

Radiation Physics Note #75

Calibration of Gamma-Ray Sources Used in Instrument
Energy Response Tests

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The ability to test the response of health physics instrumentation to photon radiation of varying energy is recognized as a QA necessity. For this reason the Fermilab Safety Section acquired (7/87) two low energy gamma-ray sources (^{241}Am and ^{57}Co). These along with the ^{137}Cs and ^{60}Co sources in our possession, provide the capability of checking the energy response characteristics of selected instruments at four distinct points, from 60 Kev to 1.25 Mev (nominal), without the expense of a calibrated x-ray generator.

Calibration of the four sources used in the tests was required to obtain meaningful data. The ^{137}Cs and ^{60}Co sources used in the tests were calibrated for exposure rate against NBS certified sources of the same isotope, using an air equivalent ion chamber (STRAD) in an intercomparison study. Using this method for the ^{241}Am and ^{57}Co sources was not possible, as no exposure rate reference sources are available for these isotopes. Also NIST does not provide exposure rate calibration service for these isotopes. The nominal energy response curve is known for the STRAD (ref. 7), however, the response below 200 Kev was obtained using a filtered X-ray generator (ref. 5), producing a fairly broad spectrum compared to gamma-ray sources. Since the response of the STRAD changes rapidly in the 50-200 Kev region, and the response to a predominantly narrow spectrum is uncertain, it was decided to determine the exposure rate for the ^{241}Am and ^{57}Co sources by use of gamma ray exposure rate constants.

The activity of each source was determined by the Fermilab Safety Section Low-Level Counting Lab, and the gamma-ray constants (Γ) calculated. The exposure rate (R/hr) of the gamma-ray sources at 1 meter were determined by the product of the activity and the exposure rate constant, Γ . Photon emissions below 30 Kev were not used in determining the gamma ray constants since the source capsule

provides shielding (ref. 4). For comparison purposes, the exposure rates of the ^{137}Cs and ^{60}Co sources were also determined with this method, with results from both methods displayed in the summation table. The calculations follow:

From reference 1:

$$\Gamma = 19.38 \cdot \left[\sum_{i=1}^n K_i \cdot E_i \cdot \left(\frac{\mu_{en}}{\rho} \right)_{E_i, \text{air}} \right] \frac{\text{R}\cdot\text{m}^2}{\text{Ci}\cdot\text{hr}},$$

Where:

K = emission probability (from ref. 2),

E = photon energy in Mev (from ref. 2), and

$\left(\frac{\mu_{en}}{\rho} \right)_{E_i, \text{air}}$ = mass energy absorption coefficients for photon interactions in air (from references 1 and 3. Reference 1 uses reference 3 values. Interpolations are used from ref. 3 since it is more extensive).

Then, for photons above 30 Kev:

^{241}Am - 59.5 Kev:

$$\Gamma = 19.38 [(.0011 \times .033 \times .11) + (.359 \times .0595 \times .0306) + (.0018 \times .0692 \times .0264)]$$

$$\Gamma = 0.0128 \frac{\text{R}\cdot\text{m}^2}{\text{hr}\cdot\text{Ci}}$$

^{57}Co - 125 Kev (ave.):

$$\Gamma = 19.38 [(.8551 \times .1221 \times .0241) + (.106 \times .1365 \times .0245) + (.0016 \times .692 \times .0294) + (.0003 \times .536 \times .0296)]$$

$$\Gamma = 0.0564 \frac{\text{R}\cdot\text{m}^2}{\text{hr}\cdot\text{Ci}}$$

^{137}Cs - 662 Kev (for comparison purposes only):

$$\Gamma = 19.38 [(.0207 \times .0318 \times .122) + (.0382 \times .0322 \times .118) + (.0139 \times .0364 \times .0834) + (.8998 \times .6617 \times .0294)]$$

$$\Gamma = 0.344 \frac{\text{R}\cdot\text{m}^2}{\text{hr}\cdot\text{Ci}}$$

^{60}Co - 1250 Kev (ave.) (for comparison purposes only):

$$\Gamma = 19.38 [(1 \times 1.173 \times .0269) + (1 \times 1.33 \times .0262) + (.0002 \times .6938 \times .0294)]$$

$$\Gamma = 1.288 \frac{\text{R}\cdot\text{m}^2}{\text{hr}\cdot\text{Ci}}$$

The calibration results are summarized below:

Calibration Summation Table

Energy (Kev)	Isotope	Source No.	Cal Date ⁶ m/d/y	Activity (mCi)	Γ $\frac{R \cdot m^2}{Ci \cdot hr}$	DR @ 1 M (mR/hr)	Half- Life ² (yrs)	Dr @ 1 M 4/1/88	Comments
59.5	Am-241	241-4.2-1	4/22/88	25.6	0.0128	0.328	432.2	0.328	Calculated
125 ave	Co-57	57-3.5-1	4/22/88	2.033	0.0564	0.115	0.74	0.121	Calculated
662	Cs-137	137-3.1-1	2/9/72	1.2	0.344	0.413	30.17	0.285	Calculated
662	Cs-137	137-3.1-1	4/1/87	N/A	N/A	0.255	30.17	0.249	X-Cal
1250 av	Co-60	60-3.7-1	6/28/88	0.738	1.288	0.951	5.26	0.981	Calculated
1250 av	Co-60	60-3.7-1	7/1/88	N/A	N/A	1.058	5.26	1.093	X-Cal

References:

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5. ISO 4037 (1979). X and γ reference radiations for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy. International Organization for Standardization, Switzerland.
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