Package and Large Object Profiling With a Gamma/Neutron Sensitive Detection System

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Introduction

This paper summarizes a series of experiments performed at Savannah River Site for the purpose of determining the ability of a parallel plate collimator to constrain a detectors field of view with the goal of identifying the location of sources inside packages. These experiments took place in several locations at SRS using different types of sources, detectors and geometries. Broadly, these included profiling a heat exchanger lay down pad, a control rod cask, a shielded compound containing sealand containers filled with discarded jumpers from the canyons on site and some lab tests.

The collimator used for the testing is a parallel plate type collimator. This collimator consists of a series of lead sheets sandwiched in layers of expanded polystyrene foam. The foam, containing mainly carbon and hydrogen and being of very low density, is almost transparent to gamma radiation and serves to support the lead sheets. The arrangement of the lead sheets as parallel plates allows for large attenuation of radiation in directions at an angle to the collimator axis since these photons will have to pass through one of more lead sheets, with larger angles being more heavily attenuated. This allows for a constrained field of view for very low system weight increase, a major advantage for field applications.

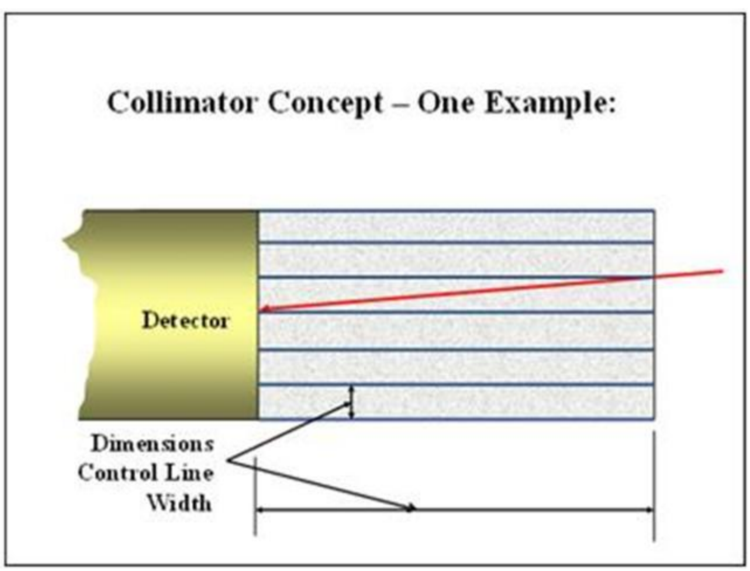

Figure 1 - Parallel Plate Collimator design

Control rod cask

Five production reactors were run on Savannah River site. Various components of these reactors are stored on site; some have been disposed of. Some of the control rods from the site reactors are stored in a large lead cask. The control rods still have a high level of activity from activation and contamination within the reactor vessels.

Figure 2 - Control Rod Cask (lower right)

A five inch sodium iodide detector and a Falcon 5000 high purity germanium detector were used with a parallel plate collimator to investigate any spatial variation of the gamma spectra across the cask. With a distributed source inside the cask, and the heavy shielding (4 inches of lead), very little spatial variation was seen in the spectra but the spectra did reveal an unexpected detail.

