G-M “Hotdog” Detectors:
Everything You've Wanted to Know (But Were Afraid to Ask)

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Introduction

In the last issue of *RSO Magazine*, the subject of G-M pancake detectors was covered in some detail. This article is a sort of continuation of that, this time focusing on G-M “hotdog” detectors. Since both are G-M detectors, some information in this article will be redundant, but this is necessary to ensure that each article is capable of standing on its own.

G-M hotdog detectors (also called *G-M sidewall* detectors) are a very commonly used radiation detector. They are certainly the most commonly used exposure rate instrument. They are most effective for measuring gamma and x radiation, but they are somewhat sensitive to beta particles with the “window” open. They will not detect alpha particles at all. From the ways they are sometimes misused, however, it appears they are also among the most misunderstood.

These detectors are primarily designed for the quantification of *gamma- and x-* radiation, but some designs try to make provisions for the detection of beta particles.

Editor’s Note: *This article, now out of print, has been one of the most-requested articles in our archive. It is presented here in an “encore” for the convenience of our readers.*

Operating Principles

The G-M detector is one of the oldest types of radiation detector still in use today, intro-duced by Hans Geiger and Walter Müeller in 1928. The basic G-M hotdog tube represents the simplest form of G-M tube, consisting of a sealed metallic cylinder filled with a counting gas. (A counting gas is one which will readily ionize when struck by an incident charged particle.) A small wire or plate (called the anode or positive terminal) is suspended in the center of the tube, electrically insulated from the case. A high voltage is applied between the anode and the cylinder wall (called the cathode or negative terminal). The high voltage is set such that the gas is just slightly below the point at which it will ionize; the small amount of energy added by incident radiation is enough to create an electronic discharge (or pulse) which can then be recorded by the instrument electronics. In instruments utilizing G-M hotdog detectors this count rate is then converted to an exposure rate, and usually displayed in units of mR/h (milliroentgens per hour).

It is ironic (although exceedingly esoteric, so skip this section if you like) that G-M detectors are not, strictly speaking, capable of detecting gamma- or x-rays. Rather, photons (i.e., gamma- or x-rays) are detected *indirectly* following their interaction with the metal atoms in the detector case and the wall of the G-M tube. When a photon interacts with one of these metal atoms, very often an electron is ejected into the tube as a result. It is these *secondary electrons*—charged particles—which are detected by the counting gas.

G-M detectors are essentially 100% efficient for detecting charged particle radiations (i.e., beta particles, alpha particles, positrons, and electrons) which actually enter the counting gas. This indirect detection of photons is not, however, very efficient because once the secondary electron is produced it must also pass through any remaining thickness of wall before it loses its energy. Only those photons which interact with the innermost layer of the wall of the detector tube will be recorded. See Figure 1 for an illustration of this.

Construction

Figure 2 shows a fairly typical G-M tube used in many different G-M hotdog detectors. The tube chassis is made of thin stainless steel about 0.076 mm thick, ribbed to give the tube structural strength to contain the counting gas at sub-atmospheric pressure. The tube is about 9.5 cm long (about 11 cm long including the electrical connector) and about 1.9 cm in diameter. The active length of the tube, however, is about 5.8 cm, roughly in the center of the length of the tube. It is within this active area that reliable detection is achieved. Tubes used in G-M hotdog detectors are almost all made by either TGM Detectors, Inc.[1] or LND, Inc.[2] and are effectively inter-changeable. Figure 2, in fact, represents both the TGM N112 and the LND 725.

The G-M tube is held centered inside a detector case by the spacer ring. The detector cases vary in design and style, but have some common characteristics. They are typically constructed of aluminum, and usually have some method for exposing a portion of the unshielded tube as a “beta window.” (Note: Use of these “beta windows” usually isn't appropriate or even a good idea—further explanation follows.) Figure 3 shows a Ludlum[3] 44-6 detector, in which the “beta window” is opened by twisting the knob to rotate a shield away from a series of openings. Figure 4 shows a Bicron[4] SWGM, in which the “beta window” is opened by sliding the interior portion of the detector out. These two detectors both utilize the tube shown in Figure 2, and are fairly representative of the majority of G-M hotdog detectors available. All of the major instrument manufacturers (and probably all of the smaller instrument manufacturers) offer one or more versions of this type of detector.

