

# Spectral Performance of Mercuric Iodide Gamma Ray Detectors at Elevated Temperatures

Lodewijk van den Berg\*, Alan E. Proctor, and Ken R. Pohl  
Constellation Technology Corporation, 7887 Bryan Dairy Road, Largo FL 33777

## ABSTRACT

The effects of elevated temperatures on the spectral performance of a planar mercuric iodide ( $\text{HgI}_2$ ) gamma ray detector were evaluated at 25°C, 35°C, 45°C and 55°C using two test isotopes,  $^{137}\text{Cs}$  at 662 keV and  $^{241}\text{Am}$  at 59 keV. Spectral analysis was used to determine the spectral parameters (i.e. %FWHM of the full energy peak, the peak channel position and the peak to background ratio). Spectral performance degraded slightly with increasing test temperatures, but recovered on returning to ambient conditions. The results demonstrate that temperature excursions up to 55°C minimally degrade the spectral performance of mercuric iodide detectors.

**Keywords:** gamma ray detector, mercuric iodide, elevated temperatures

## 1. INTRODUCTION

The development of mercuric iodide ( $\text{HgI}_2$ ) as a solid state radiation detector material is motivated by the need for compact spectrometer grade detectors, which operate at ambient temperatures. Among candidates for solid state detectors, mercuric iodide possesses the highest intrinsic resistivity with values ranging from  $10^{12}$  to  $10^{13}$  Ohm.cm. It can therefore sustain high bias voltages while still generating low leakage currents. In addition, the large atomic numbers of the constituent elements of mercuric iodide (mercury  $Z=80$  and iodine  $Z=53$ ) in conjunction with a high density of  $6.3 \text{ g/cm}^3$  result in a high efficiency for the absorption of higher energy radiation and a potentially high full-energy peak efficiency.

The synthesis and purification processes used in our laboratory result in high purity material from which large (500g) single crystals with high structural quality can be grown using a physical vapor transport method. This makes it possible to fabricate planar detectors with active areas of  $6.25 \text{ cm}^2$  and thicknesses up to 3mm or more. These detectors can have a spectral resolution of approximately 3% FWHM at a gamma ray energy of 662 keV, without using special electronics to improve the performance<sup>1</sup>.

This paper reports on the effects of elevated temperatures which can be expected to occur outside the laboratory, with emphasis on changes in the spectral performance and possible permanent effects of the temperature excursions on the detector.

## 2. EXPERIMENTAL ARRANGEMENTS

The experimental equipment consisted of a light-tight test box, which contained the detector and the preamplifier. Connectors in the wall of the box were used to provide power for the detector and the preamplifier and to conduct the detector output to a signal processing system. The test box was placed inside a temperature chamber which was able to control the temperature within  $\pm 2^\circ \text{C}$ . The other equipment was located close to but outside of the temperature chamber so that it remained at room temperature. Once a certain temperature was established in the chamber, a residence period of at least twenty minutes was maintained to make sure that the sample had equilibrated at the chamber temperature before a new measurement was made. Because of the location of the preamplifier in the test box, the relative contributions of the detector versus the preamplifier electronics to the temperature dependent variation in spectral

performance can not be differentiated. Significant electronic noise was generated as temperatures increased, which limited the experiment range to 55° C.

The detector used for these experiments was selected from inventory and had a spectral resolution at room temperature of approximately 6% FWHM at the energy of 662 keV. The thickness of the detector was approximately 2.5 mm. The performance of this detector was measured at 25°C, 35°C, 45°C, and 55°C and again at 25°C.

Two radiation sources were used, <sup>137</sup>Cs with an energy of 662 keV and <sup>241</sup>Am at 59 keV. Since the spectra showed a major anomaly on the high-energy side which made ‘traditional’ peak shape analysis virtually impossible, the reported FWHM was constructed by doubling the measured width of the low-energy side of the peak at half the maximum of its height. This technique has been used before by others to report data from spectra with anomalies on the low-energy side of the peak.

The spectral performance parameters generated were:

1. The percent full width at half of the full-energy peak maximum (%FWHM) which is an indication of the spectral resolution capability of the detector
2. The peak to background ratio (P/BG) which is the ratio of the number of counts at the maximum of the photopeak divided by the number of counts for the background at the same channel as the maximum. The peak to background ratio is an indicator of the detector signal to noise ratio.
3. The photopeak channel position indicates the gain stability of the detector system when the operating temperature is changed.

### 3. RESULTS

#### 3.1 Tabulation of the data.

A summary of the performance parameters obtained with the two sources at different temperatures is shown in Table I for the <sup>241</sup>Am spectra and in table II for the <sup>137</sup>Cs spectra.

