Gamma Ray Counting Efficiency of Geiger Mueller Counters

by Tatsusaburo SUZUKI, Kazumasa INOUE**, Noboru SUZUKI*** and Kazuo GOUDA*****

A method of calculation of the counting efficiency of GM counters for gamma radiation is investigated. The efficiency due to the cathode wall is calculated when the gamma photons pass through the cathode tube perpendicular to the inner surface. The computation is carried out by using the empirical transmission equation of the secondary electrons created in the solid wall. The calculated value is compared with the experimental results and gives a good agreement.

1. Introduction

The counting efficiency of GM counters for gamma radiation was measured in detail(1),(2),(3). The average local efficiency is shown in Fig. 1. In the Figure the efficiency curve has three maximum values [(1), (4) and (7)] and two minimum values [(3) and (5)]. For the measurement of the gamma radiation from a narrow opening, it is recommended that the detection should be performed in the region (3) or (5) in Fig. 1 where the radiation passes through approximately perpendicular to the cathode wall and the efficiency gives the minimum value, then the variation of the local efficiency across the diameter of the counter is very small.

2. Calculations

If gamma rays pass through the counter approximately perpendicular to the inner wall as shown in Fig. 2, the counting efficiency due to the cathode wall is represented as

$$\varepsilon = \sum_i \int_{x_1}^{x_2} \exp[-(\sum \sigma_i N_i)x]\eta_i(\varphi, x)\sigma_i N_i \, dx + \sum_i \int_{x_3}^{x_4} \exp[-(\sum \sigma_i N_i)x]\eta_i(\varphi, x)\sigma_i N_i \, dx. \quad (1)$$

Where σ_i and N_i is the cross section and the number of atoms in unit volume of each element composing the cathode wall, respectively. $\eta(\varphi, x)$ is the probability of the secondary electron created at the position x and emitted in the direction φ,

* 理工学部物理学科教授　放射線物理学
** 理工学部物理学科専任講師　放射線物理学
*** 理工学部物理学科助手　宇宙線
**** 理工学部物理学科助手　放射線分子物性

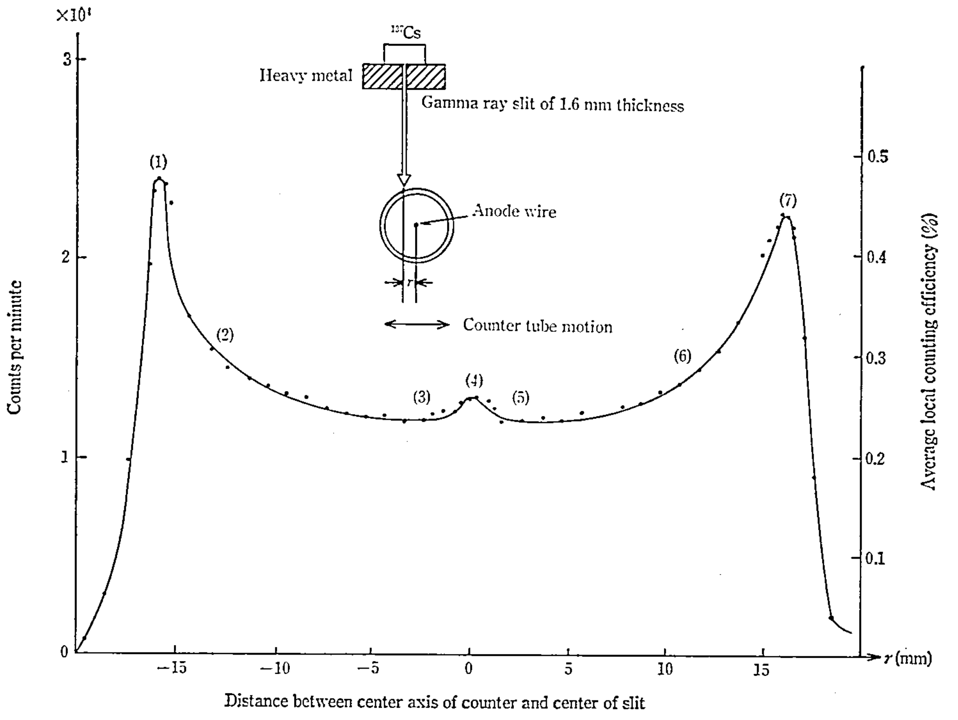

Fig. 1. Variation of the counting rate and average local efficiency across the diameter of Tracerlab TGC type counter (No. 23682) for gamma radiation of 0.662 MeV from a narrow slit at a distance of 195 mm. The solid circles indicate the values of measured counting rate, and the solid line is average local counting efficiency.

and reaches the sensitive volume of the counter gas. In this calculation, an assumption is given that the secondary electrons produced in the wall are ejected in the average direction

$$\langle\varphi\rangle=\frac{\int \varphi K(\varphi)\, 2\pi \sin\varphi \,\mathrm{d}\varphi}{\int K(\varphi)\, 2\pi \sin\varphi \,\mathrm{d}\varphi} \tag{2}$$

where, $K(\varphi)$ is the differential cross section for the number of the secondary electrons scattered in the direction φ[4].

