

## THE N-16 GAMMA RADIATION RESPONSE OF GEIGER-MUELLER TUBES

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**ABSTRACT** - This paper describes an evaluation of various Geiger-Mueller (GM) tubes for N-16 gamma radiation response. The work is an extension of investigations regarding the various radiation response characteristics of these devices. Previously acquired photon energy response data were from 10 keV to 1.25 MeV. Utilizing the 6 MeV gamma ray of N-16, the pair production interaction response with different GM tube styles was studied. The new relative response ratios of N-16 to Cs-137 are presented with a discussion of results. Additionally, two full energy response curves are presented.

### INTRODUCTION AND METHODS

Recently, evaluations for radiation response characteristics of GM tubes with respect to beta energy, dose rate, photon polar and photon energy response have been performed in conjunction with the NRPB in the UK (Allard 1987). That work investigated photon energy response from 10 keV to 1.25 MeV. The dominant interactions in this energy range are photoelectric and Compton scattering. An investigation presented herein extended the photon energy testing into the 6 MeV range using an N-16 source. At this energy the pair production interaction will become more apparent with respect to detector response. Various styles of "pancake", mica end window, thin wall, thick wall and energy compensated GM tubes were included in this study. The mechanical aspects of the various styles are noted in Table 1 and TGM Detectors' product specifications. In this evaluation a portable high voltage supply/digital scaler was set up adjacent to the N-16 source at the University of Lowell's research reactor facility. This source has been fully characterized for the specific purpose of measuring response of portable radiation protection instruments (Neault, 1980). It should be noted that a 1.5 inch thick iron plate was placed in front of the source to attenuate the high energy beta component and provided secondary electron buildup. This arrangement also furnished an exposure scenario that is similar to what is encountered in a nuclear power plant. The various GM tubes were irradiated with the N-16 source at known exposure rates, and observed counts and times recorded. Efforts were made to obtain at least 10,000 counts for statistics. Similarly, the same detectors were irradiated with a calibrated Cs-137 source. The background was measured in each area and corrections applied. Collected data were then used to determine a count rate per unit exposure rate value. A response ratio of N-16 to Cs-137 was then calculated in order to fold this information into the previously acquired photon energy response measurements made at NRPB.

## RESULTS AND DISCUSSION

Table 1 is a summary of the N-16 to Cs-137 response ratios. As noted, the relative response ratio varied from nearly unity to about two. Considering the interactions and number of secondary charged particles produced, this would be expected. If one were to plot of photon fluence versus photon energy, a peak would be observed below 200 KeV. This is mentioned in that GM tubes are basically photon counters, and will more or less exhibit the same generally shaped curve. However, differences in GM tube construction does cause notable discrepancies at high photon energies and variable peak spread at low photon energies. Figures 1 and 2 are energy response curves for a bare and energy compensated version of a GM tube. The data presented are a combination of the NRPB and this study's results (i.e. N-16 data point).

GM tubes will respond to any charged particle that enters their sensitive volume. A discharge may be produced by charged particles directly entering the tube through a mica window or thin cathode wall. Alternately a discharge may result from secondary electrons; thus, the construction of any given GM tube will greatly influence an energy response curve by the complex contribution of primary photon transmission/ attenuation and secondary particle production/attenuation at various depths in the GM tube window, wall or outer energy compensation filter. Again, the data shown in Figures 1 and 2 are the relative response values for the GM tube on an exposure rate basis. Because Cs-137 is a very common calibration source, by convention 662 keV is used as the normalization point. This allows comparison of tubes that may have quite different gamma ray sensitivities due to overall size.

