Gamma Energy Response of Detector Probes.

By George Dowell

A complicated issue, let's shed some light on it and simplify.

First what is energy level as applied to nuclear radiation?

We all know what color is when applied to light. Most of us know what frequency is when applied to radio or television signals. We know automatically when a metal object is heated in a fire, that the hotter it gets, the color changes from red to orange to yellow and then to white. Finally consider the baseball. This object will fly through the air with some speed, more or less, depending on how hard it was hit. In this case the SPEED is the unit used to measure the ENERGY imparted to the ball. These are all examples of the same thing that energy level is, as applied to nuclear radiation. The more energy that is in a particle or electromagnetic radiation, the higher is its frequency, color or energy level. All are the same thing.

Nuclear radiation that we amateurs are likely to encounter come in 3 basic types, two are particles of matter, one is electromagnetic. Often more than one type will come from a particular radioactive material. Some mixed sources like Uranium ore will have all types.
Please download the Natural Decay Series charts and keep them for future reference:

SEE
http://groups.yahoo.com/neo/groups/GeigerCounterEnthusiasts/files/101%20Tutorials

ALPHA PARTICLES **are tiny clusters of matter consisting of two *PROTONS* and two *NEUTRONS*. Since they come from inside a *NUCLEUS* of an *ATOM* during *NUCLEAR DECAY*, they are technically called *NUCLEAR RADIATION.* The two Protons add a double positive charge to the Alpha particle as well as two mass units of weight. Two Neutrons each add mass units of weight, but do not add any charge one way or the other. Alpha particles are the heavyweights of nuclear radiation, being the most massive type of all. Their size, weight, and electrical charge keep them from penetrating very much other matter, even air. They cannot penetrate even the outer layer of dead skin on people, nor more than 2 inches or so of air. Set by the mechanisms that create them inside the nucleus, Alpha particles will have an inherent energy of 4 to 7 Million electron Volts (abbreviated MeV, the unit of radiation energy). That energy is quickly imparted to thousands and thousands of other atoms in the environment in a very short period of time. Once their energy is gone, the Alpha particle will pick up a few electrons from the environment and retire as an atom of helium.**

Most Geiger Counter probes, especially those made of metal, cannot detect Alpha particles because the wall material blocks the radiation from entering to the sensitive gas inside. There are a few specially designed detector probes that can pick up Alpha particles; those are called mica-window tubes, which come in two styles called PANCAKE and End-Window. The difference is the shape of the tube.

BETA PARTICLES **are also tiny bits of matter that come out of decaying nuclei. In this case, they are exactly like electrons in weight and charge. Their mass units of weight are so small as to be ignored. Beta particles come in energy ranging from a few eV to many thousands of eV (called keV). Usually a Beta particle has a negative charge, but sometimes they can have a positive charge, in which case we call them** ***POSITRONS*****. Beta particles can penetrate much deeper than Alpha particles, to a distance of about 10 or 12 feet in air, and up to half an inch in wood. Their range in air can be calculated as about 10 feet per MeV of energy. Neither Alpha radiation nor Beta radiation is much of a concern to humans when they are outside the body. Great care should be taken so as not to ingest or inhale any radioactive material though, as they can cause real damage inside the body.**

Both Alpha and Beta particle's energy level should be compared directly to the baseball analogy. The more energy they contain, the FASTER they will travel. Pretty simple. How fast they travel will determine how far they can travel, or how deeply they can penetrate.

GAMMA RAYS **>Now we get to the electromagnetic radiation. Gamma Rays and X-Rays are identical electromagnetic radiations, consisting of photons. Just like radio waves and light waves but of much higher frequency. Gamma Rays come from** ***INSIDE*** **the nucleus, making it a nuclear radiation. X-Rays come from the area of atoms** ***OUTSIDE*** **the nucleus so they are not NUCLEAR but ATOMIC radiation. It is important to remember that once they leave the atom, there is so way to tell them apart. Any time we refer to Gamma Rays, the same applies to X-Rays.**
Gamma Rays can have energy levels from a mere few eV to many MeV. They can be ***extremely*** **penetrating, being able in some cases to go through many FEET of concrete! Gamma Rays are called** ***Penetrating Ionizing Radiation*****. In air they can travel a great distance, many hundreds of feet, maybe much more. In space, they have NO range limitations; Gamma Rays arrive at earth from other solar systems, even other Galaxies. Electromagnetic photons of any types travel at the speed of light. Nothing can make then travel any faster than that. When extra energy is poured on, they don't go faster, but their frequency increases. This extra energy is very real and must be dissipated before the photon can slow down enough to be absorbed by a physical particle. Energy is lost to physical particles through several mechanisms,** ***COMPTON SCATTERING*****,** ***PAIR PRODUCTION*** **and** ***PHOTOELECTRIC EFFECT*****..**

