Deadtime in Geiger Mueller Tubes

By George Dowell

Inside any discharge tube is a fill gas that ionizes when it encounters a charge that exceeds its breakover potential.
Some examples of discharge tubes are neon lamps, mercury vapor lamps, microwave T-R switches, Voltage regulators, and Geiger Tubes. In all cases, the "on" resistance* is very low compared to the "off" resistance*, and external means are provided to limit the total current drawn by the device, as it is essentially a short circuit when the gas is ionized.
For most of the glow tube applications, discharge, once established, is maintained as a part of the tube's function. To extinguish the discharge,
the supply Voltage is reduced significantly, or removed.

Consider now the a tube which is charged to a steady DC Voltage somewhat below it's ionization potential. Any extra energy added to the gas will cause it to ionize totally. This energy can be in the form of RF, light, electricity, x-ray, or a charged subatomic particle. Indeed, RF "sniffers" have been made that rely on this principle.
Since the extinguishing Voltage level is much lower than the ionizing Voltage level, a tube once ionized will remain so until the steady state
Voltage is reduced or removed.

When a GM (Geiger-Muller) tube is used in a Geiger Counter, a series of pulses is desired instead of a single pulse. Removing the Voltage and
reapplying it would be difficult and cumbersome, so another gas, called a quench gas is introduced into the fill gas. The purpose of this addition is to chemically extinguish the ionization after a short period of time, rendering the tube ready to respond to the next charged particle. In**
practice this approach works well, but takes a finite amount of time to complete each cycle. During the time in which the tube is ionized by the last radiation particle, it is of course not available to register any subsequent particles that may
arrive, until the quench cycle is complete.

Quench cycle time delay is short but measurable and very meaningful, as it gives rise to two important parameters that deleteriously affect all GM tubes, namely "*SATURATION*" and "*DEADTIME*". Both are easy to understand in theory but somehow are just as easily overlooked in practice.

All GM (Geiger-Mueller) tubes need a certain time to refresh themselves after a pulse, before they can be ready for another pulse. The period of time after a pulse but before the tube can create another pulse is called DEADTIME.
Even though this time is short, on the order of 20 microseconds for the pancake tube, longer for metal tubes, when the pulses come fast and furious there reaches a point where

the tube simply can't respond any more. Modern instruments recognize this situation and respond with an alert of some kind. Some sound an alarm; most send the meter to beyond full scale. Without this protective action, a meter can actually read zero in a very high radiation field. Such a condition is called SATURATION.
When in saturation, a tube cannot indicate radiation any more and presents a short circuit to the electronics. CDV-700's have no such protection circuit so will go dead in a high radiation field.

Way before saturation, a GM tube will start to suffer effects of deadtime. Simply stated, doubling the actual radiation field will not yield twice the count rate, but less than twice. The higher the count rate, the less will be the increase, up to a point where there will be no further increase in a higher field.

First let's examine *SATURATION*. It should be obvious if a heavy stream if radiation is encountered, the particles will arrive faster than the tube has
a chance to recycle itself. Such a condition results in continuous discharge, and in essence the tube goes dead. A saturated GM tube will seem
to be reporting low or even zero radiation, even though the actual radiation is dangerously high. A serious and possibly life threatening situation for workers in areas where such high fields might be encountered, as in nuclear power generation and nuclear medicine applications. In order to at least recognize the onset of saturation, most modern Geiger Counters are equipped with a "*saturation alarm*" which is an electronic system that recognizes the effects of over saturation and alerts the operator that reading are inaccurate at that point. Some manufactures include an audible alarm, but almost all will cause the meter reading to go full-off-scale. Photo Multiplier Tubes (PMT) used in scintillators have no such limitations, and can report many times more pulses than a GM tube, depending upon the crystal in use. Plastic scintillation material, although only about 15% as effective as NaI, does have a much faster (narrower) pulse than NaI (Tl), into the nanoseconds. When a scintillator is used with a Geiger Counter that incorporates a saturation alarm, the alarm must be disabled. Some makers include a switch for the purpose, in some models there is no way to easily disable the circuit, so essentially hey are made for GM use only. We have overcome this deficiency in some units, and published some easy mods on the Web.

