Hue University Journal of Science: Natural Science
Vol. 134, No. 1D, 83–89, 2025

pISSN 1859-1388
eISSN 2615-9678

Determination of the dead time of the TCS-172 gamma survey meter by using the two-source method

Pham Dang Quyet*

Nuclear Research Institute, 01 Nguyen Tu Luc St., Dalat, Vietnam

* Correspondence to Pham Dang Quyet <quyetpd@gmail.com>

(*Received: 15 October 2024; Revised: 30 September 2025; Accepted: 03 October 2025*)

Abstract. Dead time is one of several major parameters of a nuclear radiation measurement system. To estimate the dead time and its uncertainty for the TCS-172 gamma survey meter at the Training Center of the Nuclear Research Institute, we conducted 240 count rate measurements using the two-source method with the non-paralysable model and two standard radioactive sources, Cs-137 and Co-60. The results indicate that the dead time for this instrument was 11.29 μs, with an uncertainty of ±1.01 μs. These values align closely with those presented in the textbook and several articles.

Keywords: TCS-172, dead time, two-source method

1 Introduction

The TCS-172 gamma survey meter (GSM) is a portable radiation detection instrument that includes an NaI(Tl) scintillator and energy compensation, allowing it to measure gamma rays in different units that can be chosen with a switch setting: Sv/h or ks^{-1} [1]. The primary characteristics of the detector response are detector efficiency, directional sensitivity, energy resolution, and dead time [2]. The dead time of a Geiger-Müller counter typically ranges from about 100 to 300 μs [3], while the NaI(Tl) scintillation detector used in a gamma spectrometer often has it in the range of 0.1 to 18 μs [3–8]. The dead time is often determined with the two-source method, in which two dead-time correction models are commonly used to calculate the dead time for a radiation counting system: the non-paralysable model and the paralysable model [4, 8]. However, most detection systems are designed to minimise paralysable effects and perform with non-paralysable characteristics [8]. In a previous study, we employed the two-source method with the non-paralysable model to assess the dead time for the Geiger-Müller counter at the Nuclear Researcher Institute's Training Center [9]. Similarly, Akyurek also used the non-paralysable model to determine the dead time for an NaI(Tl) scintillator detection system [4]. Determining the dead time of a radiation counting system is useful for training students majoring in nuclear physics because it allows them to not only understand the technical characteristics of the measuring device but also to calibrate experimental data when determining the activity of a standard radioactive source. Nevertheless, we found that the dead time for a portable radiation detection instrument equipped with an NaI(Tl) detector, such as the TCS-172 GSM, has been scarcely documented. Therefore, in this study, we present experimental measurements and select an approximation equation to determine the dead time for the TCS-172 GSM at the Training Center of the Nuclear Research Institute.

2 Materials and methods

2.1 Materials

In this investigation, we employed two radioactive sources provided by the Board of Radiation and Isotope Technology, Government of India Department of Atomic Energy, one Cs-137 (produced in July 2000) and the other Co-60 (created in October 2000), with activities of 106 kBq and 10 μCi, respectively [10], to determine the dead time for the TCS-172 GSM. Furthermore, we also utilised polyethylene to create a sample stand and flat plates with appropriately sized holes to fix the location and distance between the two sources, as well as between the two sources and the surface of the NaI(Tl) detector. In addition, a Pb chamber with 5 cm thickness was also employed to reduce the background for the radiation count rate measurements. Fig. 1 illustrates the devices and equipment used in this study.

Fig. 1. Experimental devices and instrument

2.2 Methods

First, we utilised the TCS-172 GSM to measure the background radiation rate when the NaI(Tl) detector was and was not placed inside the Pb chamber to see how the Pb chamber affected the measurement results. Then, radiation count rates were measured for each source of Cs-137, Co-60, and combined sources by using the two-source method. The sources are placed at a distance of 1 cm from the NaI(Tl) detector surface. Finally, an approximation equation was employed to estimate the dead time for the detection system according to the data obtained above.

3 Results and discussion

3.1 Measured count rates according to the two-source method

In our laboratory, the unshielded radiation background for count rates was approximately 20 cps (count per second) for TCS-172 GSM; however, utilising the lead chamber to shield the NaI(Tl) detector of the TCS-172 GSM reduced the radiation background to around 4 cps. To conduct the measurements for this experiment, we positioned the measuring equipment, which included the radioactive sources, the sample stand, and the NaI(Tl) detector, within the lead chamber.