<i>Temperature, °C</i>	<i>Spectrum Peak Channel</i>	<i>FWHM</i>		<i>Peak to background ratio</i>	<i>Pulser peak channel</i>
		<i>Channels</i>	<i>%</i>		
25	123	11.4	9.3	3.64	375.4
25	123	11.8	9.6	3.68	375.8
35	122	13.6	11.2	4.13	376.3
45	123	25.6	20.8	3.91	376.6
55	126	32.7	26.0	2.02	378.9
25	124	13.0	10.5	4.08	376.2

Table I: <sup>241</sup>Am results

Table II: HgI <sub>2</sub> Detector Results at 661.6 keV					
Temperature, °C	Spectrum Peak Channel	FWHM		Peak to background ratio	Pulser peak channel
		Channels	%		
25	1434	49.0	3.42	4.13	1896.7
35	1428	64.0	4.48	3.68	1883.1
45	1403.5	67.0	4.77	3.01	1862.4
55	1388	96.0	6.92	2.79	1856.7
25	1434	44.6	3.11	3.17	1897.5

Table II: <sup>137</sup>Cs results

During the measurements of the Cesium spectra, the pulser position tended to drift some, which is reflected in the spectral peak positions.

### 3.2 <sup>241</sup>Am spectra

The spectra of Americium at different temperatures are displayed in Figure 1. In order to maintain the clarity of the figure, the individual spectra have been offset on the vertical scale by 1000 counts so that they would not fall on top of each other.

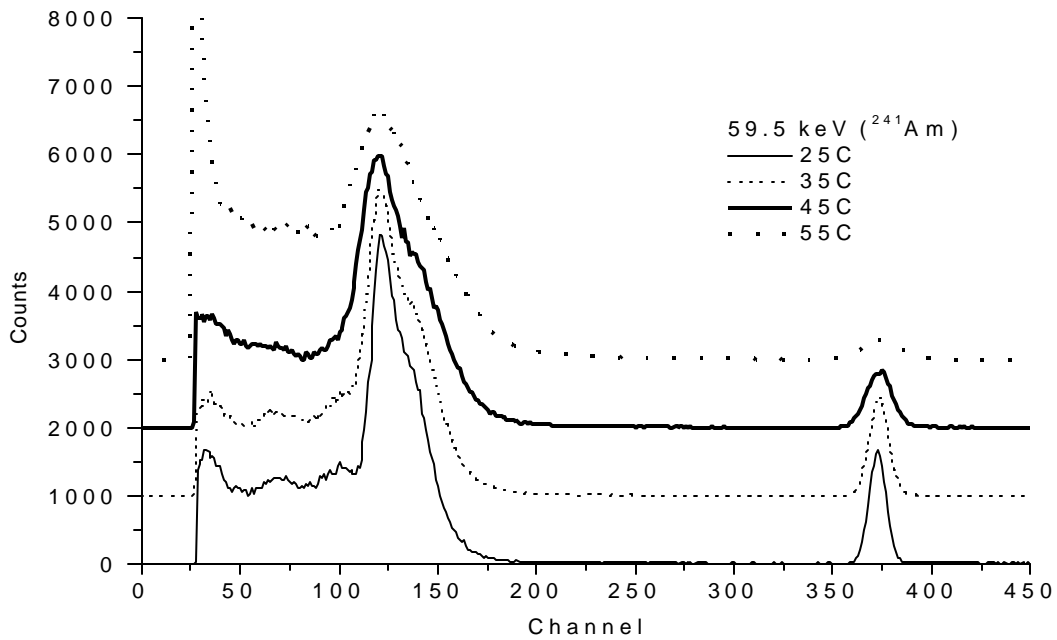


Fig. 1: Spectra of <sup>241</sup>Am at different temperatures

### 3.3 $^{137}\text{Cs}$ spectra

The spectra of Cesium at different temperatures are displayed in Figure 2. Again, the individual spectra have been offset on the vertical scale by 300 counts. In addition, the spectra have been shifted so that the positions of the pulsar peaks are aligned to compensate for drift.