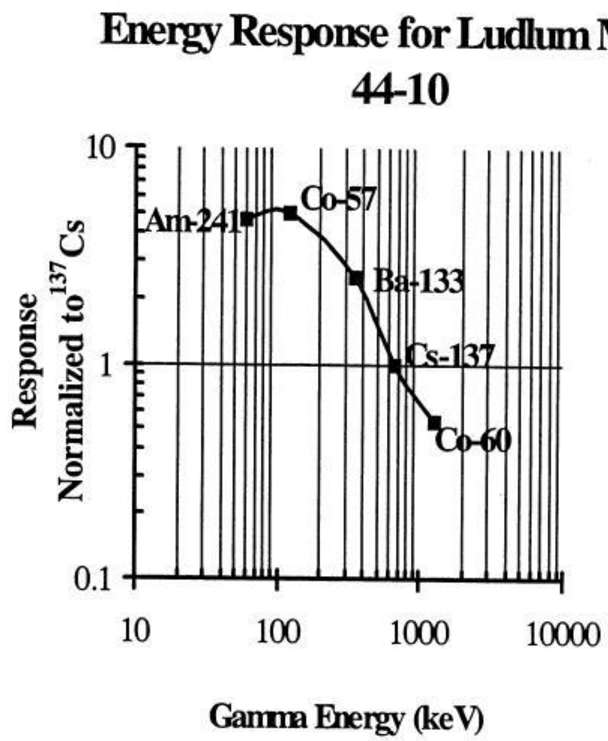
Now the basics have been covered, let's move forward to our subject of ***Gamma Energy Response*** **of detector probes.**

Detecting Gamma Rays presents many interacting challenges. The mechanism of detection varies depending on the type of probe. Geiger Muller Tubes (GM tubes) work by gas ionization when a photon interacts with an atom, giving off a charged particle. It is actually the charged particle that is detected. Less than a fraction of one percent of the detected interactions come from the Gamma Ray interacting with a gas molecule. Mostly they come from the Gamma Ray hitting an atom in the tube wall. It should be obvious that the location of that interaction must be just in the right place for the secondary charged particle to be able to escape into the sensitive gas volume thus being detected. Virtually all charged particles that enter into the sensitive gas volume will be detected, unless the tube is busy recovering from a recent pulse from another event just previous. The time it takes for the tube to reset and be ready for the next pulse has a large bearing on how many pulse the tube can detect in a given time frame. Most GM tube based probes are very efficient at detecting Beta particles, Alpha Particles if they have a mica window, but inefficient at detecting Gamma rays (<1% common)

Scintillations probes work on a different principle, this being the Gamma Ray interacts with the molecules in the detection crystal and give off a pulse of light. It is those light pulses that get detected by a very sensitive electric eye tube called a *PHOTOMULTIPLIER (PMT).* These light pulses are converted into electrical pulse by the PMT. Those electrical pulses are processed by the Geiger Counter Meter in a way very similar to the pulses from GM tubes.
Efficiencies are at least an order of magnitude better than GM tubes.