To estimate the dead time of the radiation detection system on the basis of radiation count rates with the two-source method, we collected data (a data set) from the measurements of four parameters, which are the radiation count rates for background, source 1 (Cs-137), source 2 (Co-60), and both sources combined. Table 1 presents detailed data of 240 measurements, which correspond to 60 data sets. These data were employed to estimate the mean and error count rates for each group as a multiple of five data sets,

pISSN 1859-1388
eISSN 2615-9678

which were then used to determine the dead time and its uncertainties (Table 2).

3.2 Calculation of dead time and its uncertainty

Table 2 displays detailed estimates of the mean and error values of 12 data groups, divided from 60 data sets in Table 1. Our previous work [11] described in detail how to choose an equation for estimating the dead time value (τ) of a radiation detection system with the two-source method. In this work, we utilised Eq. 1 to compute the dead time for data from the first group in Table 2.

$$\tau = \frac{2(x+y-z)}{(x+y)z} \quad (1)$$

where x, y, and z represent the measured radiation count rates for source 1, source 2, and the combined sources 1 and 2, respectively; τ denotes the dead time of the counter system.

Then, multiplying the calculated dead time (13.39 μs) by the average lower radiation count rate (645.80 cps) yields a value of 0.01. According to Quyet [11], for this value (less than 0.04), we should apply Eqs. 2 and 3 to determine the dead time and its uncertainty, respectively.

$$\tau = \frac{x+y-z-b}{2(x-b)(y-b)} \quad (2)$$

$$\sigma_\tau = \frac{1}{2(x-b)^2(y-b)^2} \times \sqrt{\begin{aligned} &(y-b)^2(y-z)^2\sigma_x^2 \\ &+(x-b)^2(x-z)^2\sigma_y^2 \\ &+(x-b)^2(y-b)^2\sigma_z^2 \\ &+\begin{pmatrix}(x-b)(y-b) \\ +(x+b-z-b)(2b-x-y)\end{pmatrix}^2\sigma_b^2 \end{aligned}} \quad (3)$$

where b is the background count rate, and σ_z, σ_y, and σ_z are the radiation count rate errors for source 1, source 2, and both combined sources, respectively.

Finally, applying Eqs. 2 and 3 to the 12 data groups in Table 2, we calculated the dead time and its uncertainty (σ_τ), and the values are listed in the final column.

Table 1. Count rates of 240 measurements by using TCS-172 GSM correspond to the two source method

No. of set	Count rate [cps]			
	Bgr.	Sou.1	Sou.12	Sou.2
1	4	1282	1911	649
2	5	1283	1898	646
3	5	1294	1902	641
4	4	1278	1904	644
5	4	1282	1909	649
6	4	1285	1898	647
7	4	1295	1919	645
8	4	1290	1919	648
9	4	1275	1926	644
10	4	1276	1911	640
11	4	1295	1907	647
12	4	1290	1916	651

No. of set	Count rate [cps]			
	Bgr.	Sou.1	Sou.12	Sou.2
13	4	1290	1916	651
14	4	1276	1921	644
15	4	1281	1917	649
16	4	1298	1915	650
17	4	1288	1924	653
18	4	1297	1923	653
19	4	1291	1908	648
20	4	1285	1931	650
21	4	1291	1917	643
22	4	1287	1919	648
23	4	1298	1924	644
24	4	1302	1923	646
25	4	1306	1917	651
26	4	1301	1911	654
27	4	1300	1933	646
28	4	1287	1929	647
29	4	1279	1919	646
30	4	1294	1912	647
31	4	1291	1900	648
32	4	1287	1908	649
33	4	1283	1923	649
34	4	1305	1916	648
35	4	1290	1906	649
36	4	1303	1930	651
37	5	1291	1933	659
38	4	1279	1915	654
39	4	1273	1923	648
40	4	1288	1910	650
41	4	1287	1904	647
42	4	1294	1923	650
43	4	1291	1909	651
44	4	1277	1914	650
45	4	1280	1909	650
46	4	1281	1914	652

pISSN 1859-1388
eISSN 2615-9678

No. of set	Count rate [cps]			
	Bgr.	**Sou.1**	**Sou.12**	**Sou.2**
47	4	1294	1921	642
48	4	1286	1921	647
49	4	1294	1904	649
50	4	1287	1902	649
51	3	1298	1906	649
52	4	1290	1893	657
53	4	1298	1917	650
54	4	1283	1922	652
55	4	1287	1915	648
56	4	1274	1914	646
57	4	1270	1919	649
58	4	1285	1914	651
59	4	1291	1903	652
60	4	1301	1902	651

Note: [cps] is the count per second; Brg., sou., and 12 are the background, source, and 1 and 2 combined, respectively.