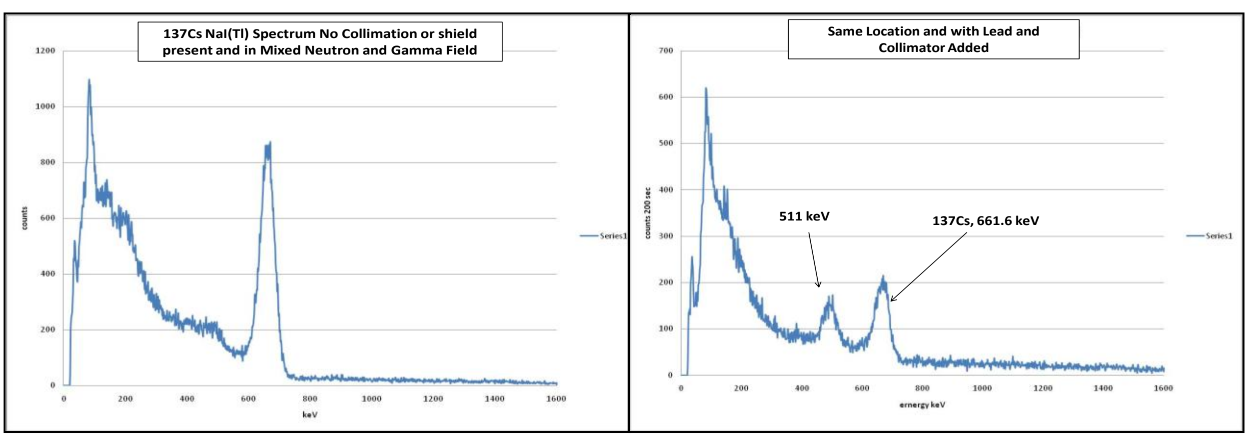

Figure 3 - Cask spectra with and without collimator

With and without the collimator and shielding, the Cs-137 peak was evident from the cask but when the collimator was added, a large increase in the 511 keV annihilation peak was observed. Further measurements were taken using the collimator and the Falcon 5000 to confirm the peak was at 511 keV. This effect was investigated further with modeling and some lab testing.

Heat Exchangers

Heat exchangers for the site reactors are stored together at SRS in a lay down area. The heat exchangers are large objects with considerable internal structure, much of which will have been contaminated from circulating coolant while the reactors ran.

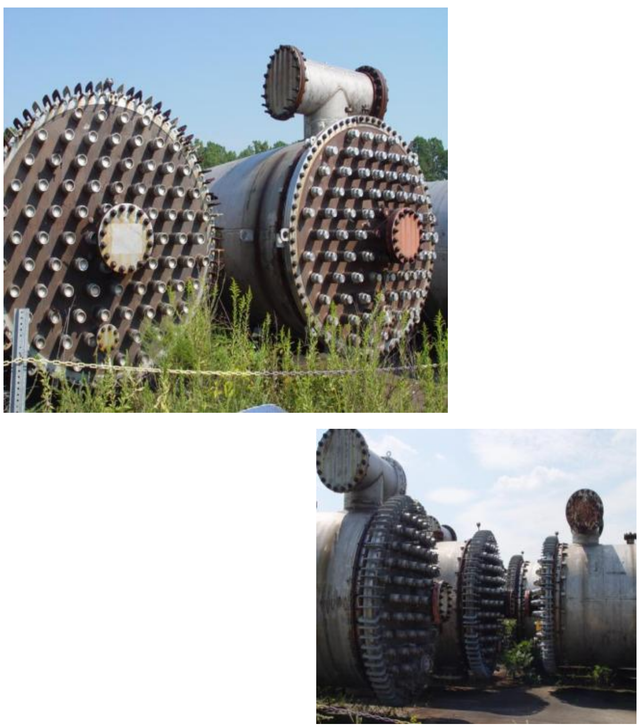

Figure 4 - Heat exchanger lay down

Given the size of the heat exchangers, their internal structure and they proximity to each other, this represented a good test of the parallel plate collimator's ability to distinguish these objects from one another in a significant radiation back ground. The following profile was obtained from a scan across the front of one of these heat exchangers surrounded by others on both sides. The peak counts are from 1173 keV Co-60 peak. These measurements were taken using the 5 inch sodium iodide detector with parallel plate collimator.