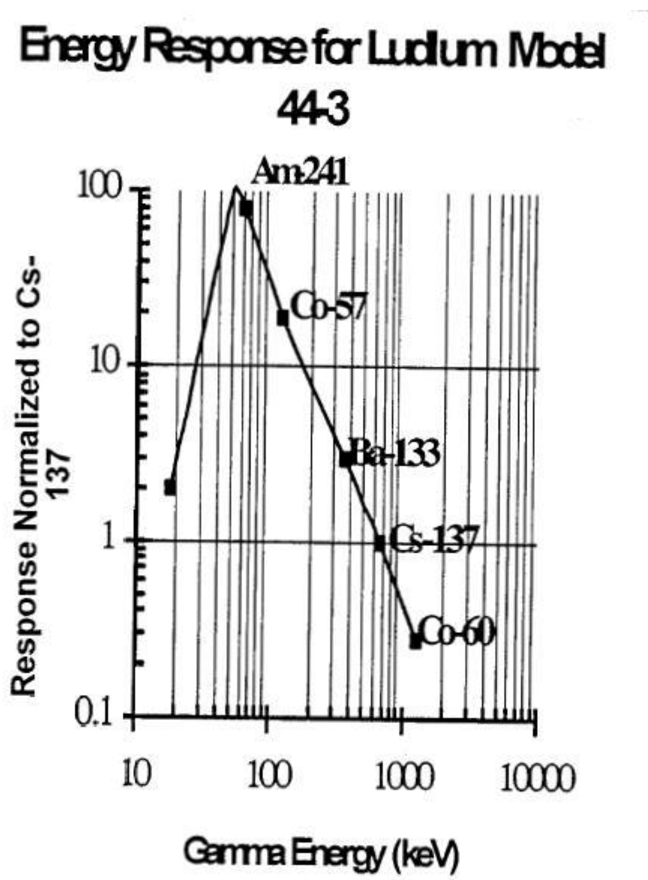
***Gamma Energy Response* of any probe will be altered by the wall thickness of the probe, the mass of the sensitive volume material and the thickness or volume of that sensitive material.**
First the Gamma Ray must be able to penetrate the probe wall. The thicker or denser that wall, the higher the energy level needed to penetrate it. Weak energy Gamma Rays will simply be absorbed by the wall material.
Once the critical energy of penetration is reached, the detection efficiency will increase right along with increase of energy level. This will remain constant until the Gamma Ray energy reaches a point where it simply starts to pass right through the probe without interaction.

With the scintillator probe, that is pretty much the end of the story. Refer to the energy curve of the Ludlum 2" x 2" NaI(Tl)



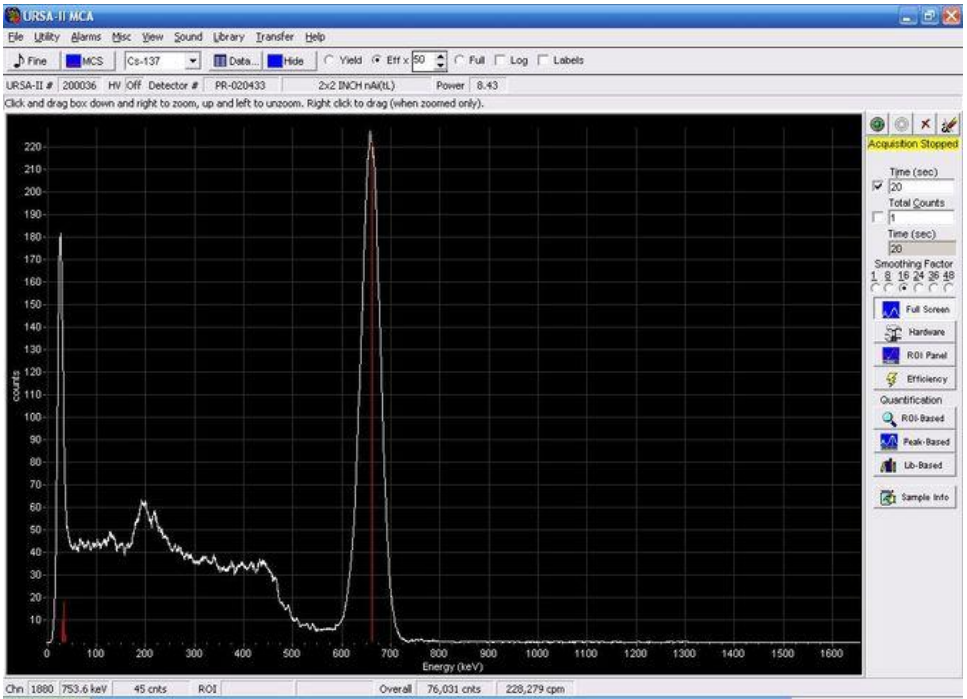
Below a certain energy, the Gamma Ray cannot get inside. Once it does, detection increases with increasing energy until about 100 keV, where it falls off in a pretty straight line. This Model 44-10 probe is a general purpose High Energy Gamma only detector with relatively thick walls, and a thick crystal. The roll off towards higher energies is gentler than a smaller crystal would be. Downside of this construction geometry is the higher background count rate.

