CALCULATED EFFICIENCIES OF CYLINDRICAL Ge(Li) DETECTORS

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ABSTRACT. Detection efficiencies of Ge(Li) detectors of cylindrical geometry for point sources placed on the axis of the detector were calculated for gamma ray energies ranging from 0.01-10.00 MeV on a CDC 3600 computer. Detectors of area of cross-section 2-10 sq. cm. and of various depletion depths were considered for source to crystal distances ranging from 1-25 cm.

Lithium drifted germanium detectors are widely used now-a-days in gamma-ray spectroscopy studies in view of their very high energy resolution. A knowledge of their detection efficiencies is necessary for quantitative measurements of gamma-ray intensities in nuclear reactions as well as in the study of decay of radioactive nuclei. Hotz *et al*, (1965) have calculated efficiencies of Ge(Li) detectors of rectangular cross-section. Black and Gruhle (1957) have calculated the efficiencies of Ge(Li) detectors of cylindrical cross-section over the gamma-ray energy range 0.1-3.0 MeV, for source to detector distances ranging from 1-10 cm, for a few detectors. We felt it desirable to extend these calculations for cylindrical detectors to cover both a wider gamma-ray energy range and larger source to detector distances, for a variety of detectors.

A gamma ray interacting in the germanium crystal gives an electrical pulse signal proportional to the energy it deposits in the depleted region of the detector. This signal forms the basis of the counting of gamma-rays. We define the efficiency of the detector as the ratio of the number of counts to the number of gamma-rays emitted by the source. The efficiency ϵ can then be expressed in terms of the absorption coefficient μ by the expression.

$$\epsilon = \frac{1}{4\pi} \int_{crystal} \{1-\exp(-\mu x)\} d\Omega \qquad .. \quad (1)$$

where x is the thickness of the detector as seen by the gamma-ray and Ω the solid angle subtended at the source by the detector.

Shown in fig. 1 is the geometrical arrangement of the source and detector. Let the source be situated at a height 'H' above the front face of the detector on the line passing through its axis, 'T' the thickness (or depletion depth) of the detector and 'R' the radius of the detector and $x(\theta)$ the thickness of the detector

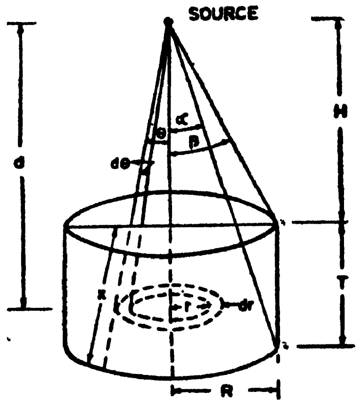

Fig. 1. Geometry of the cylindrical detector. The dotted straight line shows the path of a gamma ray in the detector.

as seen by a gamma-ray incident at an angle θ with respect to the axis of the detector.

$$\text{Then} \quad x(\theta) = T \sec \theta \quad \text{for} \quad 0 \leqslant \theta \leqslant \tan^{-1} \frac{R}{\mathrm{H+T}} = \alpha \qquad .. \quad (2)$$

$$\text{and} \quad x(\theta) = R \operatorname{cosec} \theta - \mathrm{H} \sec \theta \ \text{ for } \ \alpha \leqslant \theta \leqslant \tan^{-1} \frac{R}{H} = \beta \qquad .. \quad (3)$$

Consider an annular disc of radius γ and width dr in the volume of the detector. Let the distance from the source to the centre of the disc be denoted by d. Then the area of the annular disc $= 2\pi\gamma dr$.