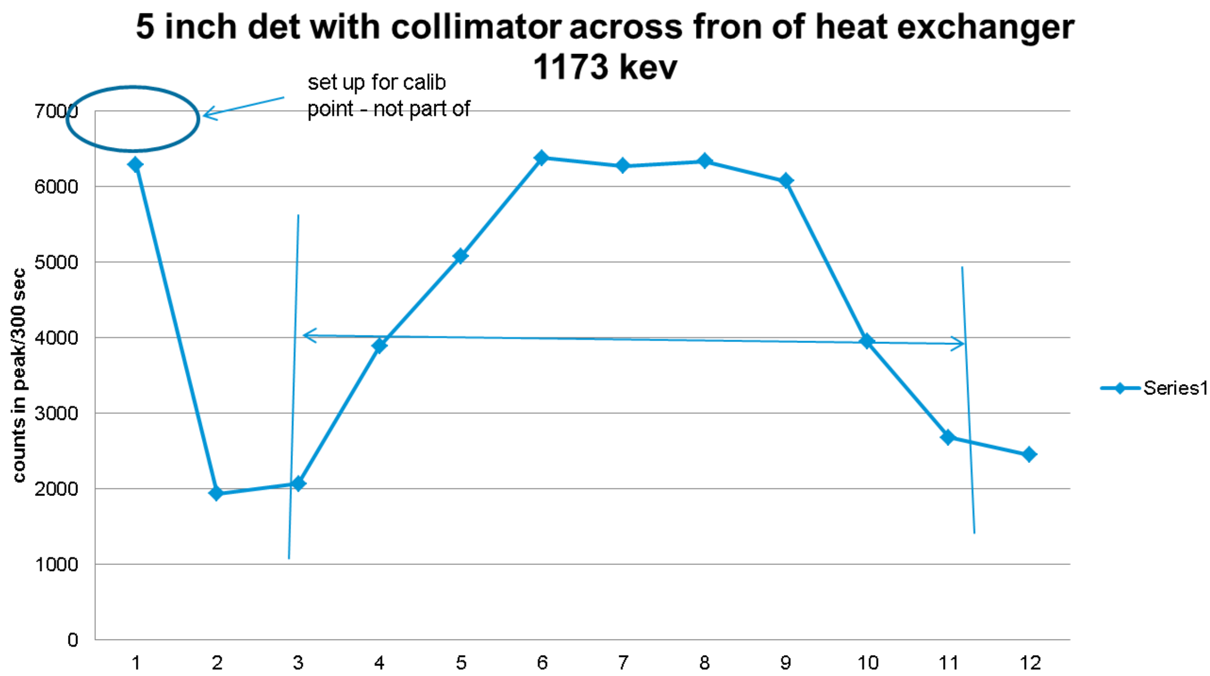

Figure 5 - Profile scan of heat exchanger

The point of the upper left part of the plot was a calibration spectrum taken away from the heat exchangers. The two vertical lines represent the edges of the heat exchanger as the detector is scanned across in increments (x-axis). Precise measurement of each incremental position change was difficult in the field; each step was approximately 18 inches.

The profile clearly distinguishes the heat exchanger from the background, and shows a fall off in count rate when the detector is aimed down the lane between heat exchangers. Given the distributed nature of these sources and the large amount of scatter present, this is a useful result.

Sealand Containers

A large shielded compound exists at SRS containing sealand containers. These containers have been filled with discarded jumpers from the reprocessing canyons on site. The jumpers are modular tank connectors and as such were heavily contaminated during reprocessing operations. Measurements taken during over flight of the compound suggest some of the sealands may have radiation fields as intense as 1R/hr at the top of the container.

Figure 6 - Shielded Sealand container compound

Measurements with two different purposes were taken at the compound. The first was an examination of the “skyshine” scatter above the compound. The five inch sodium iodide detector was set up on a rise overlooking the compound at a distance of approximately 70 feet. Lead bricks were used to shield the detector on all sides and the parallel plate collimator was placed on the front, facing the sealand containers. A separate measurement was then taken with the upper lead bricks removed in order to measure the scatter from the air above the containers which scattered down into the detector. The following spectra were obtained.