Next look at the energy response curve of a Ludlum 44-3 probe.



It has a much thinner crystal, and a specially designed entrance window of low mass material. Initial energy of a very low 10 keV will start to be detected, but efficiency rolls off very quickly at higher energies. The description of this design is Low Energy Gamma Probe or LEG. It OVER-RESPONDS at the energy around 100 keV by X10 and UNDER-RESPONDS by a factor of .5 at Energies around 1000 keV, using the "normalized" energy reference of 662 keV, the Cs-137 peak as the reference point. Most probes use Cs-137 to rate their performance.

Shown



is a Gamma Spectrum Scan that I took using a High Energy Gamma Probe, and a Spectrum Analyzer. The 32 keV peak from the Cs-137 is on the left, while the 662 keV is represented on the right. Actual detected pulses outline the shape of the scan, but underlain are red lines that indicate the TRUE ratio of the disintegrations. It is obvious that the lower energy disintegrations produce MORE COUNTS than their higher energy partners. When doing real science, these over- and under- response factors must be accounted for, using the charts given for each probe types. The makers of the different probes ALWAYS have those charts.

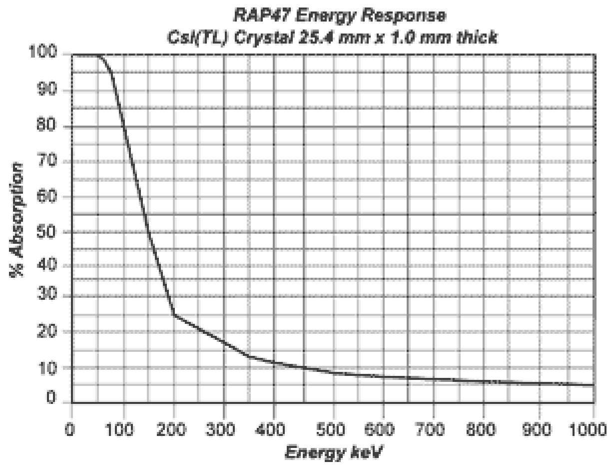
Keep a copy of DECAY program on your computer for ready reference as to the ratios of different energies, their energy level and "probabilities" of occurrence.

Get it FREE Here:

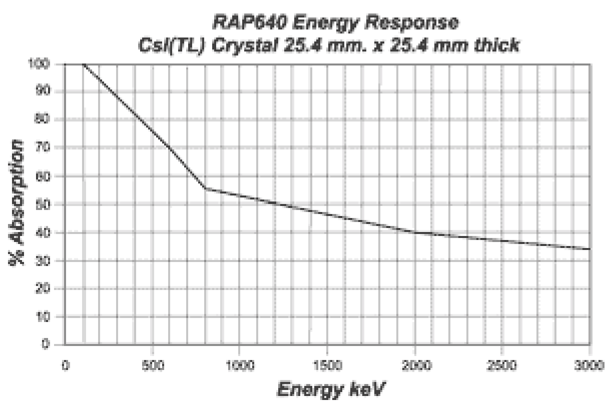
http://tech.groups.yahoo.com/group/GeigerCounterEnthusiasts/

Probability just means for a certain number of disintegrations, what percentage of them will contain these energies. Since radiation is a random event, the probabilities will even out to real statistics with more and more samples taken.

