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(Research Article)

Determination of the dead time of a GM counter using the two-source method

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Abstract

Calculations and experiments of the dead time and standard error of the ST360 counter have been carried out at the Training Center of Dalat Nuclear Research Institute employing the Sr-90 and Cs-137. The average dead time and standard error of the counter for measurements lasting 300 seconds or longer is (141.5 ± 11.8) μs. This value is in good agreement with that mentioned by the manufacturer.

Keywords: GM; ST360 counter; Dead time; Two source method

1. Introduction

In the radiation detection field, a Geiger-Muller (GM) counter - the simplest and most sensitive radiation detection equipment - has been used to measure radiation emitted by radioactive materials [1]. The GM counter has three fundamental characteristics: operating voltage, dead time, and detection efficiency. There are three main characteristics of a GM counter: operating voltage, dead time, and detection efficiency [2]. For every radiation detection system, a minimum separation time is necessary for two radiation events to be recorded, which is known as the detection system's dead time [1]. There are several methods for assessing a detector system's dead time, including the two-source method, the pulser method, the decaying source method, and the increasing power method [2]. However, the two-source method has been more commonly used, as described by the authors [1-3]. In this study, we use radioisotope sources of Sr-90 and Cs-137 to determine the dead time for the GM counter (the ST360 model is manufactured by spectrum techniques, Oak Ridge, Tennessee 37830).

2. Material and methods

At the Training Center of Dalat Nuclear Research Institute, we used the ST360 counter that has BNC and MHV connections, as well as a precise high-voltage supply that can be adjusted from 0 to +1200 volts to power the GM tube. Besides, we employed Sr-90 and Cs-137 radioisotope sources provided by spectrum techniques at Oak Ridge, Tennessee, as radiation sources. Information about these radiation sources is presented in Table 1.

Table 1 Information about the radiation sources used in this study [4]

No.	Source	A_0 (μCi)	T (year)	Manufactured
1	Sr-90	0.1	28.8	02/2014
2	Cs-137	0.250	30.07	12/2013

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In order to assess the dead time for the above-counter system, a sample stand was used to maintain the distance between the radiation sources and the GM tube. Experimental devices in our study are presented in Figure 1.

Figure 1 Experimental devices

2.1. Calculate the slope of the plateau curve and operating voltage

The slope of the plateau curve can be expressed in terms of percent change per 100 volts of operating potential and is calculated using equation (1), with the operating voltage generally selected near the middle of the plateau curve [2, 5].

$$\%slope\Big|_{100V} = 100\left(\frac{100(N_b - N_a)}{V_b - V_a}\right)\left(\frac{2}{N_b + N_a}\right) \quad \text{.....................(1)}$$

where, N_a and N_b are the measured counts at operating voltages V_a and V_b, respectively.

2.2. Calculate the dead time and its standard error

According to the two-source method with the non-paralyzed dead-time correction model, the dead time (τ) and its standard error (σ_τ) of the GM counter are determined by equations 2 and 3, respectively [3].

$$\tau = \frac{1 - \sqrt{\dfrac{r_1 r_2 - r_{12}(r_1 + r_2 - r_{12})}{r_1 r_2}}}{r_{12}} \quad \text{..................(2)}$$

$$\sigma_\tau = \frac{1}{2 r_1 r_2 r_{12}^2 \left(r_1 r_2 - r_{12}(r_1 + r_2 - r_{12})\right)}\sqrt{A + B + C} \quad \text{..................(3)}$$

$$A = \sigma_{r1}^2 \frac{r_2 r_{12}^2}{r_1}\left(r_1 r_2 - r_{12}(r_1 + r_2 - r_{12})\right)\left(-r_1 r_2 + r_1(r_2 - r_{12}) + r_{12}(r_1 + r_2 - r_{12})\right)$$

$$B = \sigma_{r2}^2 \frac{r_1 r_{12}^2}{r_2}\left(r_1 r_2 - r_{12}(r_1 + r_2 - r_{12})\right)\left(-r_1 r_2 + r_2(r_1 - r_{12}) + r_{12}(r_1 + r_2 - r_{12})\right)$$

$$C = \sigma_{r12}^{2} r_1^2 r_2^2 \left(-r_{12}\left(r_1 + r_2 - 2r_{12}\right)\sqrt{\frac{r_1 r_2 - r_{12}\left(r_1 + r_2 - r_{12}\right)}{r_1 r_2}} + 2\left(r_1 r_2 - r_{12}\left(r_1 + r_2 - r_{12}\right)\right)\left(1 - \sqrt{\frac{r_1 r_2 - r_{12}\left(r_1 + r_2 - r_{12}\right)}{r_1 r_2}}\right) \right)^2$$

where, r_1, r_2, and r_{12} are the measured net count rates from the first source only, from the second source only, and from both sources counted together, respectively.