One other variation on the G-M hotdog detector theme is the “end-window G-M,” illustrated in Figure 5. These tubes are made of a thicker stainless steel and have a mica window on one end similar to G-M pancake detectors. The end-window G-M is in fact intended as a combination of G-M hotdog and G-M pancake detectors; exposure rate measurements can be taken through the side of the detector and alpha and beta contamination assessed through the mica end-window. One example of a detector which uses an end-window G-M tube is the Victoreen[5] 489-35, shown in Figure 6.

Gamma and X-Ray Response

G-M hotdog detectors are designed primarily to detect gamma and x radiation. They are often a good choice for performing exposure rate surveys because they are rugged, relatively inexpensive, and do not require a sophisticated (i.e., expensive) meter. The detached detector can also get into places where instruments with built-in detectors can’t. There are, of course, some drawbacks.

Figure 1. *Some of the electrons produced by gamma interactions in the "hotdog" detector and tube walls cause most of the response to gamma radiation.*

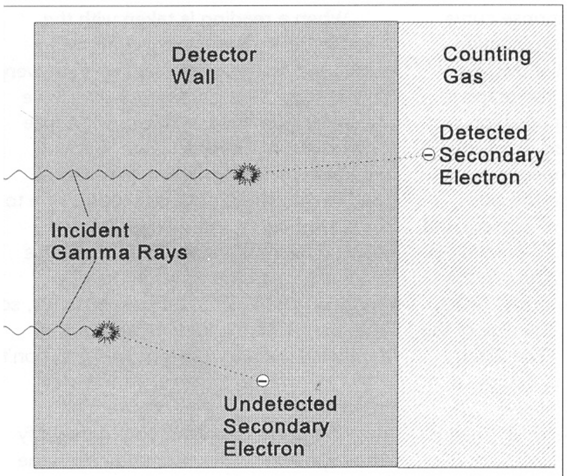


Figure 2. *Typical G-M "hotdog" detector tube, without case or holder*

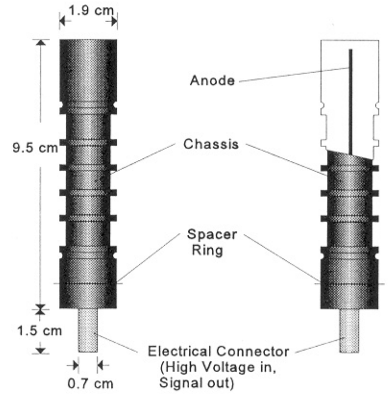


Figure 3. *Ludlum 44-6 "hotdog" G-M detector*

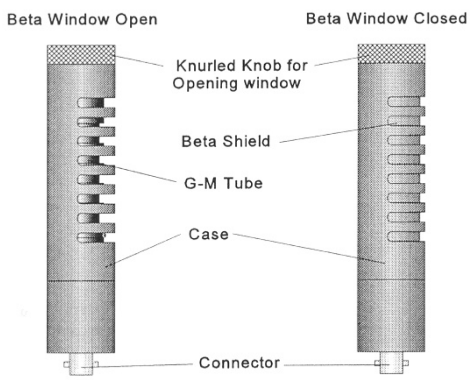


Figure 4. *Bicron SWGM "hotdog" G-M detector*

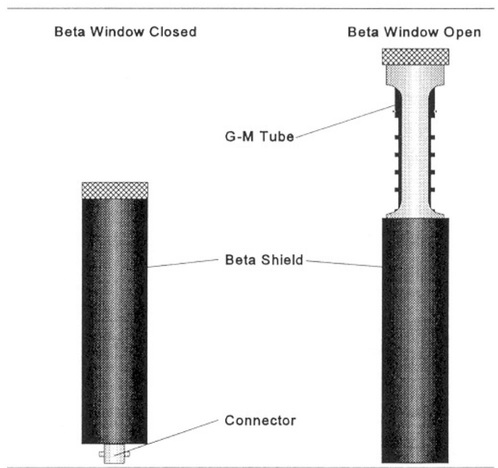


Figure 5. *Typical end-window G-M detector tube, without case or holder*

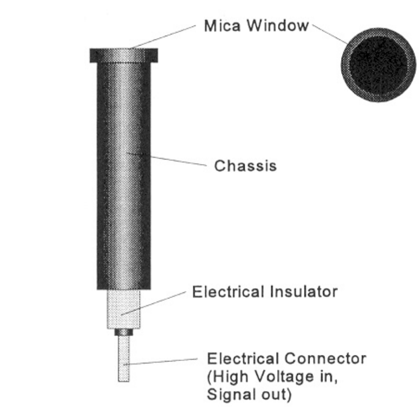


Figure 6. *Victoreen 489-35 end-window G-M detector*

The first is that they are not very good at measuring low exposure rates. It is impractical to accurately quantify exposure rates below about 0.1 mR/h (100 µR/h) with a G-M hotdog detector simply because that low an exposure rate has too few counts per minute to give a steady meter indication. Note that ambient background is usually in the range of about 10-25 µR/h (0.01-0.025 mR/h). On the other end of the scale, these detectors cannot be used to accurately quantify radiation fields greater than about 50 mR/h without dead-time correction, or greater than 500 mR/h with dead-time correction. There are G-M tubes specifically designed for quantifying higher (much higher, in fact) levels of gamma- and x-radiation, but these do so at a sacrifice of their ability to operate at lower exposure rates. It may be said, then, that G-M hotdog detectors have a limited range of operation, and are incapable of quantifying "environmental" levels of radiation.

