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GEIGER COUNTERS
and also
Notes on radioactivity and its measurement

TECHNICAL TERMS

"Geiger Counter" is the general colloquial term for a device that detects radiation.

When reading this booklet a more precise definition might be useful:

- The Geiger Counter is the probe that connects to the box (inside the probe is a Geiger Muller Tube). It is these probes that are manufactured here in Watford, England. The probe can be referred to as a Geiger counter, Geiger detector probe, Geiger counter probe, the Detector, or the Counter.

- The remainder of the machine is the box containing the electronics, the batteries and the meter that gives the reading. These are manufactured nearby in London.

- The complete instrument is a Radioactivity Monitor, it is checked and calibrated here in Watford.

Most manufacturers use halogen-quenched counters because they have a low operating voltage, large signal output and infinite count life. However, they are dependent on the electronics for their performance. By contrast, our counters are organically-quenched, they are not circuit-dependent *and* they are 100% efficient in counting every electron that enters the active volume (a halogen-quenched Geiger counter is only 95% efficient). Finally, halogen-quenched counters have windows that are "dag" coated whereas the windows on our organically-quenched counters are nano coated (aluminised). There is no other manufacturer in Europe/USA (and quite possibly the world).

BULK ORDERS and TUBE-ONLY ORDERS

We are happy to sell the radioactivity monitors from our web site. For those laboratories, electronics companies and Government Departments who wish to buy in bulk, or who wish to buy the Geiger Counters alone, please email your details.

THE RANGE

We supply three models of radioactivity monitor. See overleaf for prices.

The first two (the Gem 400 and Gem 500) are variations of the same instrument. The Gem 400 is a low-cost portable instrument for carrying into the field, the Gem 500 is a high quality bench instrument for use in laboratories. The third model (the Gem 100) is completely different, giving two modes of counting for greater accuracy.

This booklet was last modified in April 2011

GEM 400 SPECIFICATION

£475.00 including VAT

- The instrument has a Geiger counter sensitive to Alpha and Gamma radiation and high sensitivity to Beta particles.
- The analogue meter indicates the level of radiation in counts per second and an internal loudspeaker provides the familiar Geiger counter clicks.
- The complete instrument is easily handheld.
- Powered by 1.5 volt AA batteries (will run for up to 200 hours).
- The instrument is supplied with an operating manual which enables the user to relate the number of counts to radiation levels. A calibration certificate is supplied.
- A carrying case is included
- The Geiger counter detector itself has a 50mm diameter ultra-thin window protected by a stainless steel grill
- Only one control knob. No adjustments are necessary.
- Always ready for immediate use.
- British made.

Radiation	Typical sensitivities* ($cps/Bq.cm^{-2}$)	Source	Max energy (MeV)
Alpha	1.3	^{241}Am	5.49
Beta	3.6 3.3 1.5 1.0	$^{90}Sr/^{90}Y$ ^{204}Tl ^{147}Pm ^{14}C	2.27 0.77 0.23 0.16
Gamma	7 ($cps/\mu Gy.h^{-1}$)	^{137}Cs	0.66
* to within ±25%. Individual calibration supplied with instrument			

Background count rate	less than 1cps
Geiger tube lifetime	approx 5 X 10^8 counts
Geiger tube max count rate	approx. 1500 cps
Geiger window area	$19.6cm^2$ (50mm dia)
Nominal window weight	less than 2mg/cm

GEM 400 RADIOACTIVITY MONITOR

- Geiger counter (50mm dia.) with high sensitive to high-sensitivity to Beta particles and useful sensitivity to alpha and gamma radiation.

- Only one control knob. No adjustments necessary.

- British made.

GEM 500 SPECIFICATION

£720.00 including VAT

The *GEM500* is a high-grade laboratory radiation measuring instrument. The detector is a 50mm diameter end window (mica) Geiger Muller counter fitted with a protection grille. This can easily be removed to allow closer access to the window. The organically-quenched counter has, unlike its halogen counterpart, a 100% counting efficiency to any electron entering the active volume of the counter. The instrument is supplied with a calibration certificate and manual.