As can be noted in Figure 1, the "thin wall" style GM tube with an 80 mg/sq. cm window provides excellent transmission for low energy photons below 100 keV. However, relative to Cs-137 it does over-respond by nearly a factor of 13 at 70 keV. This results from the high photon fluence being transmitted through the cathode wall, a high interaction probability, and the subsequent discharge events being counted. In the intermediate energies the response is relatively flat, but does begin to increase slightly above 1 MeV. The latter is due to the increase in number of secondary charged particles from pair production. Over-response below about 200 keV may be reduced by adding a thin layer filter of high atomic number metal over the tube with an appropriate open area. This effectively attenuates a portion of the low energy photon fluence. With proper engineering, one can easily obtain a +/-20% response from 50 keV to 1.25 MeV using a "thin wall" GM tube and energy compensation filter. However, as can be noted by comparing the response curves in Figures 1 and 2, the high atomic number filter actually causes an increased over-response in the 6 MeV range compared to the bare tube. This is no doubt due to energetic secondaries produced in the energy compensation filter, passing through the GM tube cathode wall and causing a discharge.

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# REFERENCES

Allard, D.J., Geiger-Mueller Tube Radiation Response Characteristics, Proceedings of the Health Physics Society's 21st Midyear Topical Meeting on Power Reactor Health Physics, Miami, FL, 1987.

Neault, P.J., The Dosimetry of Nitrogen-16, University of Lowell Masters Thesis, 1980.

**Table 1. Ratio of N-16 Gamma Response Relative to Cs-137**

GM Tube	Ratio	Comments
N1002/8767	1.88	Through mica window.
N1002/BNC	1.90	Through mica window.
N1003	1.96	Through mica window.
N201	1.71	Through 0.047" SS wall.
N205	1.90	Through 0.010" SS wall.
N210/BNC	1.58	Through 0.109" SS wall.
H220/7840	1.90	Through mica window.
N107	1.61	Through 30 mg/sq.cm SS wall.
N112	1.65	Through 30 mg/sq.cm SS wall.
N114	1.73	Through 30 mg/sq.cm SS wall.
N115-1	1.09	Through 80 mg/sq.cm SS wall.
N115-1S1	1.42	Through 80 mg/sq.cm SS wall with high Z filter.
N116-1	1.24	Through 80 mg/sq.cm SS wall.
N116-1SE	1.63	Through 80 mg/sq.cm SS wall with high Z filter.
N117-1	1.74	Through 30 mg/sq.cm SS wall.
N117-1S	1.73	Through 30 mg/sq.cm SS wall with high Z filter.
N118-1	1.03	Through 120 mg/sq.cm SS wall.
N118-1S	1.49	Through 120 mg/sq.cm SS wall with high Z filter.
N302	1.76	Through 0.020" SS wall.
N305	1.82	Through 0.010" SS wall.
N305S	1.99	Through 0.010" SS wall with high Z filter.
NP315-6	1.52	Through 0.020" SS wall, platinum plated inside.
NP334-6	1.48	Through 0.012" SS wall, platinum plated inside.
NP358-6	1.69	Through 0.009" SS wall, platinum plated inside.