The second drawback to using G-M hotdog detectors is the fact that their response is dependent on the energy of the gamma- or x- radiation being measured. Figures 7 and 8 show response curves for the Ludlum 44-6 and the Bicron SWGM, respectively. The data for these curves was taken from manufacturer's literature, and plotted on identical scales in order to better see the comparison. Note first that these detectors use the *same detector tube*; the easily visible differences in response are due to differences in the design of the detector *case.* Next, note that the overresponse to low-energy photons is greatly exaggerated with the beta shield open, especially in the range around 60-70 keV, which is the vicinity many industrial and medical x-ray machines operate in.

Figure 9 shows the response curve for the Victoreen 489-35 combination "hotdog"/end-window G-M shown in Figure 6. For comparison, the graph is plotted on the same scales used for Figures 7 and 8, but instead of having curves for "beta window" open and closed, they are for through the side (analogous to "beta window" closed) and through the end window (i.e., pointing at the source, analogous to "beta window" open). Note that these response curves, especially the one through the side of the detector, are much flatter. (The ideal response curve would be, of course, a straight horizontal line at Relative Response = 1. A response of "1" means that

$$\frac{\text{indicated reading}}{\text{actual reading}} = 1.$$

A response of "3" means that the indicated reading is 3 times the actual exposure rate.) The reason for the relative flatness of response for this detector is due to the thickness of the stainless steel making up the case or housing of the detector tube. The thicker the wall of the tube or case (actually the combination of tube *and* case), the flatter the response will be, because fewer lower energy photons will be able to penetrate.

This brings us to *energy-compensated* G-M detectors. These generally utilize the same G-M tube as in any other hotdog detector, but have a thicker housing. In these, an "optimum" thickness is used which is thick enough to level out the response (usually to within 15% of the response to ^{137}Cs) while still allowing detection of relatively low-energy gammas and x-rays (down to about 50 keV).