Radiation	**Typical sensitivities*** **($cps/Bq.cm^{-2}$)**	**Source**	**Max energy (MeV)**
Alpha	1.0	^{241}Am	5.49
Beta	3.6 3.3 1.5 1.0	^{90}Sr/^{30}Y ^{204}Tl ^{147}Pm ^{14}C	2.27 0.77 0.23 0.16
Gamma	7 ($cps/\mu Gy.h^{-1}$)	^{137}Cs	0.66
* to within ±25%. Individual calibration supplied with instrument			

Background count rate	less than 1cp
Geiger tube lifetime	approx 5 X 10^8 counts
Geiger tube max count rate	approx. 1500 cps
Geiger window area	19.6cm^2 (50mm dia)
Nominal window weight	less than 2mg/cm
Batteries	4 X AA/IEC6 1.5 V cells
Battery lifetime	250 hours (alkaline)
Size	55 X 65mm dia (probe), 160 X 135 X 100mm (electronic unit)
Weight	1 Kg

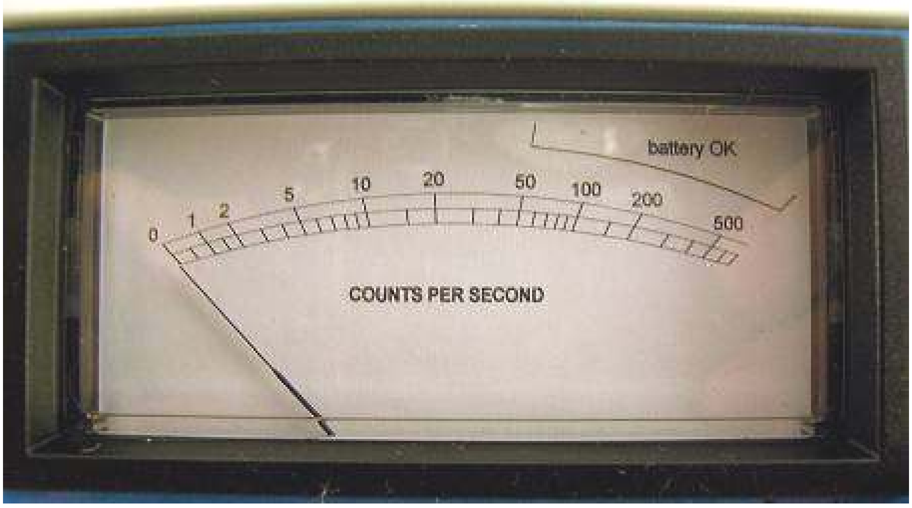
OPERATING AND STORAGE CONDITIONS

Temperature	-10 to +40°C
Pressure	65cm Hg min.
Humidity	85% RH max.

MADE IN UK

GEM 500 RADIOACTIVITY MONITOR

- Laboratory Standard radiation monitor.
- Geiger detector probe sensitive to Alpha and Gamma radiation, and with a high-sensitivity to Beta particles.
- Damped meter movement
- Easy removal of protective grille, easy tube replacement



GEM 100 SPECIFICATION

£835.00 including VAT

The Gem100 is a handheld battery-operated radioactivity measuring instrument which consists of a detector probe connected by coiled lead to an electronic unit. The detector is an end-window Geiger-Muller tube fitted with a protective grille. This can easily be removed to allow closer access to the window, and hence increase the sensitivity. The instrument has two basic modes: *ratemeter* which displays measured activity in counts per second (cps) and *scaler* which displays the total counts measured in a fixed, or user-determined, time period. The latter gives greater accuracy when measuring low activities. The instrument is supplied with a carrying case, calibration certificate and comprehensive manual.