where $\qquad \gamma = d. \tan \theta$

and $\qquad dr = d. \sec^2 \theta d\theta$

Solid angle subtended by this annular disc at the source is

$$d\Omega = \frac{2\pi r dr \cos \theta}{(d. \sec \theta)^2} = 2\pi \sin \theta d\theta \qquad .. \quad (4)$$

$$\text{Thus} \qquad \epsilon = \tfrac{1}{2} \int_0^\infty (1 - \exp\{-\mu x(\theta)\}] \sin \theta d\theta \qquad .. \quad (5)$$

or $$= \tfrac{1}{2}(I_1 - I_2 - I_3) \quad .. \ (6)$$

where $$I_1 = \int_0^{\beta} \sin\, \theta d\theta \quad .. \ (7)$$

$$I_2 = \int_0^{\alpha} \exp\{-\mu x(\theta)\} \sin\, \theta d\theta \quad .. \ (8)$$

$$I_3 = \int_0^{\beta} \exp\{-\mu x(\theta)\} \sin\, \theta d\theta \quad .. \ (9)$$

The integrals I_2 and I_3 in equation (8) and (9) were calculated by Gauss Quadrature method on CDC 3600 computer at this Institute. The absorption coefficients for gamma-ray energies from 10 keV to 10MeV were taken from those calculated by Storm *et al* (1958) for germanium. The total absorption coefficient μ was taken as the sum of the photoelectric absorption coefficient, pair production absorption coefficient plus the compton absorption and the compton incoherent scatter components. The linear absorption coefficients were obtained by multiplying the mass absorption coefficients by the density of germanium (Hotz, *et al,* 1965) at 77°K viz. 5.325 g/cm^3 since lithium drifted germanium detectors are most often used at liquid nitrogen temperature.

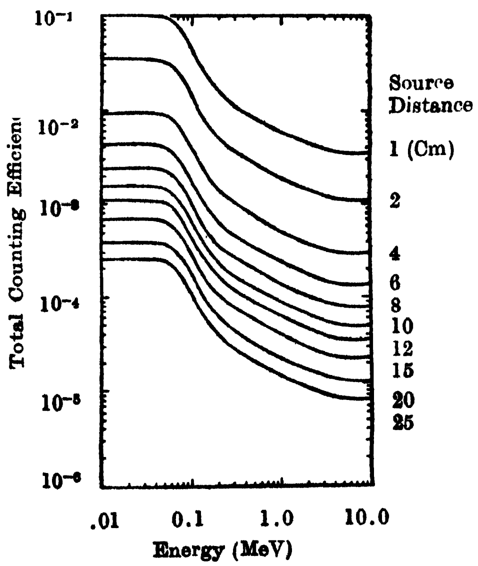

Fig. 2. Area 2 sq. cm. and depletion depth 2 mm.

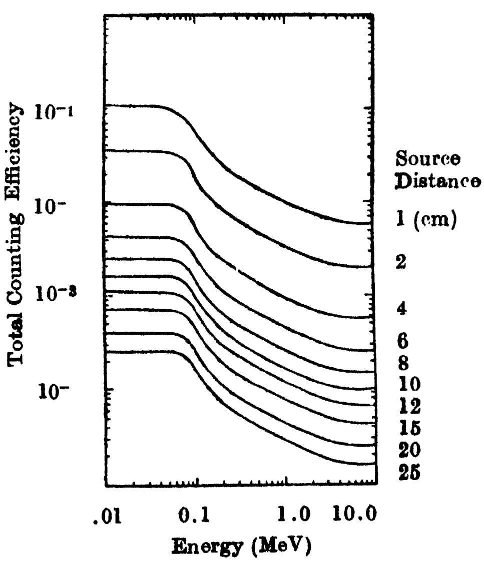

Fig. 3. Area 2 sq. cm. and depletion depth 4 mm

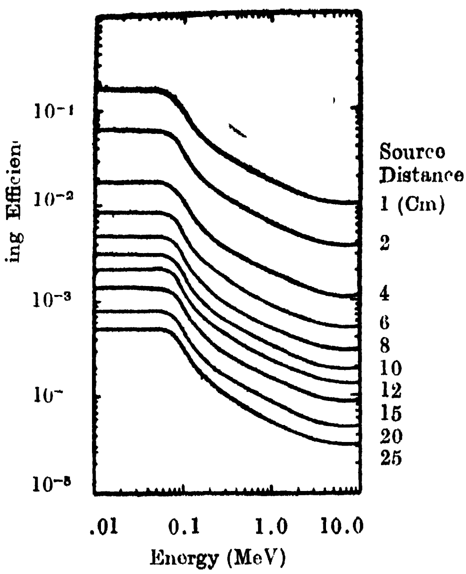

Fig. 4. Area 4 sq. cm. and depletion depth 4 mm.