Beta Response

It is true that beta particles with energies greater than about 200 keV can be detected through the "beta window" of a G-M hotdog detector. My recommendation, however, is don't bother. In the "old days," we used to be taught that all you needed to do was to subtract the closed-window measurement

Figure 7. *Response curve for Ludlum 44-6 G-M "hotdog" detector*

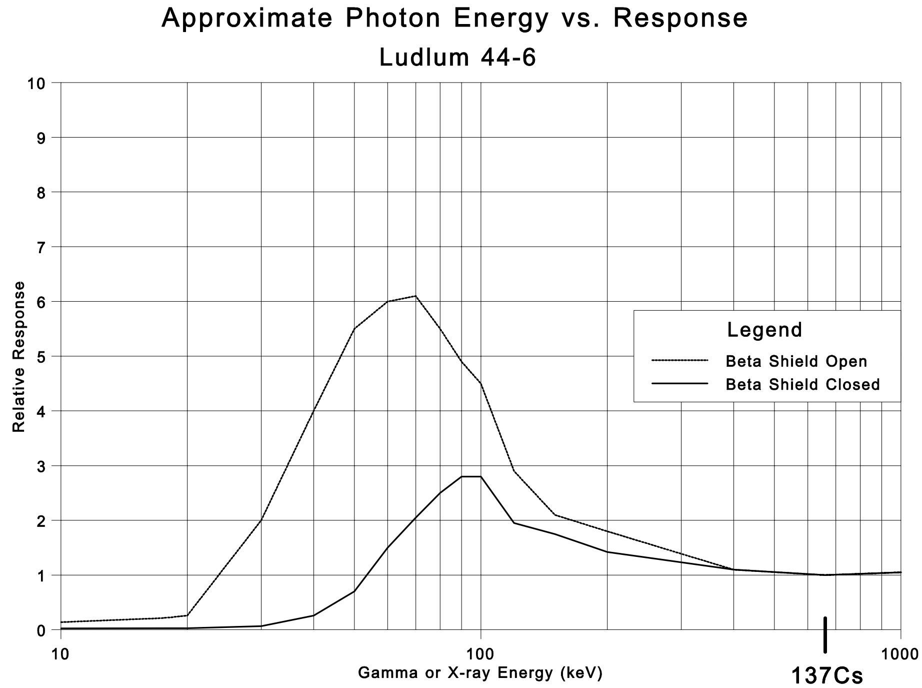
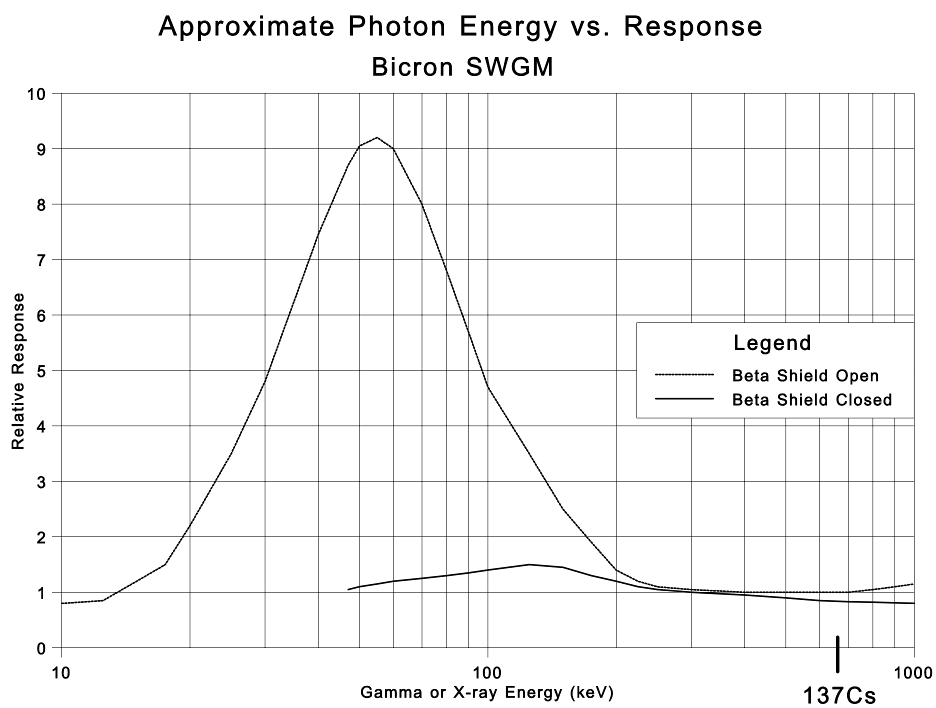