The transmission probability of electrons normally incident on the absorber (thickness t) is obtained as

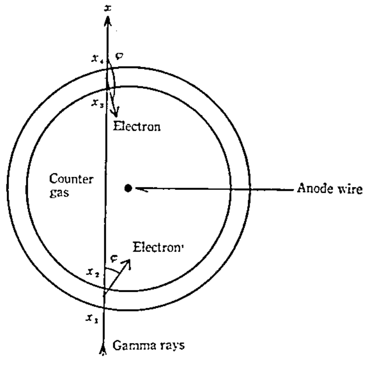

Fig. 2. Schematic diagram of the secondary electron created in the counter wall and scattered in the direction φ, when gamma rays pass through the counter wall approximately perpendicular to the inner surface of the cathode tube.

$$\eta(t)=\frac{1+\exp[-s_0]}{1+\exp\left[(s_0+2)\frac{t}{R_{ex}}-s_0\right]}, \tag{3}$$

for the energy region $T_0=8\,\text{keV}-30\,\text{MeV}$, and for the atomic number of the element of the absorber $Z=4-82$[5]. R_{ex} in Eq. (3) is the extrapolated electron range and is shown in Appendix. s_0 in Eq. (3) is the empirical constant for the given electron energy T_0 and the given atomic number of the element of the absorber and is written as

$$s_0=a_1\exp\left[-\frac{a_2}{1+a_3\left(\frac{T_0}{m_ec^2}\right)^{a_4}}\right]. \tag{4}$$

a_i ($i=1,2,3$ and 4) is given[5] as

$$a_1=10.63Z^{-0.232}, \tag{5}$$

$$a_2=0.220Z^{0.463}, \tag{6}$$

$$a_3=0.042, \tag{7}$$

$$a_4=1.86. \tag{8}$$

In the present calculations, the transmission probability $\eta(\varphi, x)$ in Eq. (1) is given from Eq. (3) by substituting t to $(x_2-x)\sec\langle\varphi\rangle$ [in the region $x_2>x>x_1$] or $(x-x_3)|\sec\langle\varphi\rangle|$ [in the region $x_4>x>x_3$] (see Fig. 2).

3. Results and Discussions

The GM counter used in this experiment is the Tracerlab TGC-2 type [No. 23682]. The counter is an organic gas quenched one and is filled with He gas of 720 torr pressure, and the cathode of the counter is a glass tube of 33 mm inside diameter and 2.5 mm thickness[6]. A Cs-137 source which emits homogeneous gamma rays ($h\nu=0.66165\,\text{MeV}$) was used. The radiation from the source was collimated by a

Table I. Calculated and measured efficiency [minimum value in the region (3) or (5) in Fig. 1.] for gamma radiation of 0.662 MeV energy for the GM counter with glass tube.

	Counting Efficiency (%)		
	Cathode Tube	Counter Gas	Total
Calculated	0.216	0.004	0.22
Experimental			0.24

heavy metal slit (1.6 mm wide and 10 mm long) and reaches the counter. The number of gamma photons from the slit in unit time is determined from the increase of counting rate by platinum anode wire[7] and obtained as 5.1×10^6 photons min^{-1}. The counting rate of the counter is measured at a distance of 195 mm from the slit and is shown in Fig. 1. The experimental value of the counting efficiency is obtained from the counting rate in the region (3) or (5) in Fig. 1 and the number of photons reaches the counter in unit time and is shown in Table I. The calculated efficiency due to the cathode wall is obtained from Eq. (1), and the efficiency due to the counter gas is obtained from the cross section of the interaction and the traveling distance of the gamma rays in the counter gas. The calculated values are shown in Table I. The total calculated counting efficiency gives a good agreement with the experimental one, and this method of calculation can be applied for the GM counter of glass cathode tube.

Appendix

The extrapolated electron range R_{ex} [in Eq. (3)] of a given electron energy $\tau_0 = T_0/m_ec^2$ in a given absorber [atomic number Z and atomic weight A] is given[5] as

$$R_{ex}=c_1\left[\frac{\ln(1+c_2\tau_0)}{c_2}-\frac{c_3\tau_0}{1+c_4\tau_0^{c_5}}\right], \quad (9)$$

where:

$$c_1=0.2335AZ^{-1.209}\ \text{g cm}^{-2}, \quad (10)$$

$$c_2=0.000178Z, \quad (11)$$

$$c_3=0.9891-0.000301Z, \quad (12)$$

$$c_4=1.468-0.01180Z, \quad (13)$$

$$c_5=1.232Z^{-0.109}. \quad (14)$$

References

(1) T. Suzuki, J. Nucl. Sci. Technol., **20**, 970 (1983).
(2) T. Suzuki, J. Nucl. Sci. Technol., **17**, 385 (1980).
(3) T. Suzuki and J. Yuhara, J. Phys. Soc. Japan, **16**, 152 (1961).
(4) C.M. Davisson and R.D. Evans, Rev. Mod. Phys., **24**, 79 (1952).
(5) T. Tabata and R. Ito, Nucl. Instr. and Meth., **127**, 429 (1975).
(6) T. Suzuki. K. Inoue, N. Suzuki and K. Goda, This Bulletin, **20**, 15 (1984).
(7) T. Suzuki, J. Atomic Energy Soc. Japan, **3**, 416 (1961).