2.3. Experimental procedure

First, we determined the plateau curve for the Geiger tube using the Sr-90 source, which was placed 2 cm away from the face of the GM tube. Supply 600 V to the GM tube, then establish the measuring parameters: voltage rises by 20 V each time, and each measurement lasts 30 seconds. Second, the operating voltage of the GM counter will be calculated using the plateau curve obtained above. Finally, we setup measurements based on the calculated operating voltage to establish the dead time for the ST360 counter.

3. Results and Discussion

3.1. Slope of the plateau curve and operating voltage

Table 2 High voltage and count of the ST360 counter for the Sr-90 source

No.	High voltage U (V)	Count	No.	High voltage U (V)	Count	No.	High voltage U (V)	Count	No.	High voltage U (V)	Count
1	660	0	8	800	9721	15	940	11367	22	1080	12400
2	680	226	9	820	9878	16	960	11667	23	1100	12653
3	700	7855	10	840	10174	17	980	11757	24	1120	12855
4	720	8543	11	860	10494	18	1000	11922	25	1140	12812
5	740	8951	12	880	10714	19	1020	12127	26	1160	12971
6	760	9150	13	900	10934	20	1040	12294	27	1180	13125
7	780	9513	14	920	11089	21	1060	12398	28	1200	13361

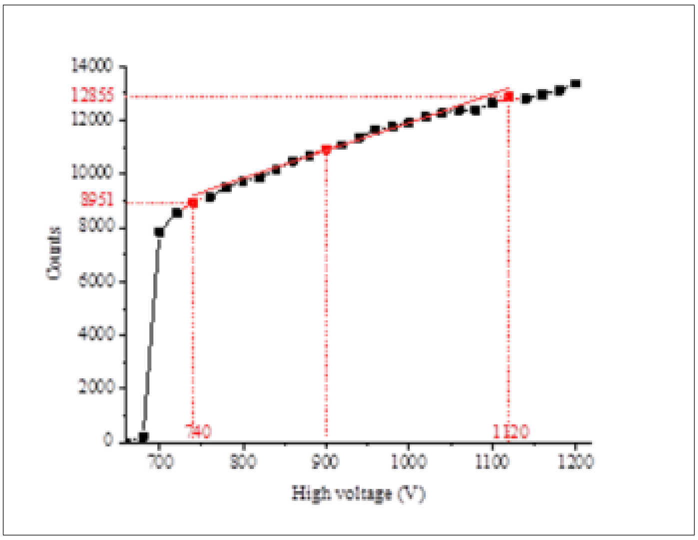

Figure 2 Plateau curve of ST360 counter for Sr-90 source

Table 2 shows the high voltage and count of the ST360 counter for the Sr-90 source as measured at the Training Center of Dalat Nuclear Research Institute. Figure 2 displays the distribution of the count based on 28 measured high voltage levels.

Figure 2 displays that in the high voltage range of 740 V to 1120 V, the observed counts grow linearly. Using equation (1), the slope of the plateau curve per 100 V and operating voltage are determined to be 8.9% and 900 V, respectively. These values agree with those reported by Eichholz [5] (slope < 10% per 100 V) and the manufacturer (recommended high voltage 900 V) [6].

3.2. Dead time and its standard error

Table 3 shows the measured results by the ST360 counter for cases of background, each individual single source of Sr-90 or Cs-137, and the two combined sources, as well as estimations of dead time and its standard error using equations 2 and 3, respectively.

Table 3 Measured and calculated results of dead time and its standard error for ST360 counter

No.	Time (s)	No. of mea.	Background (count)	G-Sr (count)	G-Sr,Cs (count)	G-Cs (count)	Dead time τ (μs)
1	30	1	9	6564	10312	3875	132.8 ± 86.9
		2	8	6432	10134	3828	
		3	11	6544	10163	4054	
		R_ave.	0.31	217.1	340.1	130.6	
		r_ave.		216.8	339.8	130.3	
2	60	1	21	12756	20121	7701	152.5 ± 63.1
		2	22	12734	19950	7703	
		3	24	12795	19945	7858	
		R_ave.	0.37	212.7	333.4	129.2	
		r_ave.		212.3	333.1	128.9	
3	90	1	35	19050	29903	11511	157.7 ± 51.9
		2	30	19020	29748	11554	
		3	32	19069	29900	11694	
		R_ave.	0.36	211.6	331.7	128.7	
		r_ave.		211.3	331.3	128.4	
4	100	1	36	21163	33116	12791	156.5 ± 49.3
		2	34	21086	33137	12868	
		3	36	21128	33150	12949	
		R_ave.	0.35	211.3	331.3	128.7	
		r_ave.		210.9	331.0	128.3	
5	120	1	42	25371	39633	15341	171.5 ± 45.2
		2	40	25269	39572	15430	
		3	42	25431	39682	15408	
		R_ave.	0.34	211.3	330.2	128.3	
		r_ave.		211.0	329.9	127.9	
6	150	1	57	31645	49518	19164	