Figure 8. *Response curve for Bicron SWGM, G-M "hotdog" detectors*



(gamma) from the open window measurement (beta + gamma only) to determine the beta component of a radiation field. Based only on the response curves in Figures 7 and 8, you can see that due to the differing responses to gamma radiation, such a calculation will only be a rough approximation at best.

When a reading is taken with the window open, three things happen to confound an accurate reading. First, very low-energy photons, which would have been excluded by the shield, will cause the detector to over respond. Second, any beta particle radiation present will add to the reading but will not be able to be sorted out from the low-energy photon over-response. Third, gammas and x-rays passing through the open window will be detected *less* efficiently, so this will cause some *reduction* in the indicated reading. Bottom line, you don't have any way to interpret your meter reading.

If it is important for you to quantify the exposure rate contribution from the beta component in a radiation field, use an ion chamber, not a G-M hotdog detector. This should not be necessary in any but the highest of beta exposure situations, such as in a nuclear power plant.

For determining and quantifying beta-emitting surface contaminants, G-M hotdog detectors are similarly useless. While it is possible that some beta particles from surface contamination may be detected through the "beta window," quantification of that activity is virtually impossible. To measure surface contamination, use an instrument designed to do so, like a G-M pancake detector.

End-window G-M detectors, on the other hand, are fine for quantifying surface contamination so long as they have been calibrated properly. Efficiencies for various isotopes are usually not quite as good as for a G-M pancake detector, but still remain in a useable range. The end-window G-M will have more gamma counts than a G-M pancake detector when making beta measurements. The primary limitation in using one of these detectors for assess-ing surface contamination is the fact that the active window area ($5.1\ cm^2$) is so small. For example, a 15% efficient end-window detector which indicates a net count rate of just 50 corrected counts per minute would correspond to an activity of >6,500 dpm/100 cm^2.

Alpha Response

G-M hotdog detectors are not capable of measuring or even detecting alpha particles. The end-window G-M variety, however, is capable of detecting and quantifying alpha-emitting surface contamination at a reasonable efficiency. Again, the primary limiting factor is the small window area, and of course a current alpha efficiency calibration must be available. It is not possible, however, to differentiate between alpha and beta quantitatively using this instrument alone.

Response Time

The electronic circuitry used in conjunction with the G-M hotdog detector averages the number of counts per minute (cpm) from the detector, and converts the number of cpm to an exposure rate. This is done by averaging the number of cpm over a period of time called the *response time*. Response time is defined as "the time interval required for the instrument reading to change from 10% to 90% (or vice versa) following a step change in the radiation field at the detector." Many instruments have a switch for shifting between "fast" and "slow" response times. Actual times will be listed in the technical manual for each instrument.

On fast response, the interval over which the count rate is averaged is relatively short, typically on the order of 4 seconds. Therefore, the needle will respond quickly to changes in the radiation field, but may also be somewhat jerky and unsteady. On slow response, where the count rate is typically averaged over about 22 seconds, the needle indication will be much steadier but will take longer to respond to changes. A suggestion: use slow response for routine surveys; use fast response if searching for a lost source, for example.