Radiation	**Typical sensitivities*** **($cps/Bq.cm^{-2}$)**	**Source**	**Max energy (MeV)**
Alpha	1.0	^{241}Am	5.49
Beta	3.6 3.3 1.5 1.0	$^{90}Sr/^{90}Y$ ^{204}Tl ^{147}Pm ^{14}C	2.27 0.77 0.23 0.16
Gamma	7 ($cps/\mu Gy.h^{-1}$)	^{137}Cs	0.66
* to within ±25%. Individual calibration supplied with instrument			

Background count rate	less than 1cps
Geiger tube lifetime	approx 5 X 10^8 counts
Geiger tube ma count rate	approx. 1500 cps
Geiger window area	19.6cm^2 (50mm dia)
Nominal window weight	less than 2mg/cm

RATEMETER MODE		**SCALER MODE**	
Accuracy	± 1 count or ± 1%	**Timing intervals**	10, 50, 200, 1000, 5000s
Response time	2.5s	**Timing accuracy**	± 15ppm ± 3ppm/degC
Alarm level	750 cps	**Maximum count**	999999 (6 digits)

Batteries	4 X AA / IEC6 1.5V cells
Battery life	80 hours (standard and rechargeable NiCd, per charge), 250 hours (alkaline)
Size	55 X 6mm dia. (detector probe), 180 X 100 X 45mm^3 (electronic unit)
Weight	140g (detector probe), 450g (electronic unit)

OPERATING AND STORAGE CONDITIONS

Temperature	-10 to +40°C
Pressure	65cm Hg min.
Humidity	85% RH max.

GEM 100 RADIOACTIVITY MONITOR

Geiger detector probe sensitive to alpha and gamma radiation, and with high sensitivity to Beta particles.

- Ratemeter and Scaler functions and tube replacement versatility.

- Powered by standard 1.5 Volt AA cells giving long battery life (up to 250 hours continuous operation).

NOTES ON RADIOACTIVITY AND ITS MEASUREMENT

by Nick Hartley (edited by Raffi Katz)

INTRODUCTION

Geiger Counters are generally known as Contamination Monitors and are the first line of defence in alerting people to radiation leaks or accidents. They make an otherwise invisible threat audible and measurable. Counts per second (cps) is what you should be measuring if you want to detect materials that have been contaminated, you would then contact the authorities if you found anything with a high reading, it is not for you to decide the level of risk.

Radioactivity is the emission of energetic particles from substances with unstable atomic nuclei, it can be produced in a nuclear reactor, as fall-out from a nuclear explosion or in a particle accelerator. It also occurs naturally.

Very few of the 92 elements making up the natural world are radioactive. Those that are, tend to be the ones with high atomic weight (e.g. Uranium, Radium, Polonium) and have a stable form (e.g ^{238}U) and one or more unstable forms (referred to as isotopes, e.g. ^{235}U, ^{239}U). The left superscript refers to the atomic weight (i.e they have the same proton number, in this case 92, hence the same chemical properties, but a different neutron number from the normal, stable element).

When an atom emits a particle, it changes into another element (unless a gamma is emitted) which itself may be unstable, then emits another particle and so on until a stable element is reached. In the case of Uranium 235, there is a long chain of so-called daughter radio-isotopes ending in Lead. This process is called radioactive decay, as the source material is eventually spent. The time it takes for half of the source material to be used up is known as the half-life, and can be anything from microseconds to thousands of years.

UNITS OF MEASUREMENT

The most basic unit of measurement is the **Becquerel (Bq)** which tells you how many radioactive particles (alpha, beta or gamma) are being produced by a source every second. These spread out equally in all directions. A Geiger Counter (GC) placed close to the source will detect up to half of these (the other half go in the wrong direction), provided the source is smaller than the GC window (this is what the text books mean by , “It depends on the geometry of the source and the detector” below) and provided they are sufficiently energetic to pass through this window (a thin mica sheet). E.g. Tritium, an isotope of hydrogen, cannot be detected for this reason. Most common sources (^{14}C, ^{32}P, ^{131}I, ^{137}Cs…) can be detected.

A Geiger counter indicates **cps (counts per second)** and this is easily converted into Bq using the calibration factors provided with the instrument.

An older unit of measurement is the **Curie (Ci)**, which equals 37 x 10^9 (37 billion) Bq, a huge quantity, so milli- (thousandths) or micro- (millionths) of a Ci are more commonly quoted.