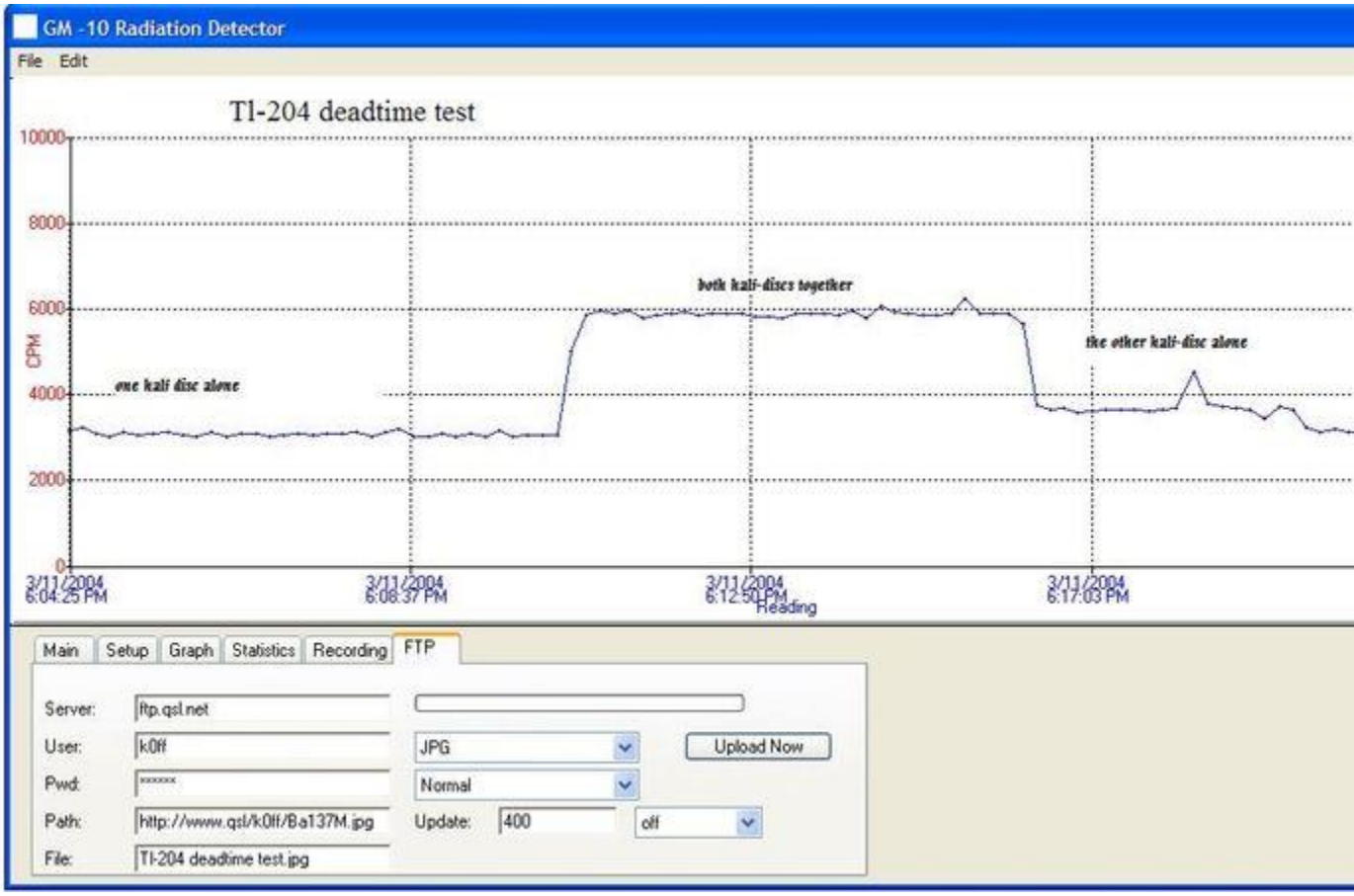
Next we'll investigate *DEADTIME*.
The action of recycling a GM tube takes a certain amount of time as we have discovered. In a typical pancake tube that time is 20 microseconds, some end-window tubes run 90-150 microseconds, and metal hot-dog tubes are typically 100 microseconds.

Using the pancake' s figure of 20 uS, you might expect that the tube could produce
1,000,000/20= 50,000 CPS or
50,000 CPS x 60S= 3,000,000 CPM.

In practice I have found the max pulse rate to run far short of the calculated, by experimenting with 4 similar Alpha sources, each capable of

giving 150,000 CPM (on a pancake). Two such sources used together yield 300,000 CPM as expected. Increasing the number of sources to three only increases the count to 400,000, not the 450,000 expected. Adding the fourth source does not increase the count beyond 400,000 CPM. This indicated to me that deadtime has come into play. Even with 4 sources, we still have not saturated the tube however.