One parameter listed for G-M hotdog detectors is *sensitivity*, usually expressed in cpm per mR/h (counts per minute per mR per hour). For example, the Ludlum 44-6 lists a sensitivity of 1200 cpm per mR/h. The higher the sensitivity, the easier it is to quantify lower exposure rates. For example, it would be easier to read an exposure rate in the range of 0.05 to 0.1 mR/h with a detector with a sensitivity of 1200 cpm per mR/h than one with a sensitivity of 600 cpm per mR/h. This is because the instrument would have twice the number of counts in any given amount of time to incorporate into an average for the higher sensitivity detector, so the indication on the meter needle would be much steadier and less "jerky" than that for the lower sensitivity detector.

Dead Time and Saturation

When a G-M tube ionizes, generating a pulse to be recorded by the instrument, virtually every atom of counting gas within the tube is ionized. Until the counting gas molecules recombine and return to the ground state, no additional radiation can be detected. From an initial pulse, it takes an amount of time on the order of 200 microseconds for the detector to be capable of registering another pulse. The amount of time during which no events can be registered is called *dead time*.

Dead time is usually not a big issue with G-M hotdog detectors because it is compensated for during calibration when all scales are adjusted to read 10% or less of true exposure rate. An artifact of its effect can be seen on the highest scale of some detectors, which is often logarithmic rather than linear like the lower scales. Figure 10 shows a meter face with these markings on it. This method is used by some manufacturers to extend the useful range of a detector without using expensive dead-time compensation circuitry.

Another phenomenon which can occur in all G-M detectors is that of *saturation*, which is the effect of dead time taken to an extreme. At very high count rates (and thus, very high exposure rates), the time between each ionizing event is much less than the dead time; the counting gas is kept in an ionized state and is never able to recover sufficiently to record another event. The result of this is that in very high radiation fields the G-M hotdog detector may read zero. This saturation point is a listed parameter in the specifications of the detector, and some instruments provide anti-saturation circuitry which pegs the needle off scale and/or signals the user of saturation by way of an alarm or light. This is a good thing to have in a G-M detector. Where potential for very high exposure rates exist, an ion chamber may be a more appropriate instrument than a G-M detector.

(*Editor's note: Ion chambers and other exposure rate instruments will be the subject of future articles in this magazine.)*

__Figure 9.__ Response curve for Victoreen 489-35 end-window detector

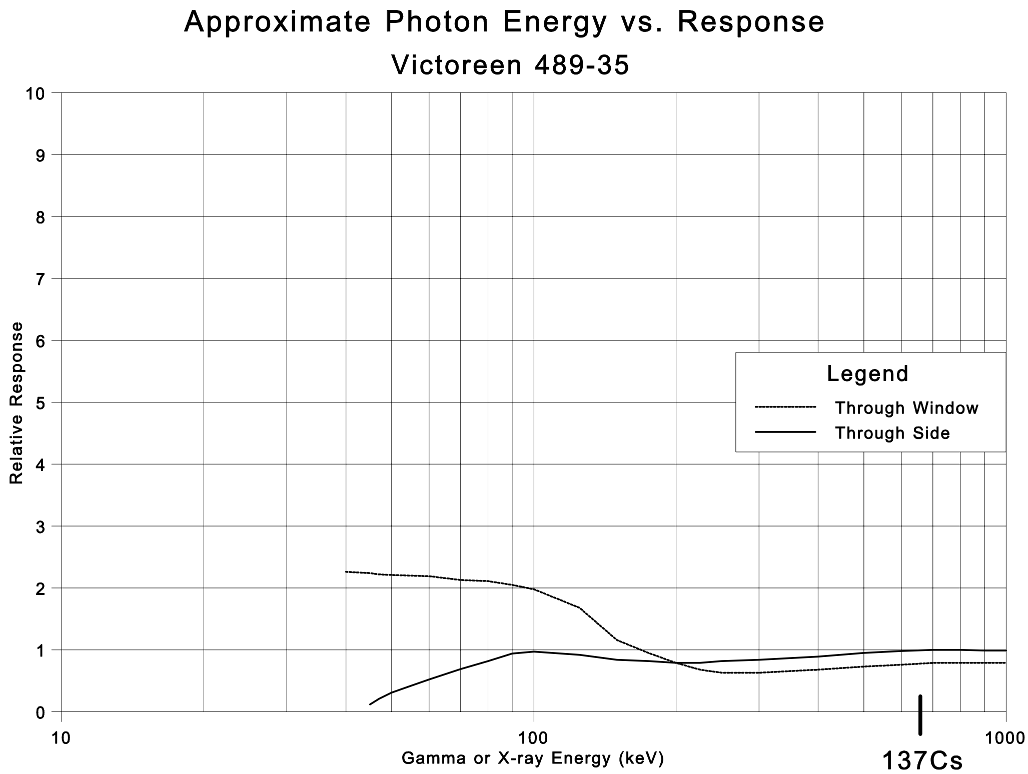
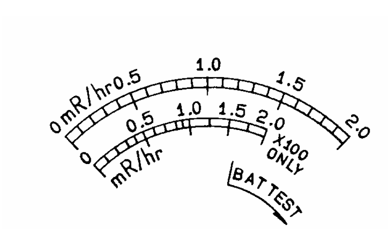


