GERMANIUM DETECTOR EFFICIENCY VARIATIONS DUE TO CHANGES IN MATRIX DENSITY FOR STANDARD MARINELLI BEAKERS

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An experiment was undertaken to study the effect of variation of density of the matrix on the efficiency of germanium detectors for Marinelli beakers.

The basic material used for the preparation of the epoxy matrix was epichlorohydrin/amidoamine resins and alumina. These materials were mixed in proper proportions to yield the desired density.

The efficiencies for the following gamma rays were studied.

Gamma ray Energy (keV)	Radionuclide	Approx. Act. (μCi)	Approx. photon emission rate (g/s)
88	Cd-109	1.424	2060
122	Co-57	0.058	1820
159	Te-123m	0.073	2230
320	Cr-51	1.96	7100
392	Sn-113	0.27	6460
514	Sr-85	0.36	12900
662	Cs-137	0.25	7740
898	Y-88	0.59	20500
1173	Co-60	0.30	10900
1333	Co-60	0.30	10900
1836	Y-88	0.59	21700

These experiments were performed with 133N Marinelli beakers, which has overall height of 15.2 cm and diameter of 13 cm. The well diameter is 7.6 cm x 8.4 cm. The efficiencies for various gamma rays were measured with the beakers fitted on the detector.

The efficiencies of the detector in terms of net counts (in the full energy peak) per photon production rate is summrized below. The results are also presented in Figure 1.

Efficiencies of the Geranium detector(in %)

Densities in g/cc

Energy keV	0.04	0.5	0.8	1.0	1.5	2.0
88	2.9255	2.6377	2.4454	2.2717	2.0137	1.7996
122	2.6686	2.3446	2.1599	2.1255	1.8504	1.6496
159	2.1977	2.0410	1.8429	1.7511	1.6036	1.4187
320	1.1533	1.0453	0.9717	0.9278	0.8688	0.7787
392	0.8954	0.8216	0.7993	0.7547	0.6890	0.6247
514	0.6862	0.6282	0.5864	0.5872	0.5307	0.4937
662	0.5229	0.4756	0.4520	0.4458	0.4145	0.3880
898	0.3836	0.3634	0.3436	0.3340	0.3170	0.2893
1173	0.3004	0.2784	0.2769	0.2619	0.2498	0.2325
1333	0.2574	0.2404	0.2394	0.2306	0.2125	0.2041
1836	0.1940	0.1840	0.1778	0.1778	0.1661	0.1599

As expected from theoretical considerations, the efficiencies for the lower enegy photons are reduced more than the higher energy ones as the density of the matrix increases. However the variations are systematic both in terms of energies and densities. For example the efficiency for the 88 keV photon is reduced by a factor of 0.623, whereas the efficiency for the 1836 keV is reduced by a factor of 0.795 when the density is increased from 0.04 to 2.0 g/cm^3

These results can also be expressed in terms of relative efficiencies (where the efficiency for each gamma ray is taken as one for the 1.0 g/cc matrix) with the folloing values

Relative Efficiencies

Densities in g/cm^3

Energy keV	0.04	0.5	0.8	1.0	1.5	2.0
88	1.2826	1.1324	1.0530	1.0000	0.8828	0.7795
122	1.2679	1.1263	1.0502	1.0000	0.8880	0.7885
159	1.2538	1.1199	1.0482	1.0000	0.8930	0.7972
320	1.2160	1.1021	1.0411	1.0000	0.9070	0.8227
392	1.1996	1.0952	1.0382	1.0000	0.9129	0.8336
514	1.1789	1.0858	1.0343	1.0000	0.9209	0.8483
662	1.1637	1.0788	1.0315	1.0000	0.9270	0.8592
898	1.1487	1.0719	1.0287	1.0000	0.9331	0.8704
1173	1.1413	1.0686	1.0273	1.0000	0.9360	0.8761
1333	1.1319	1.0638	1.0258	1.0000	0.9402	0.8834
1836	1.1013	1.0492	1.0200	1.0000	0.9531	0.9085