Table 2. Calculated results of dead time and its uncertainty for TCS-172 GSM

No. of group	No. of set	Count rate [cps]				Dead time [µs]
		Background	**Source 1**	**Source 1 and 2**	**Source 2**	
1	5	4.40 ± 0.24	1283.80 ± 2.69	1904.80 ± 2.35	645.80 ± 1.53	12.43 ± 2.34
2	10	4.20 ± 0.13	1284.00 ± 2.23	1909.70 ± 3.00	645.30 ± 0.99	9.38 ± 2.34
3	15	4.13 ± 0.09	1284.80 ± 1.83	1911.60 ± 2.21	646.33 ± 0.86	9.36 ± 1.81
4	20	4.10 ± 0.07	1286.55 ± 1.63	1913.75 ± 2.06	647.45 ± 0.81	9.79 ± 1.66
5	25	4.08 ± 0.06	1288.60 ± 1.67	1915.00 ± 1.74	647.24 ± 0.70	10.14 ± 1.51
6	30	4.07 ± 0.05	1289.20 ± 1.54	1915.97 ± 1.64	647.37 ± 0.63	10.00 ± 1.40
7	35	4.06 ± 0.04	1289.49 ± 1.41	1915.20 ± 1.53	647.54 ± 0.54	10.74 ± 1.29
8	40	4.08 ± 0.04	1289.15 ± 1.37	1916.08 ± 1.47	648.15 ± 0.58	10.35 ± 1.25
9	45	4.07 ± 0.04	1288.78 ± 1.27	1915.60 ± 1.36	648.31 ± 0.52	10.52 ± 1.16
10	50	4.06 ± 0.03	1288.74 ± 1.16	1915.28 ± 1.29	648.26 ± 0.50	10.67 ± 1.08
11	55	4.04 ± 0.04	1288.96 ± 1.09	1914.85 ± 1.25	648.53 ± 0.48	11.23 ± 1.03
12	60	4.03 ± 0.03	1288.57 ± 1.10	1914.48 ± 1.19	648.63 ± 0.45	11.29 ± 1.01

The dead time values are given in microseconds (µs) with associated uncertainty. The TCS-172 GSM has the dead time values ranging from 9.36 to 12.43 µs. This range of values is in good agreement with published data [3–8]. The dead time is maximal in the first group (12.43 ± 2.34 µs) and minimal in the second group (9.36 ± 2.34 µs). As the number of groups increases, the dead time values begin to stabilise, with less noticeable fluctuations after the fourth group. The uncertainties in dead time decrease as the number of groups grows, demonstrating greater statistical dependability with more data. The dead time uncertainty in these computations decreases from ±2.34 µs for the first two groups to around ±1.01 µs for the twelfth group because increasing the number of measurements reduces statistical variability. Consequently, the dead time of the TCS-172 GSM was 11.29 µs, with an uncertainty of ±1.01 µs. The count rate corrections for the radioactive sources used in this study were 19 cps and 5 cps, which correspond to 1.5% and 0.7% for source 1 and source 2, respectively. Although standard radioactive sources in a laboratory usually have low activity (< 10 µCi), the necessary corrections for dead-time effects are small. However, determining the dead time of the TCS-172 GSM system in this investigation improves our research capability and provides a valuable and practical reference for teaching and practising in the field of nuclear radiation measurement.