Radiation causes ionisation in living tissue, which damages biomolecules, in particular DNA, resulting in genetic damage and cancers. The ionising energy is measured in **Grays** (the same as Joules per kilogram) which requires a knowledge of radiation type (alpha, beta, gamma) and its energy. Alpha radiation has the shortest penetration distance, but is nonetheless dangerous if absorbed into the body where a ‘hot’ particle can overexpose surrounding tissue. A Geiger counter cannot tell us this energy. Grays can be measured using a Scintillation counter, Ionisation chamber, Proportional counter or semiconductor detector, and these are expensive. Often, samples of radioactive materials, detected by Geiger Counter are brought back to a lab for this kind of measurement.

To determine the actual effect of radiation on the body one needs to know the total ionising energy that has been received and which organs have been exposed. This depends on the source/body disposition, the exposure time and the radiation type. In addition, certain organs are more sensitive than others to radiation damage (e.g. gonads & bone marrow) and so a weighting factor has to be applied. The final result is measured in **Sieverts (Sv)** which and is a measure of "absorbed dose equivalent" of radiation.

For nuclear industry workers, who wear film or thermoluminescent badges for measuring radiation over a long time period, the exposure limit is 50 mSv per annum, for aircraft crew, exposed to a higher level of cosmic rays (gammas), 10 mSv, for the general public, 5 mSv. Anyone working with radioactive sources or materials should be following strict regulations to minimise exposure risk; e.g dentists will always exit their surgery when X-rays are taken. The patient gets a Lead apron for body protection. The general background level is around 1 mSv p.a. due to cosmic rays penetrating the atmosphere to ground level. (These show up as an approximate 1 count per second on the GEM range of instruments).

TAKING MEASUREMENTS

A Geiger counter measures counts per second (cps), the number of radioactive particles entering the Geiger Muller (GM) tube through the thin end window. This is directly related to the activity in Bq. However, various factors should be taken into account:

1) Geometrical: radioactivity is random in direction; the GM tube only 'sees' the particles reaching it. For a point source, the number will decrease as the square of the distance from it. Try to get an idea of the extent of the source by taking many measurements in different positions around it.

2) Radioactivity is random in time too: variation in the count rate decrease as the square root of the cps. So higher readings are more accurate. Readings below 10 cps should have the background reading (usually around 1) subtracted.

3) Radiation is absorbed by its passage through air, liquid or solid. Therefore take readings as close to the source as possible. This is particularly true for alpha particles (see below). A single sheet of paper in front of the tube window is enough to screen out alphas.

For these reasons, accurate measurements are usually made in a laboratory with a thin sample presented on a 'planchette' immediately below the Geiger window (thin in order to prevent significant 'self-absorption'). Even then, only half the emitted particles on average are travelling in the right direction to be counted.

There are three main types of radiation; each type also has a characteristic energy, depending on the source material, measured in electron-Volts (eV). 1 keV = 0.16×10^{-15} Joule. 1 MeV = 0.16×10^{-12} J.

Some radio-isotopes emit more than one type of the following particles.

Alpha particles (charged Helium nuclei) are easily absorbed in solids and even in air have limited range, depending on their energy (e.g 1 cm for 2 MeV , 6 cm for 7 MeV).

Beta particles are fast electrons and have greater range, (e.g 15 cm range in air for 0.156 MeV Betas from Carbon 14).

Gamma rays are high energy photons (i.e quanta of electromagnetic radiation) and have the greatest range. These are hardly absorbed by air or other gases at all.

A Geiger counter, such as the Gem-400, measures all three types of particle, but is least sensitive to gammas. This is because gammas are only absorbed in the internal walls of the tube, knocking out some electrons which are counted.

CALCULATIONS

Radioactivity causes ionisation in exposed material, resulting in chemical and physical changes. Each radioisotope radiates its own particle(s) at specific energies. These are well documented (see e.g. Kaye & Labye Tables of Physical and Chemical constants) and see the table below. Knowing the source, the energy deposited in Grays (Joules/kilogram) can be calculated.