No.	**Time (s)**	**No. of mea.**	**Background (count)**	**G-Sr (count)**	**G-Sr,Cs (count)**	**G-Cs (count)**	**Dead time τ (μs)**
		2	49	31639	49337	19307	171.7 ± 40.5
		3	51	31785	49661	19180	
		R_ave.	0.35	211.2	330.0	128.1	
		r_ave.		210.9	329.7	127.8	
7	200	1	71	42193	65891	25531	175.1 ± 35.1
		2	62	42087	65732	25764	
		3	67	42146	65995	25582	
		R_ave.	0.33	210.7	329.3	128.1	
		r_ave.		210.4	329.0	127.8	
8	300	1	106	63200	99115	38060	148.0 ± 28.7
		2	83	63103	98714	38381	
		3	94	63043	98925	38185	
		R_ave.	0.31	210.4	329.7	127.4	
		r_ave.		210.1	329.4	127.0	
9	400	1	143	84174	132033	50737	143.4 ± 24.9
		2	121	84077	131200	50858	
		3	134	83876	132116	50964	
		R_ave.	0.33	210.1	329.5	127.1	
		r_ave.		209.8	329.1	126.8	
10	500	1	177	105102	165108	63424	142.2 ± 22.3
		2	163	105210	163968	63465	
		3	154	104839	165000	63597	
		R_ave.	0.33	210.1	329.3	127.0	
		r_ave.		209.8	329.1	126.7	
11	600	1	208	125849	197939	75938	136.3 ± 20.4
		2	199	125876	196674	76055	
		3	190	125772	197829	76250	
		R_ave.	0.33	209.7	329.1	126.8	
		r_ave.		209.4	328.8	126.5	

Note: G-gross count; R_ave.-average count rate; r_ave.-net count rate; Sr, Cs are Sr-90 and Cs-137 radioactive sources, respectively.

As shown in Table 3, the dead time values vary from 132.8 to 175.1 μs, with an average of (148.7 ± 9.8) μs. This average dead time agrees with the value of 150 μs that were provided by the manufacturer [6]. In addition, we also found that measurements involving dead time (such as determining the activity of a radioactive source) should be performed with a time of 300 s or more because the ST360 counting system achieves stable values of the dead time and its standard error (141.5 ± 11.8) μs, as presented in Figure 3.

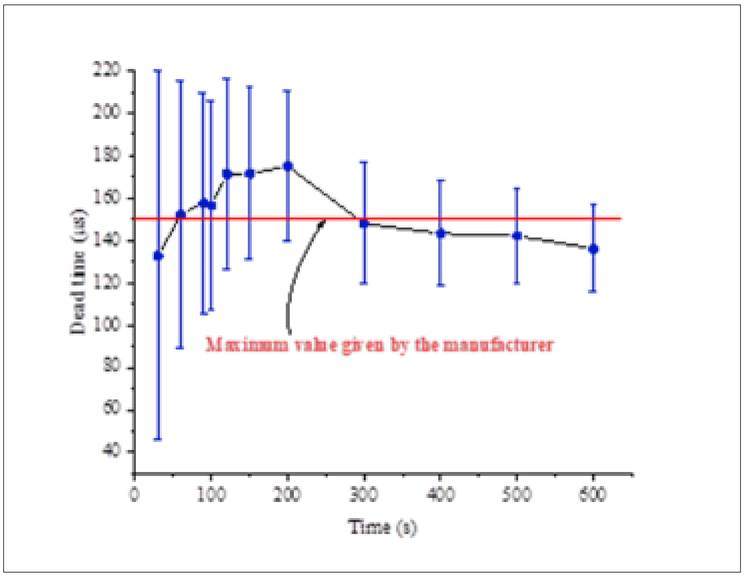

Figure 3 Dead time of ST360 counter measured at time intervals

4. Conclusion

Two of the three important characteristics of the ST360 counter, the operating voltage and dead time, were calculated and determined using the two radioactive sources, Sr-90 and Cs-137. These results are useful for teaching the students in the nuclear area when the practicum requires determining dead time, such as the activity of a radioisotope source.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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