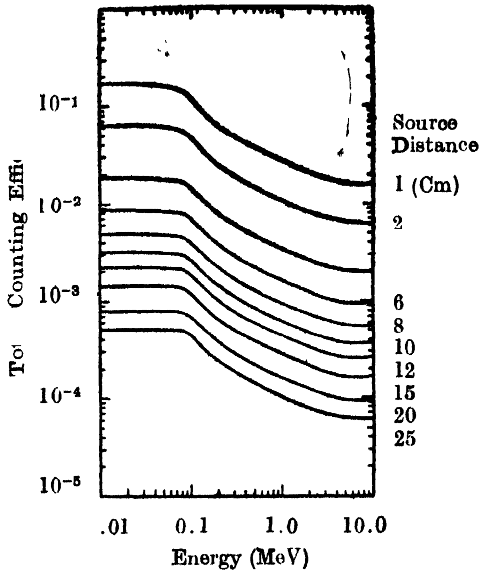

Fig. 5. Area 4 sq. cm. and depletion depth 8 mm.

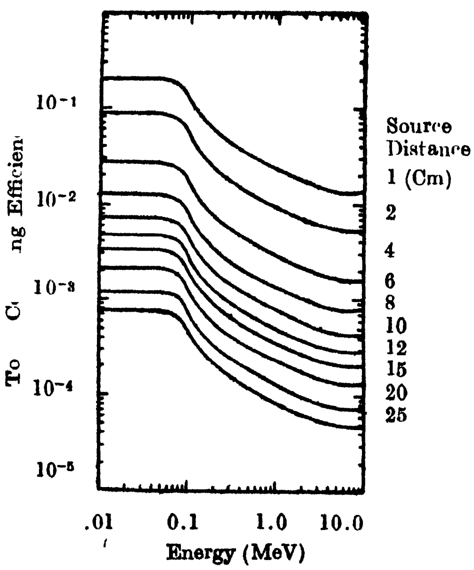

Fig. 6. Area 6 sq. cm. and depletion depth 4 mm.

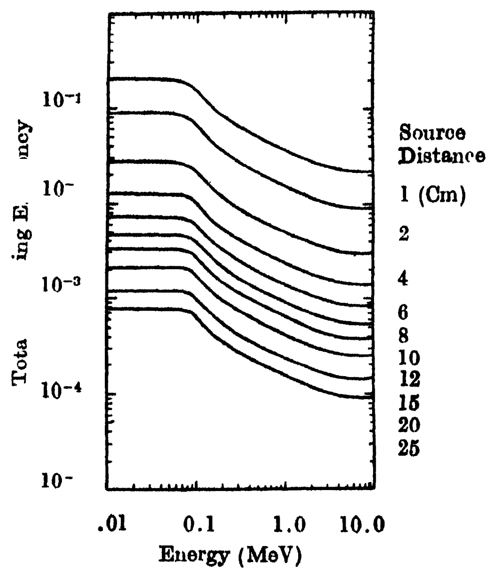

Fig. 7. Area 6 sq. cm. and depletion depth 8 mm.

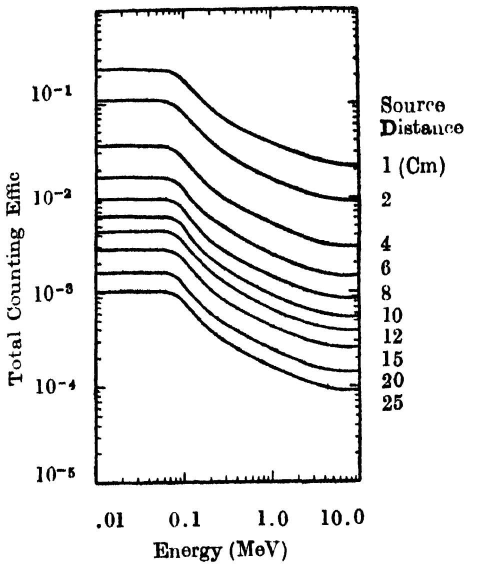

Fig. 8. Area 8 sq. cm. and depletion depth 6 mm.