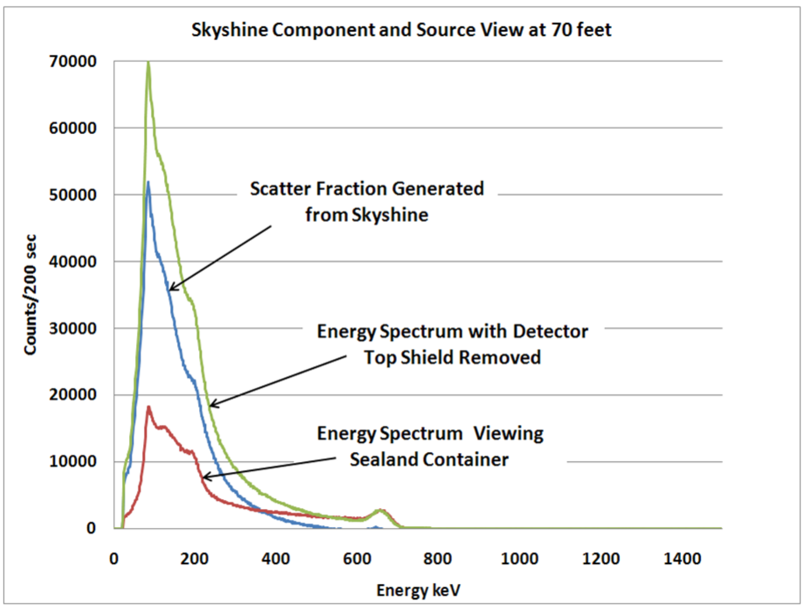

Figure 7 - Spectra of Sealand containers with and without upper shielding

The spectra clearly show a large increase in count rate at all energies when the detector is not shielded from above. This is an interesting result since it indicates that the "skyshine" from these containers actually represents a stronger source than a direct view of the containers themselves. This has application for situations where a direct line of sight to a source may not be possible, perhaps in homeland security applications.

The second measurement performed was a vertical scan of the compound wall with the collimated detector. The following profile was obtained.

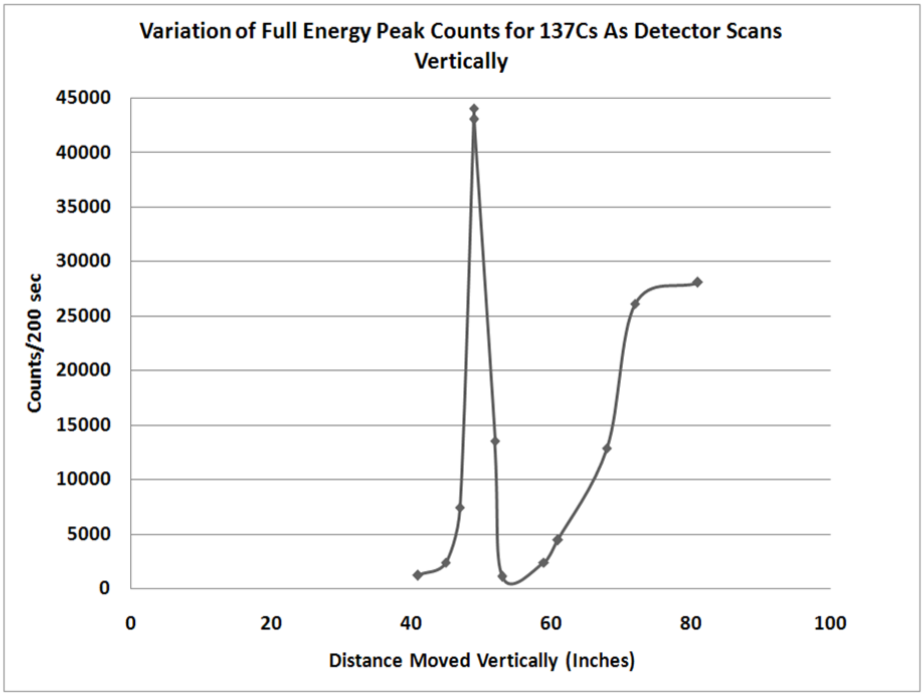

Figure 8 - Vertical scan of compound wall

The sudden peak near 50 inches is at the level of a small gap between the concrete blocks that make up the wall. Over 60 inches represents the detector pointing over the top of the wall.