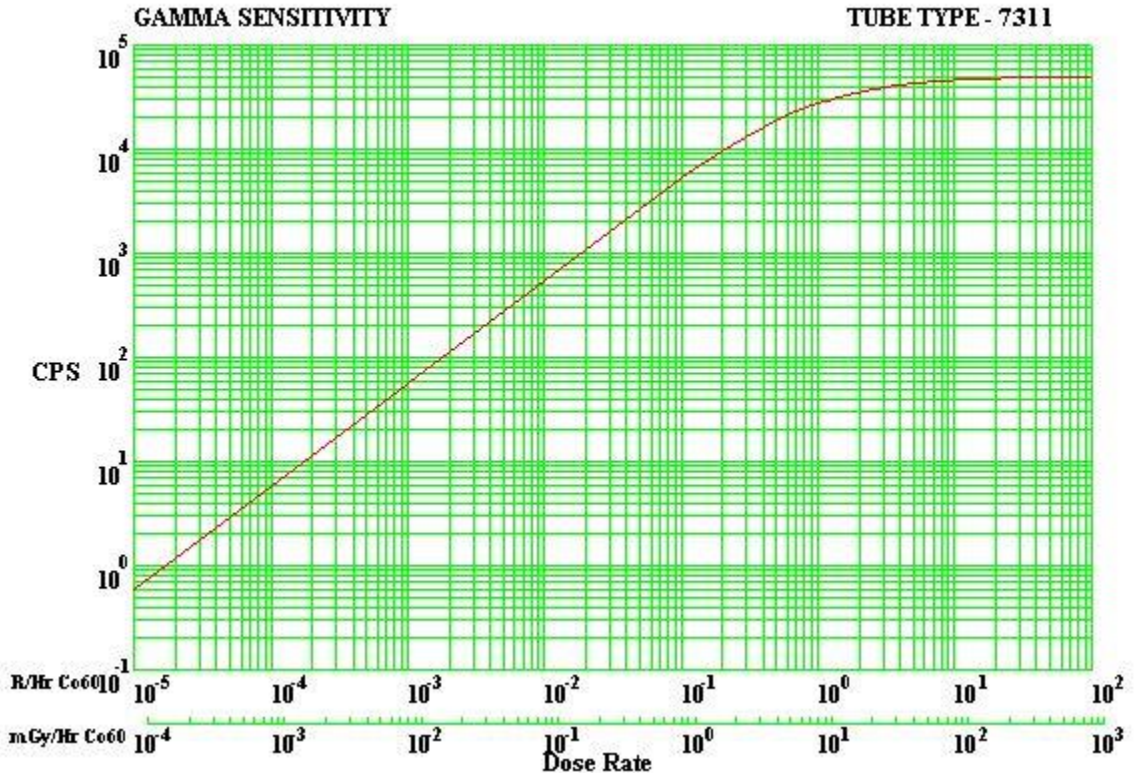
Shown here is a scan of a pancake tube subjected to the Response Test, using the Spectrum Techniques Tl-204 split disc test set. Similar to the Alpha test outlined above, but uses two Tl-204 Beta sources. Observe the close correlation to the calculated algebraic values, indicating that the total dose is still within the linear part of the curve.



Some instruments can extend the upper range of usefulness of the GM tube by electronic means. Certain military versions, especially the PDR-63 use a sophisticated HV power supply which itself is pulsed, artificially shutting off the tube, which allows more CPM to register. Another approach, as used in my Ludlum model 2500, which is the main bench instrument I use for all testing, consists of electronically delaying the acceptance of the next count by a certain amount of time. Effectively killing input from the probe for a preprogrammed time until it is known that the probe is ready again. A switch marked