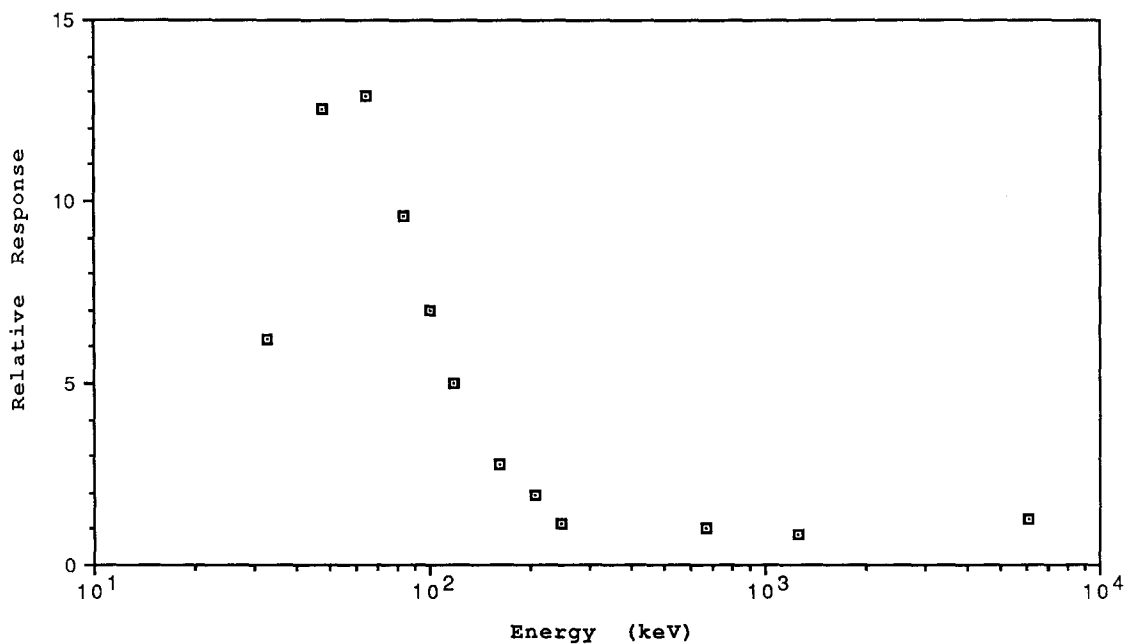


Fig. 1: Photon Energy Response of N116-1 miniature "thin wall" GM tube, normalized to unity at 662 kev with beam perpendicular to detector wall.

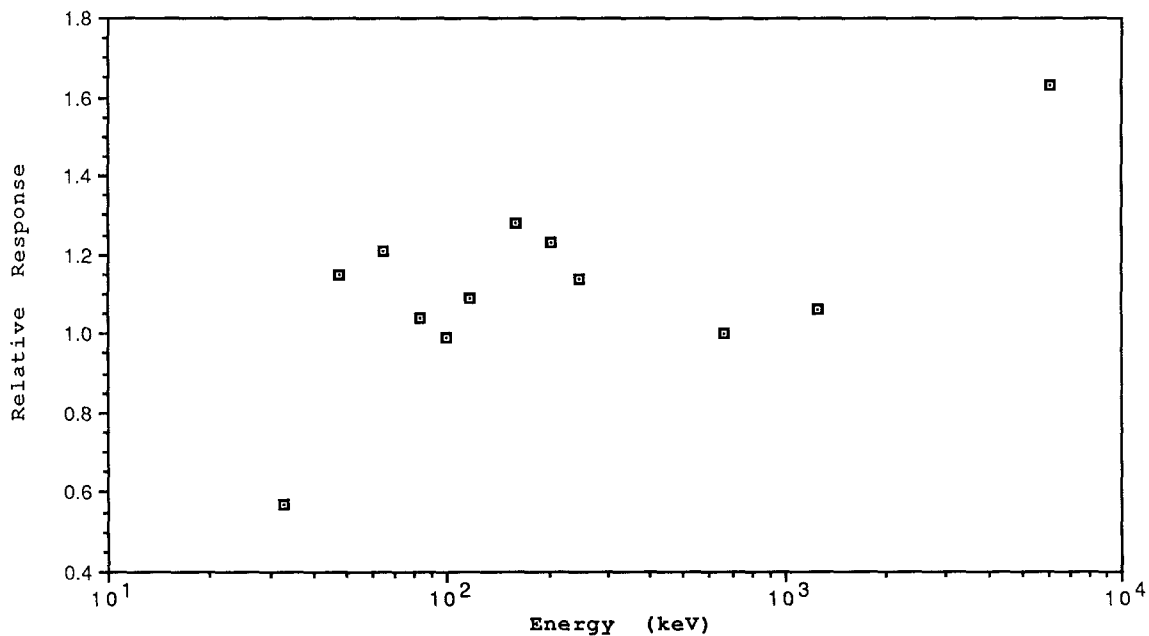


Fig. 2: Photon Energy Response of N116-1SE energy compensated miniature "thin wall" GM tube, normalized to unity at 662 keV, same geometry.