Figure 9 - Compound wall

This test shows a large increase in signal when the detector pointed at the gap in the wall and a marked decrease a small distance above and below this. The parallel plate collimator in this case provides significant spatial resolution in this scenario.

Modeling and lab tests

In order to determine the origin of the increase in 511 keV gamma detection during the control rod cask measurement a simple model was constructed in MCNP. The fact that the 511 keV peak was so much larger with the collimator added to the detector than without suggested that some part of the detector was responsible for the production of these photons (since they would have been significantly attenuated if they originated further from the detector). The concrete culverts near the control rod cask contained TRU waste and a neutron flux had been noted as the gamma measurements were taken. The model examined the effect of each elemental component of the collimator in the presence of a neutron flux, lead, carbon and hydrogen. A block of material was modeled infront of (and in contact with) the detector while a Cf-252 source was 1 meter from the detector. The model was run with the material being each of the materials in the collimator in turn. The modeling showed that (n,γ) reactions in the lead were responsible for producing photons of sufficient energy to undergo pair production, the positron then annihilating and one of the 511 keV gammas produced being detected at the detector. While the (n,γ) cross section of lead is not large, it is sufficient to produce this effect and its high density and atomic number enhance pair production and annihilation such that the presence of neutrons is discernible from the gamma spectra under these conditions.

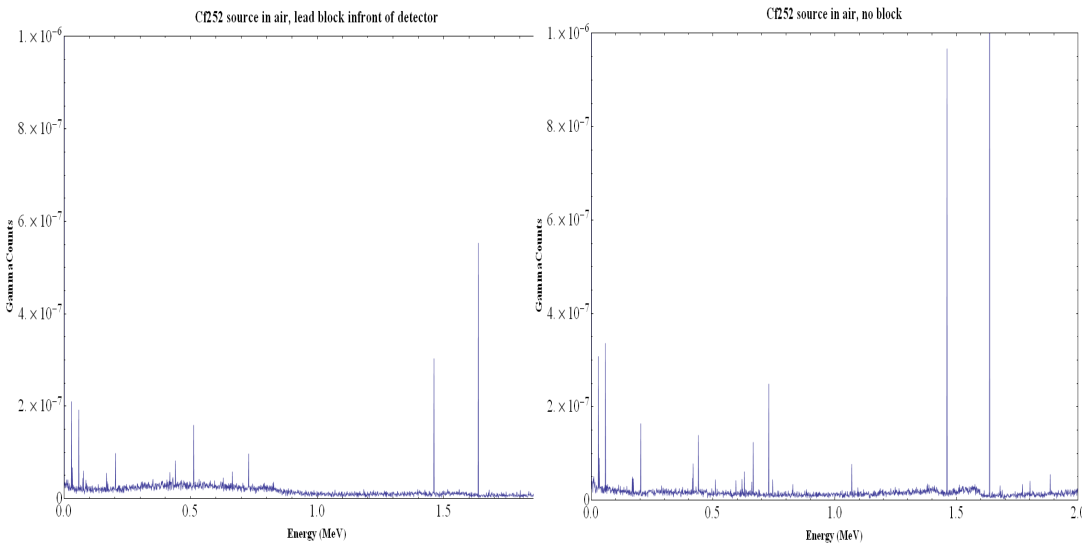

Figure 10 - Modeled spectra with lead between a Cf252 source and the detector and without lead

The increase in the 511 keV peak is evident in the above modeled spectra in the case where a small lead block shields the detector from the Cf-252 source.

A lab experiment was then performed to confirm the effect, replicating the model. A Cf-252 source was placed, in this case, 3 meters form the detector (Falcon 5000) and spectra were taken with no shielding, foam and lead between the detector. The enhancement in 511 keV detection was once again observed when the lead block was between the detector and the source.

Conclusion

These experiments allowed for some operational experience using the parallel plate collimator in a number of field applications. Spatial resolution useful for the location of sources in a number of situations was demonstrated and a potential method of detecting neutrons without a dedicated neutron counter was investigated.