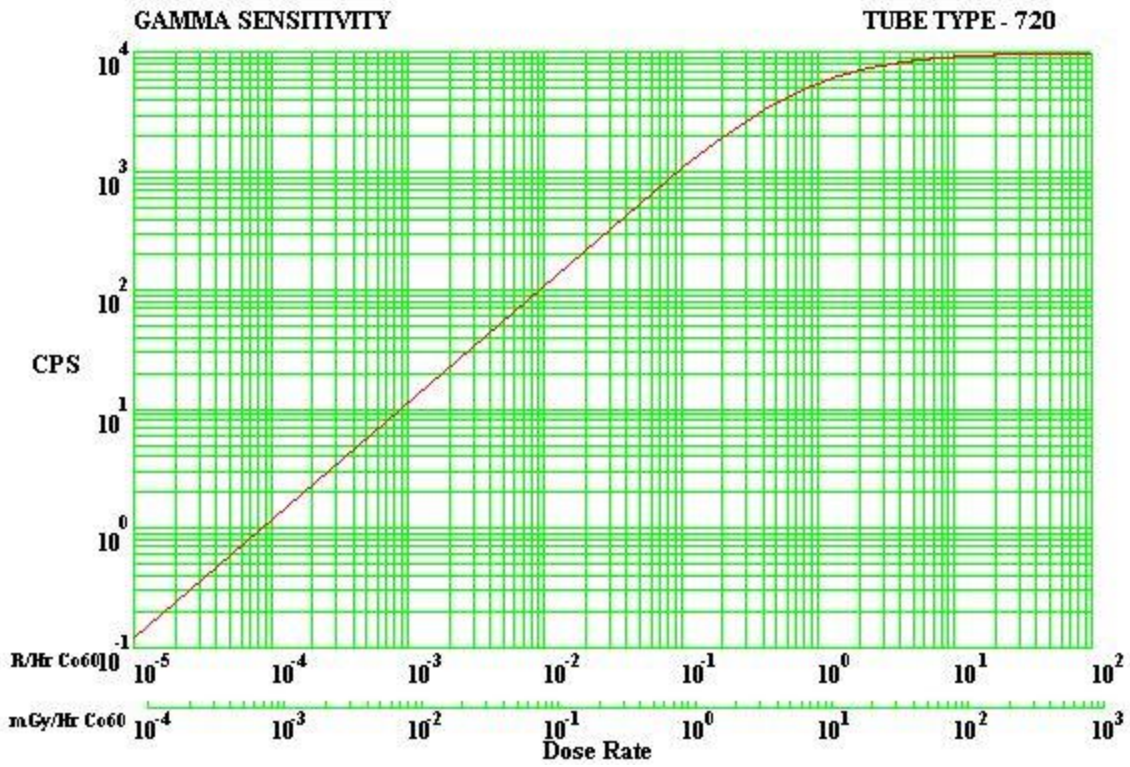
"Clock-time/Live Time" is self-explanatory, and allows the count to proceed only during periods that the tube is presumed to be "live". It may take several minutes to accumulate enough "live time" to fulfill a one-minute timed sequence. All the assumptions are made internally and may or may not be appropriate for every tube in use.

Looking at the "Gamma Sensitivity" curve of the pancake probe (LND 7311) see figure:



You will notice it has a flat response to a little beyond 10, 000 CPS. That's counts per second. Multiply that by 60 seconds in a minute for 600,000 CPM. Not bad.

Now consider the same type chart for the LND 720 tube, the closest equivalent to the standard 6993 as issued with CDV 700:



Notice that it starts to flatten out past 1,000 CPS or 60,000 CPM.

Further, look at the deadtime figures for the direct modern replacement for the CDV-700' s #6993 QPL:

720 Spec.LND 720
THIN WALL BETA-GAMMA DETECTOR

Other Available Data Gamma Sensitivity Curve Printable Line Drawing Photograph

GENERAL SPECIFICATIONS
Gas FillingNe +Halogen
Cathode Material446 Stainless Steel
Maximum Length (inch/mm)3.76 / 95.4
Effective Length (inch/mm)0.75 / 19.1
Maximum Diameter (inch/mm)0.63 / 16.0
Effective Diameter (inch/mm)0.61 / 15.5
ConnectorJedec A3-1
Operating Temperature Range 0C-40 to +75

WALL SPECIFICATIONS
Areal Density (mg/cm2)40-60

Thickness (inch/mm)0.003 / 0.076

ELECTRICAL SPECIFICATIONS

Recommended Anode Resistor (meg ohm) circuit diagram1
Maximum Starting Voltage (volts)800
Recommended Operating Voltage (volts)900
Operating Voltage Range (volts)850 - 1000
Maximum Plateau Slope (%/100 volts)10
Minimum Dead Time (micro sec)100
Gamma Sensitivity Co60 (cps/mR/hr)12
Maximum Background Shielded 50mmPb + 3mmAl (cpm)15
Tube Capacitance (pf)3
Weight (grams)20

and you will see them listed at 100 microseconds, or 5X longer than the pancake tube.

The pancake is not only more sensitive than the hot-dog, that is will return up to 5X the counts for a given Gamma sample; it is capable of recording almost 10X the total counts before going "saturated".

Even at X1000, the CDV 700 (modified) will still represent a meaningful reading at full scale when used with the GEO-210 or any 2" pancake based on the LND 7311 tube, but not the hot-dog types.

Most commercial meters which contain a X1000 scale also have markings that indicate "scintillators only" so that the operator is not tempted to believe the readings as being correct when used with the GM tube.

When making measurements to report to our group, I always use clock time, so the readings will have some meaningful comparative value to other's instrumentation.

Have FUN!

Geo

Comments, criticism and questions will be appreciated and may be directed to the author by email to GEOelectronics@netscape.com