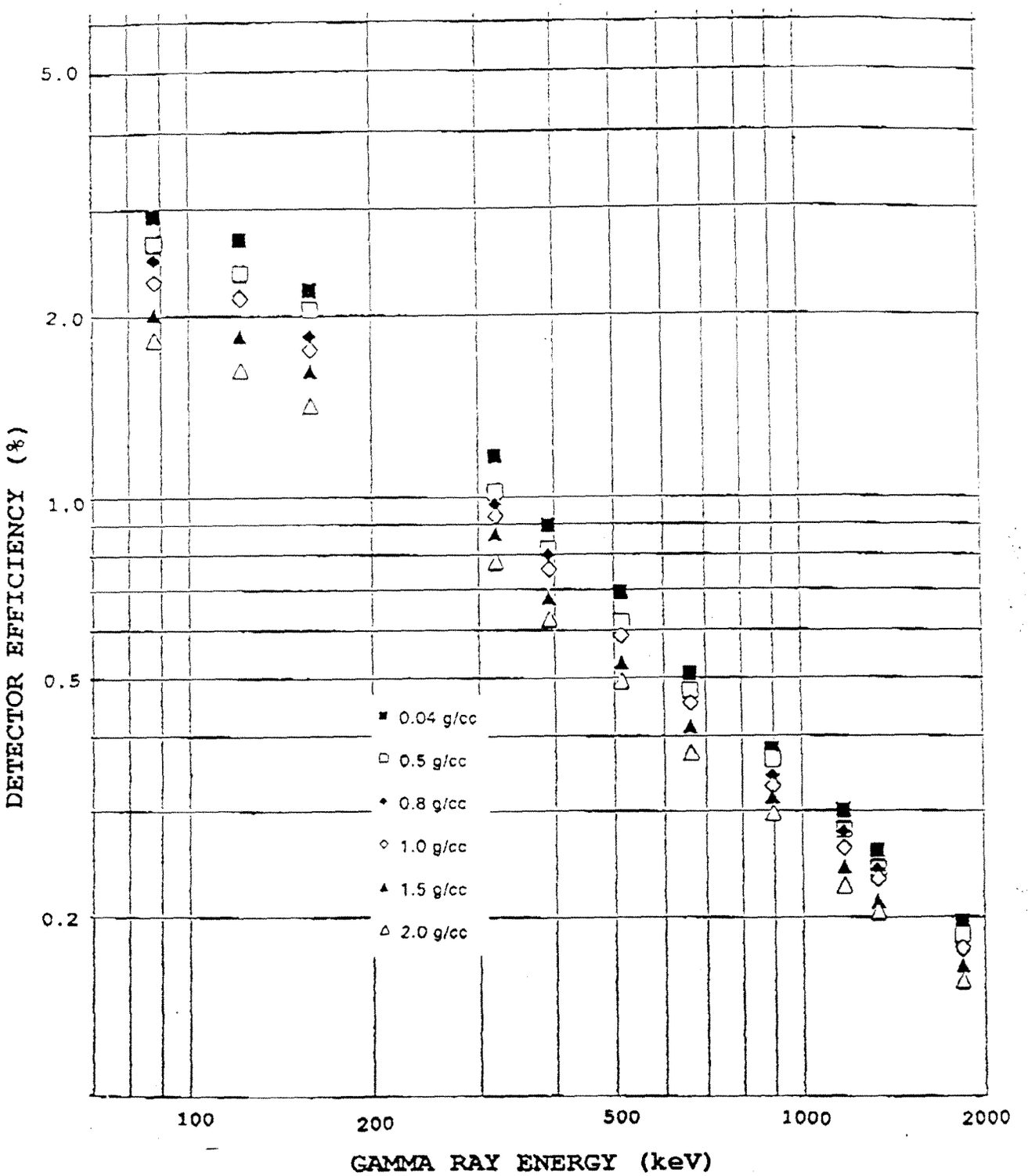

Figure 1. Ge Detector Efficiency Curves for 133N Marinelli Beakers with Vavious densities of Matrix

Using these values, the efficiencies for other density matrices can be calculated.

Care was taken to ensure the uniformity of the matrix and the reproducibility of the geometry of the counting system. The volume of material in the beaker was kept very close to 1000 mL. Experiments have shown that the efficiency decreases about 2% to 4% depending on the energy for an increase of a volume of 50 ml when the total volume is approximately 1000 ml.

These results are compared with theoretical expectations. The data for theoretical values are taken from "Photon Cross Section. Attenuation Coefficients From 10 keV to 100 GeV (NSRDS-NBS 29), 1969". The table provides the mass attenuation coefficients for various elements and compounds for selective energies. Using these values the coefficients are extracted for the energies used in this study. Then using these values the transmission factors through various materials are calculated. The results are presented below.

Transmission through 1g/cm² of material

Developed from "Photon Cross Section. Attenuation Coefficients From 10 keV to 100 GeV (NSRDS-NBS 29), 1969"

Using the equation

$$I = I_o e^{-\mu t}$$

where μ = mass attenuation coefficient in cm^2/g

t = thickness in g/cm^2

	H	C	N	O	Al
60	0.7219	0.8389	0.8336	0.8260	0.7551
88	0.7389	0.8545	0.8530	0.8499	0.8287
122	0.7557	0.8664	0.8660	0.8645	0.8597
159	0.7707	0.8759	0.8758	0.8750	0.8751
320	0.8137	0.9009	0.9010	0.9007	0.9032
392	0.8264	0.9081	0.9082	0.9079	0.9105
515	0.8431	0.9173	0.9175	0.9174	0.9199
662	0.8582	0.9257	0.9258	0.9257	0.9282
898	0.8755	0.9351	0.9352	0.9352	0.9375
1173	0.8898	0.9428	0.9429	0.9429	0.9449
1333	0.8964	0.9463	0.9464	0.9464	0.9482
1836	0.9121	0.9545	0.9545	0.9544	0.9559

Transmission through $1g/cm^2$ of material (contd)

	H_2O	Polyeth.	SiO_2
60	0.8137	0.8206	0.7768
88	0.8369	0.8366	0.8335
122	0.8515	0.8495	0.8585
159	0.8624	0.8600	0.8721
320	0.8905	0.8879	0.9000
392	0.8984	0.8959	0.9075
515	0.9087	0.9063	0.9172
662	0.9179	0.9156	0.9258
898	0.9284	0.9263	0.9353
1173	0.9369	0.9350	0.9430
1333	0.9407	0.9390	0.9464
1636	0.9496	0.9483	0.9543

Experiments has shown no significant difference between the efficiency value for a water sample and an epoxy sample having a density of 1.0 in agrrement with the theoretical expectation. From the experimental data the mean thickness of the Marinelli beaker appears to be approximately 1.8 cm