Figs. 2a and 2b illustrate graphs of the dead time with and without the uncertainty of the TCS-172 GSM experimentally determined with the two-source method. We found that uncertainty had a significant impact on the shape of the dead time graph. In both graphs shown in Figs. 2a and 2b, the dead time value decreases as the number of measurement groups increases from one to two, which is explained by the fact that as the number of measurements increases, the estimated value approaches the best value of the quantity being determined. However, in the range from group 2 to group 12, it can be seen that when the graph of the dead time value includes uncertainty, the mean dead time value is relatively stable after the measurement group number 5 (Fig. 2a); whereas, in Fig. 2b, when the graph of the dead time value does not include uncertainty, the graph of the mean dead time value appears to increase linearly with the measurement groups. As a result, while calculating the average value of dead time in particular or the average value of a quantity in general, information concerning the uncertainty of those numbers must be considered.

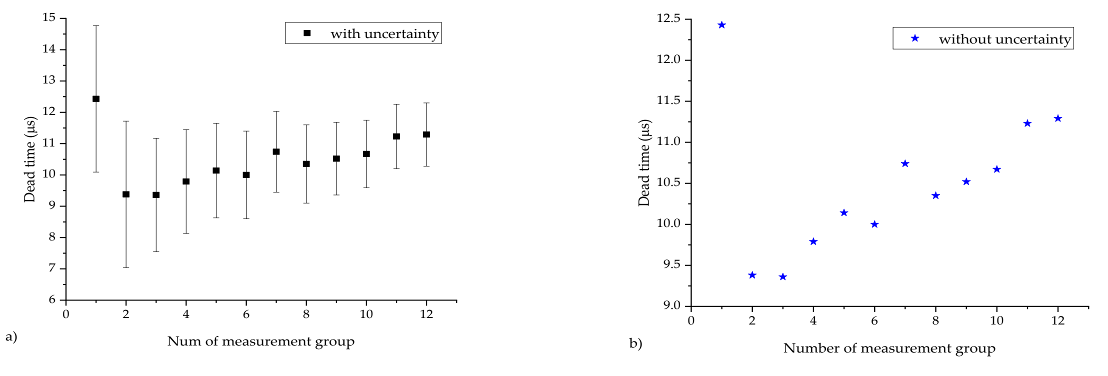

Fig. 2. Dead time of experimentally determined TCS-172 GSM: a) with uncertainty and b) without uncertainty

4 Conclusion

In this study, we determined the dead time and its uncertainty for the TCS-172 GSM by using the two-source method with the non-paralysable model. The dead time value is consistent with that published in the textbooks and some articles. Although standard radioactive sources in a laboratory usually have low activity (<10 µCi), the

pISSN 1859-1388
eISSN 2615-9678

necessary corrections for dead-time effects were small. Nevertheless, the dead time value of the TCS-172 GSM system established in this investigation can serve as a valuable reference for future studies in the field of nuclear radiation measurement. In addition, we discovered that uncertainties had a significant impact on the shape of the average value graph.

Acknowledgement

The author would like to thank the Board of Directors of the Training Center of the Nuclear Research Institute for supporting the equipment needed to perform the experimental measurements for this study.

References

1. Aloka Co., Ltd. Gamma scintillation survey meter, Model TCS-172 instruction manual.
2. IAEA-TECDOC-1363. Guidelines for radioelement mapping using gamma ray spectrometry data. IAEA; 2003.
3. Tsoulfanidis N, Landsberger S. Measurement & detection of radiation. 4th ed. CRC Press; 2015.
4. Akyurek T. A new dead-time determination method for gamma-ray detectors using attenuation law. Nuclear Engineering and Technology. 2021,53(12):4093-4097.
5. Saha GB. Physics and radiobiology of nuclear medicine. 4th ed. Springer; 2013.
6. Gupta TK. Radiation, ionization, and detection in nuclear medicine. Springer; 2013.
7. Cherry SR, Sorenson JA, Phelps ME. Physics in nuclear medicine. 4th ed. Elsevier; 2012.
8. McGregor DS, Shultis JK. Radiation detection: concepts, methods, and devices. CRC Press; 2020.
9. Quyet DP. Determination of the dead time of a GM counter using the two-source method. International Journal of Science and Research Archive. 2024;13(01):790-795.
10. Certificate of calibration, No. TT & CD/PKP/2000/1694, Board of radiation and isotope technology, Government of India deparment of atomic energy.
11. Quyet PD. Select an equation to calculate the dead time for a radiation counter system. International Journal of Science and Research Archive. 2025;15(03):433-438.