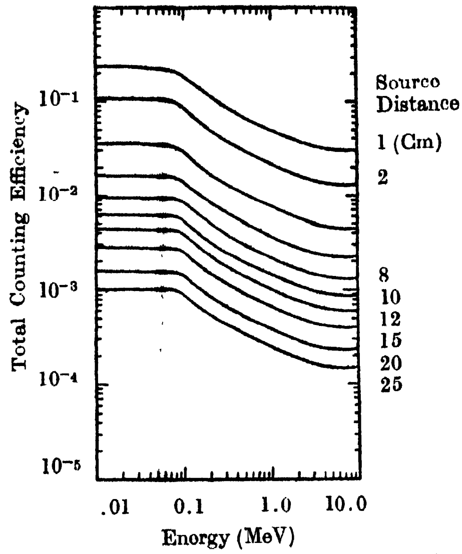

Fig. 9. Area 8 sq. cm. and depletion depth 10 mm.

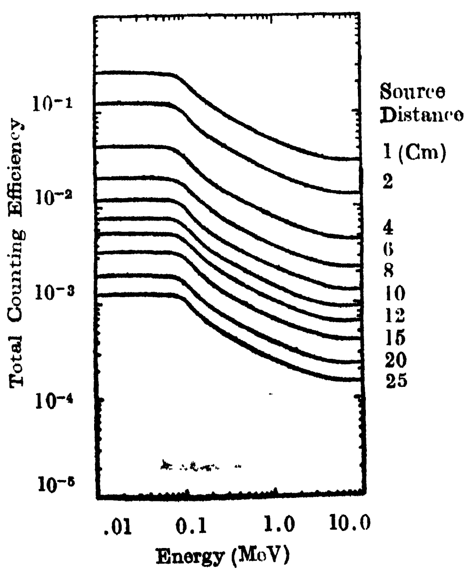

Fig. 10. Area 10 sq. cm. and depletion depth 8 mm.

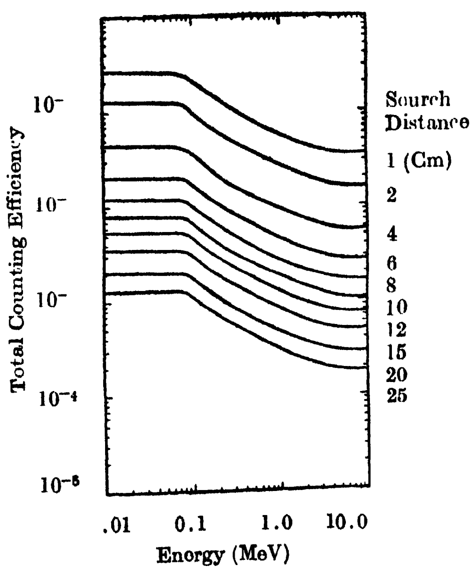

Fig. 11. Area 10 sq. cm. and depletion depth 10 mm.

Figs. 2-11 are graphs of the efficiencies (as defined earlier) for Ge(Li) detectors of different areas of cross-section and depletion depth as a function of the gamma-ray in the range 0.01-10.0 MeV for several source to detector distances ranging from 1-25 cm.

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REFERENCES

Black, J. L. and Gruhle, W., 1967, *Nucl. Instr. and Meth.* **46**, 213.

Hotz, H. P., Mathieson, L. M. and Hurley, J. P., 1965, *Nucl. Instr. and Meth.* **37**, 93.

Storm E., Gilbert E., and Israel, H , 1958, *Gama-ray absorption coefficients for elements* 1 *through* 100 *derived from the theoretical values of the National Bureau of Standards*, Los Alamos Sci. Lab. Ro. La-2237.