__Figure 10.__ Typical meter face used with G-M "hotdog" detectors



Calibration

All radiation detectors must be calibrated periodically. This is often every year, but may be more frequent for some licensees. Calibrations should also be performed if any substantial repairs are made to the instrument or detector. Replacing batteries or a detector cable of the same length are not generally considered to be "substantial" repairs, and as such do not require a re-calibration. The instrument should be calibrated with the exact detector with which it will be used; changing the detector *tube* would require a re-calibration.

Calibration of an instrument with a G-M hotdog detector consists of two parts. The first, often called pre-calibration, is a check to make sure all the parts of the instrument are mechanically sound and in good enough operating condition to continue with the calibration. Included in the pre-calibration are:

- a contamination survey of the instrument; and
- a check that the meter is mechanically zeroed, making sure the battery check indicator works properly and the batteries are good and properly

installed, that the audio indicator is working, that the different instrument response times are functioning, and that the proper high voltage is being generated.

A "precision check," in which the detector is repeatedly exposed to a known exposure rate to ensure that the same reading is indicated each time, is also part of pre-calibration.

In the second step, the detector is exposed to a known, calibrated radiation field, usually from ^{137}Cs, at intensities which will give measurements of about 80% and 20% of full scale. The instrument is adjusted so that each of these points is within 10% of the known value. This process is repeated for each range on the instrument. During calibration to a radiation field, the detector must be kept *perpendicular* to the radiation beam (i.e., the side must face the radiation source). The exposure rate calibration is also to the *center* of the detector, not to the edge of the detector. The calibration must also be performed with *the "beta window" closed*.

If your facility possesses no radioactive materials, and your only source of radiation is an x-ray machine, you should still calibrate the instrument to ^{137}Cs. In addition to being the industry standard, this sets up the instrument in such a way that any error will be in the form of an over response rather than an under response (i.e., the instrument will read higher than actual rather than lower). A correction curve or table can be attached or affixed to the instrument to more accurately quantify the measurements taken. A look at Figures 7 and 8 shows that the ^{137}Cs photon energy (662 keV) is on (or very near) an instrument's relative response of 1, which is ideal. Cesium-137 also has a 30-year half-life, which means that calibration facilities don't have to buy new calibration standards very often.

An exclusively electronic calibration for exposure-rate instruments is not acceptable. Even though a manufacturer's literature states that a particular G-M hotdog detector has a sensitivity of 1,250 cpm per mR/h, you cannot use a pulse generator to "extrapolate a calibration" from that value. Calibration of an exposure rate instrument must be performed in a calibrated radiation field. (The only exception to this would be on instruments with scales which are in the range of, or lower than, ambient background. For these, an electronic "ratio calibration" may be performed for those specific scales or portions of scales. A number of cpm per mR/h is determined at a point which was calibrated in a radiation field, and this is extrapolated to the lower range.)

