**QUESTION:** ***Can you please tell me the effect (consequence) of dead time on a Geiger-Mueller counter?***

**ANSWER:** The effect of dead time on a Geiger-Mueller (G-M) detector is to result in events not being detected that otherwise would be. The end result is that the interpreted count rate (or exposure rate depending on the use of the instrument) is less than it would be in the absence of dead time. As the name implies, dead time is an interval of time during which the detector is unable to respond to an ionizing event within the detector gas that would ordinarily produce a detectable pulse—that is, a count; the detector is “dead.” The phenomenon results from the fact that when an ionizing event occurs in a G-M detector, it results in a large avalanche of secondary ionization in the gas, brought about by fast-moving electrons accelerated in the electric field between the electrodes. These electrons collide with neutral gas molecules and transfer enough energy to cause the molecules to be ionized. When such an avalanche occurs, the large number of positive ions, whose mass is much greater than the free electrons also produced in the ionization, form a sheath around the central positive electrode (the anode, close to which most of the avalanche has occurred) and move relatively slowly toward the outer wall of the detector (the wall is the negative electrode of the detector and is called the cathode). The space charge associated with the presence of the positive ions works in opposition to the applied voltage so that the effective voltage immediately following an ionizing event in the detector may drop to near zero. The voltage gradually recovers as positive ions drift toward the cathode and are collected, but it takes a finite amount of time before the voltage is sufficiently high that another incoming ionizing particle can produce a pulse large enough to be detected. During this time, we refer to the detector as being dead, and the amount of time that must pass before another event can be recorded is called the dead time. In most G-M detectors dead times range from about 50 microseconds to several hundred microseconds, depending on the particular characteristics of the G-M detector.

The most commonly used mathematical model to correct the observed count rate for dead-time losses is the so-called nonparalyzable detector model. In this model it is assumed that any interactions of ionizing particles that occur in the detector during the dead-time interval, following a detectable event, do not influence the magnitude of the dead time. For this model, the true count rate (if the dead time were zero), $R_T$, is related to the observed (measured) count rate, $R_T$, as follows:

$$R_T=R_o/(l-R_o\tau)$$

where $\tau$ is the dead time. As an example, if we used a detector that had a 100 microsecond dead time, and we measured a count rate of 55,625 counts per minute (cpm), the true interaction rate, corrected for dead-time losses, would have been:

$$R_T = 55{,}625/(1–(55{,}625/60)(100\times10^{-6})) = 61{,}309 \text{ cpm.}$$

Note that in order to be consistent in the use of our time units, the measured count rate in the denominator was converted to counts per second by dividing by 60, and the dead time was converted from microseconds to seconds. The product $R_O\tau$ represents the fraction of time that the G-M detector is unable to respond. For the above example, this fraction is 0.093. Said differently, the detector measured 90.7% of all the events that occurred within it.

The use of the nonparalyzable model is generally adequate for dead-time losses approaching 30% or so. If count rates are very high, it turns out that the nonparalyzable model fails to predict the true count rate because events occurring within the dead time of the detector themselves cause the dead time to be extended. For this situation a paralyzable model has been used in which the relationship between the observed count rate and the true count rate is given by:

$$R_O = R_T e^{-R_T\tau}$$

where e is the base of the natural logarithm. This model is rather cumbersome to use because one cannot solve directly for $R_T$. An iterative or a graphical process must be used. In actuality, it may also happen that neither of the above models accounts properly for dead-time losses, with the truth lying somewhere between the two. In such cases it may be necessary to do some experimental work with differing count-rate sources in order to evaluate the dead-time effect.

If you want more information about dead-time considerations, you can find it in many textbooks dealing with radiation detection. One of the most popular books is by Glenn F. Knoll titled *Radiation Detection and Measurement*, published by John Wiley & Sons, Inc., New York, 2000.

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