who recently had medical procedures performed.

CONCLUSION

The ORTEC Detective-ASP HPGe secondary portal monitor installed at POE Anthony, New Mexico, USA has successfully completed nearly a year of operation. The system has exhibited a high degree of operational reliability.

The combination of a high efficiency PVT scintillator primary portal used in conjunction with a secondary high resolution HPGe portal have been shown to be an effective CONOPS: Traffic which does not cause an alarm at the primary portal passes on unimpeded, while that directed through the secondary system is quickly sent on its way after the radiation alarm is adjudicated. The combination is resistant to masking of one radiation source by another,

The information collected has been used to clear PVT alarms and in building the database of radioactivity by nuclide in commerce.

The use of the HPGe portal rather than manual searches dramatically reduces traffic delays and labor costs. A single HPGe secondary portal is capable of supporting several PVT primary portals

for the primary alarm rates encountered in this location. It is planned to expand these PRND efforts using similar technology at other New Mexico border ports.

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