Calibration of end-window G-M detectors presents a problem. It is not really possible to reliably calibrate a single detector to mR/h (through the side of the detector) and cpm (through the mica window on the end) even though your meter face may show both scales. A compromise must be made, and you must decide which feature is of more value to you. I suggest that it is probably best to calibrate the detector to mR/h and use the mica end-window as an approximate or qualitative measure of surface contamination. You may, of course, decide that it is best for your particular situation to calibrate to cpm and determine efficiencies for surface contamination, and treat the exposure rate scale as a (very) rough approximation.

Using G-M Hotdog Detectors

G-M hotdog detectors should only be used for measuring exposure rates, so they should *never* be used on a cpm scale; read mR/h only. These detectors are *not designed* for measure-ing surface contamination, for evaluating wipes, or for personnel frisking.

When quantifying exposure rates, ensure that the detector is being held perpendicular to the source. The radiation should be entering through the side of the detector, not the front. Always use G-M hotdogs with the "beta window" closed, and train your technicians to do the same. Better yet, purchase G-M hotdog detectors which have no "beta window" (such as the Ludlum 133-2). Don't bother trying to detect or quantify beta with a G-M hotdog detector.

For the end-window variety, you must decide whether you want an exposure-rate instrument *or* a count-rate instrument, and have it calibrated as such. It has been said that a tool designed to fulfill two purposes does neither well, and there are compromises in the design of the end-window G-M. It is best, in my opinion, to use a G-M pancake detector for measuring surface contamination because of its much larger surface area, and a G-M hotdog detector for exposure rates.

Conclusion

G-M hotdog detectors were the "state-of-the-art" for more than 50 years. Even now, although there are more technologically advanced radiation detectors available, there is certainly a place for G-M hotdogs in many radiation protection programs. They are inexpensive and durable detectors. On the other hand, there are some applications for which better instruments exist, and some uses for which G-M hotdogs are not appropriate.

Most of the misuses of G-M hotdog detectors come about because of the "beta window." The "beta window" is merely a vestige of earlier times in the history of radiation detection, when the G-M hotdog was the only thing available. They are still produced in that configuration only because "they have always been that way."

G-M hotdog detectors with the "beta window" closed (or without a window in the first place) can accurately quantify gamma and x radiation greater than about 60 keV. If you have an x-ray machine which has a lower energy beam, then it would be more appropriate for you to obtain a low-energy photon detector rather than trying to extend the range of a G-M hotdog detector by opening the "beta window."

As always, if you have any questions or comments regarding G-M hotdog detectors or any other type of radiation detection equipment, please write or call me in care of this magazine.

Endnotes

1. TGM Detectors, Inc., 160 Bear Hill Road, Waltham, MA 02154-1075, 617/890-2090.
2. LND, Inc., 3230 Lawson Boulevard, Oceanside, NY 11572, 516/678-6141.
3. Ludlum Measurements, Inc., 501 Oak Street, Sweetwater, TX 79556, 800/622-0828.
4. Bicron, 6801 Cochran Road, Solon, OH 44139, 800/472-5656.
5. Victoreen, Inc., 6000 Cochran Road, Cleveland, OH 44139-3395, 216/248-9300.

G-M Hotdog

“Do’s” and “Don’ts”

DO

- ❑ Use to measure exposure rates (mR/h)
- ❑ Use with “beta window” always closed
- ❑ Use to measure gamma and x radiation with energies greater than about 60 keV
- ❑ Calibrate to ^{137}Cs
- ❑ Use with detector perpendicular to source
- ❑ When purchasing new equipment, buy energy-compensated detectors.

DON’T

- ❑ Use to measure surface contamination
- ❑ Use to evaluate wipe surveys
- ❑ Use with “beta window” open
- ❑ Use for personnel frisking
- ❑ Use to measure beta or alpha radiation, or gamma- and x- radiation with energies less than about 60 keV
- ❑ Read the cpm scale
- ❑ Calibrate only electronically
- ❑ Use “head on” onto the source

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