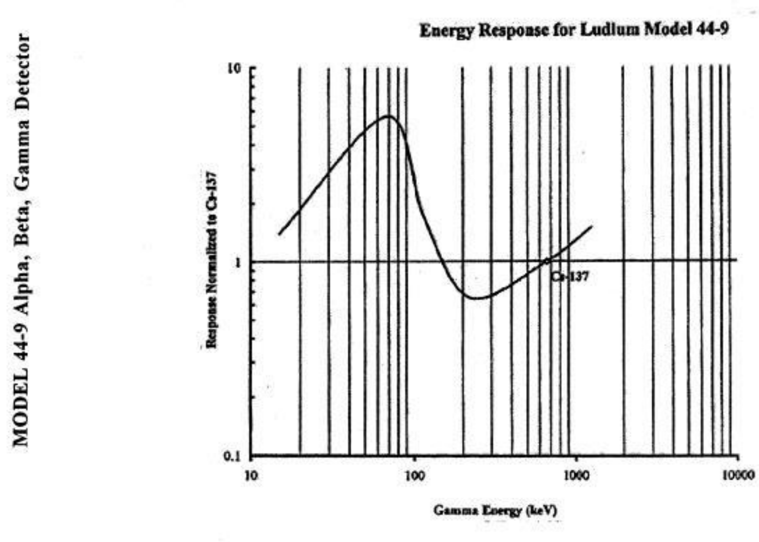
Thin section 1" diameter CsI(Tl) probe:



Thick 1” X 1” diameter CsI(Tl) probe:



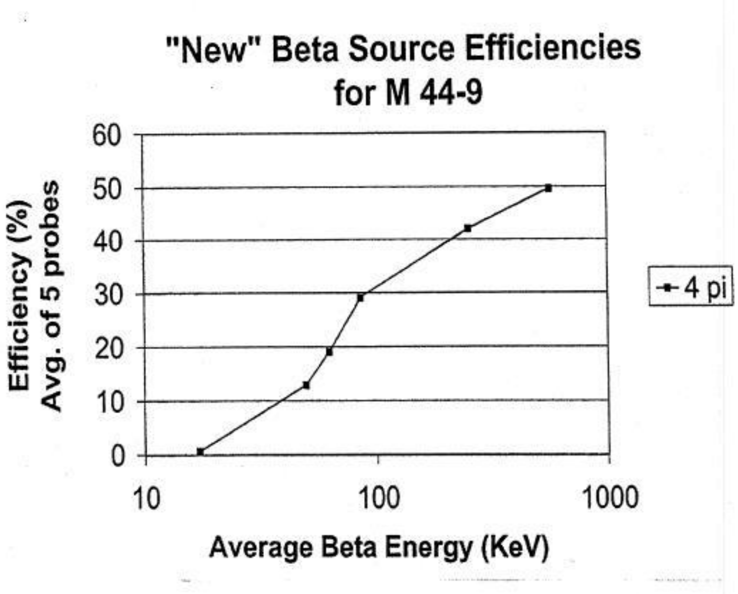
Finally. Let’s take the unique case of the mica-windowed Pancake Probe. Look at its Gamma Response curve



Here: http://www.qsl.net/k0ff/index_files/44-9-GammCurve.JPG

Notice that it has a double curve to it. Mechanisms at work here are complex and have to do with where in the tube does the Gamma Ray have an interaction, be it the near wall, the gas itself for the far wall. Also past a certain specific energy level, 1022 keV, the method of interaction changes from predominately the Photoelectric to predominately the Pair Production method. Because of this wild fluctuation, Pancakes are considered only a DETECTOR probe not a measurement probe for Gamma Rays.

Now look at the Beta Response curve for the Pancake Probe. See how it gets better and better as the Beta energy increases? The same would apply to Alpha particles. Efficiency is nearly 100% for Alpha and Beta particles that pass through the very thin mica window, making this the general-purpose, all-purpose probe of first choice.



Very few radiation detection probes will respond to all energies of Gamma radiation with the same results. These are rare, usually insensitive and always expensive. Once we realize that a certain amount of radiation of one energy will give a certain reading, but the same amount of radiation of another energy will read 10 times more or 1/10th as much on the meter, we will have a better handle on the situation. For me personally, this realization made it mandatory that I learn to discriminate the different energies, and use that information to reliably calculate toe real scenario, and further to use that same information to identify the isotope causing the radiation in the first place. This branch of our hobby is called Gamma Ray Spectrum Analysis. If you too become bitten by this bug, please join us on the Yahoo chat group:
GammaSpectrometry.

In the above text, the first instance of an important word or phrase has been *CAPITALIZED, ITALICIZED and UNDERLINED*. These are terms with which you will want to become familiar if you are not already. Depending upon your method of viewing this article, you may it may not see the underlining or italics

Have fun,
Geo
George Dowell

Comments, criticism and questions will be appreciated and may be directed to
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