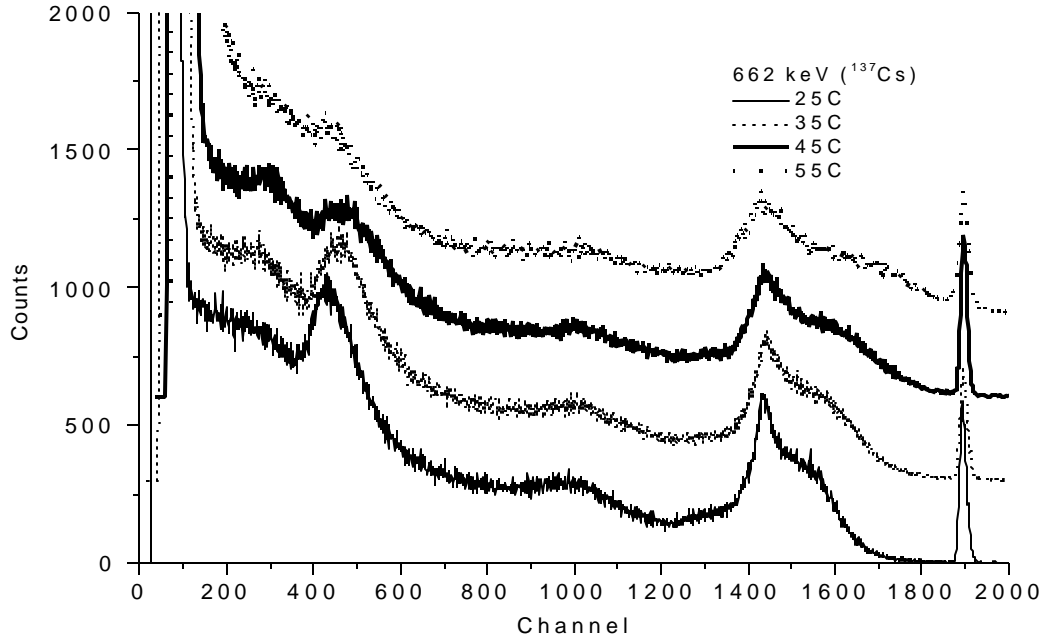


Fig .2: Spectra of  $^{137}\text{Cs}$  at different temperatures.

### 3.4 Change of the FWHM with temperature.

The calculated resolution of the spectra is shown in Figure 3. One can see that the value of the %FWHM increases with temperature, especially for the Americium data. This is due to changes in the electronic noise in the detector/preamplifier system, as can be seen in the increasing width of the pulsar peak with temperature. The effect is more pronounced for the Americium spectra since the noise has a more predominant effect on the total resolution expressed in %FWHM.

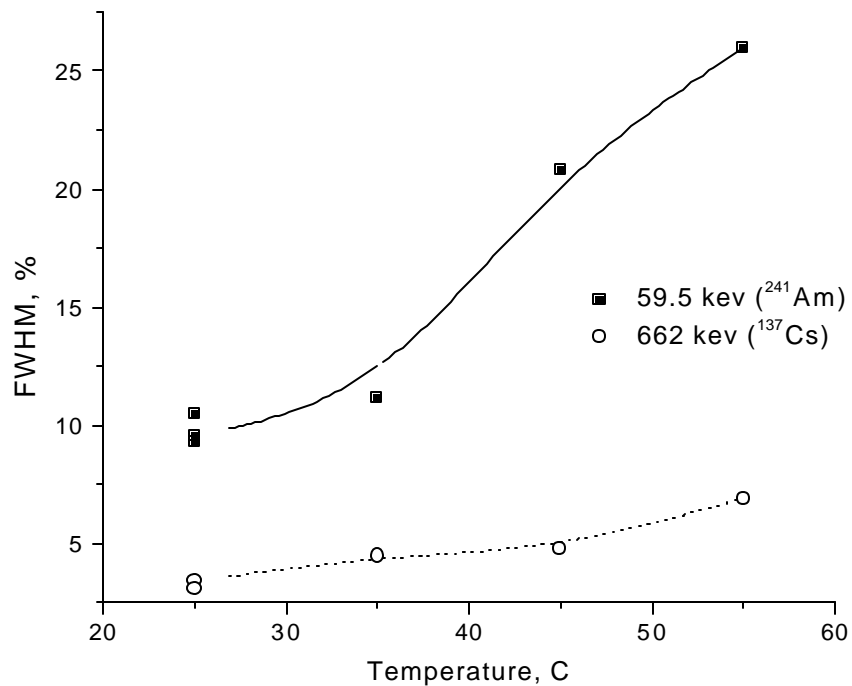


Fig. 3: Change of the %FWHM with temperature

#### 4. DISCUSSION

Several significant observations can be made on the basis of the results of these experiments. First of all, it is clear that the spectral position of the full energy peaks varies only slightly with temperature for both energies. The variation in the peak positions, corrected for the shift in pulsar channels, is less than 1% as can be seen in Figures 1 and 2. This is important for the use of mercuric iodide detectors for isotope identification at elevated temperatures. In addition, because of this, the linearity of the detector response with photon energy is maintained.

The spectral resolution of the detectors decreases with increasing temperatures, as is shown in Figure 3. This effect, when expressed in %FWHM, is especially noticeable with the results of the <sup>241</sup>Am measurements. We suggest that this effect is not only due to decreased charge transport properties in the detector material at higher temperatures, but also to a large extent to increased electronic noise. Since in practical situations the whole detector/preamplifier system will be subjected to environmental temperature changes, it becomes critical for the design of these systems to select electronic components or circuitry whose performance is less temperature dependent, or to provide cooling capability within the system.

The peak-to-background ratio used in the calculation of the spectral parameters is used as an indication of the noise level. It does not show a clear correlation with temperature changes.

When the detectors are returned to room temperature after the temperature excursions, they also return to their original performance. This confirms earlier observations that mercuric iodide detectors are not permanently damaged by temperature excursions up to 55°C.

## 5. SUMMARY

The peak channel position and its linearity with isotopic energy varied minimally with increasing temperatures. The spectral resolution degraded at the elevated temperatures, but recovered on returning to ambient temperature conditions. It is suggested that the majority of the degradation in spectral resolution with increasing temperature is due to increased electronic noise and not to degradation of the detector material. Experiments are planned in which only the detector will be heated in order to separate these effects.

## 6. REFERENCES

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[\\*lvdberg@contech.com](mailto:lvdberg@contech.com); phone 1 727 547 0600; fax 1 727 545 6150.