Radioactivity constitutes a health risk from the amount of ionisation caused by radioactive particles as they transfer their energy in living tissue and come to rest. Many thousands of atoms are ionised, causing unpredictable chemical activity in living tissue resulting in DNA code mutations, cell necrosis, etc, but the effect of ionisation depends on the nature of the radiation (alpha, beta, gamma). Alpha radiation, which is found to be particularly harmful, is ascribed a Quality Factor of 20, compared with 1 for Betas, Gammas and X rays. Neutrons have a quality factor of 10. This factor multiplies the ionising energy (in Grays) to determine the so-called *Dose Equivalent*, measured in Sieverts (Sv = J/kg). Thus 1 Gy of alpha radiation produces 20 Sv, 1 Gy of Beta radiation, 1 Sv.

A Geiger counter does not measure particle energy and hence cannot determine which radio-isotope is the source. For this an instrument with an energy-dependent response is needed, e.g a scintillation counter, ionisation chamber, proportional counter or semiconductor detector.

Finally, the effect of this radiation depends on the part of the human body exposed, and an additional risk weighting factor is introduced in order to arrive at the “Effective Dose Equivalent”.

For example:

Organ	**risk weighting factor**
Testes and Ovaries	0.25
Bone Marrow	0.12
Liver	0.06
Thyroid	0.03

The final figure is still measured in Seiverts. For nuclear industry workers the exposure limit is 50 mSv per annum (m for milli – one thousandth), for aircraft crew, exposed to a higher level of cosmic rays (gammas), 10 mSV, for the general public, 5 mSv.

The general background level is around 1 mSv p.a. due to cosmic rays penetrating the atmosphere to ground level. (These show up as an approximate 1 count per second on the GEM400.)

Some commonly encountered radionuclides:

Isotope	Particles emitted	Energy (MeV)	Half-life	Comments
^{3}H detection	beta	0.0186	12.33 years	energy too low for GM
^{14}C	beta	0.156	5730 years	
^{19}O	beta	3.26, 4.62 & 4.82	26.9 secs	
	gamma	0.197, 1.356 & 1.444		
^{32}P	beta	1.71	14.26 days	
^{35}S	beta	0.167	87.51 days	
^{60}Co	beta	0.318		
	gamma	1.173,1.333		
^{90}Sr	beta	0.550	28.78 years	
^{99}Tc	beta	0.290	2.11×10^{5} years	
^{131}I	beta	0.61		
	gamma	0.364,0.637,0.284		
^{137}Cs	beta	0.21	2.3×10^{6} years	
^{147}Pm	beta	0.22	2.6234 years	
^{210}Po	alpha	5.30	138.4 days	
^{223}Ra	alpha	5.54,5.61,5.72,5.75	11.44 days	
	gamma	0.154,0.324		
^{235}U	alpha	4.22-4.60	7.038×10^{8} years	
	gamma	0.144,0.186		
^{241}Am	alpha	5.39,5.44,5.49	432.7 years	
	gamma	0.026,0.060		

Establishing the *Absorbed Dose Equivalent* measured in Sieverts (Sv) in human tissue involves knowing the exact nature of the radiation (Alpha, beta, etc and its energy), its disposition in relation to the individual exposed, including which organs are exposed, and for what time.

Ionization chambers and film or thermoluminescent badges (worn on the body) can give a good measure of this quantity. For a Geiger counter, which only measures the particle flux, on a rough calculation, making many simplifying assumptions:

D = Q x A = Q X N x q x (Ep/Eip) x 33.8 / (V x d) Sv/s = $1.372.10^{-4}$ N(Ep/Eip) uSv/h (microSieverts per hour)

where

D = Dose equivalent in Sv per second
Q = Quality factor for radiation (above)
N = Number of particles per second
q = charge per ion pair created = 1.6×10^{-19} Coulombs
Ep = particle energy (eV)
Eip = energy per ion pair, taken as 33.8 eV here
V = Active volume of Geiger counter (m^3)
d = density of Geiger fill gas (1.2 kg/m^3)

For example (figures show uSv/h)

Radionuclide	Beta energy (MeV)	cps: 5	10	20	50	100	200	500
^{14}C	0.156	3.2	6.3	12.7	31.7	63.3	126.6	316.6
^{90}Sr	0.550	11.2	22.3	44.7	111.6	223.3	446.5	1116.3
^{131}I	0.610	12.4	24.8	49.5	123.8	247.6	495.2	1238.0
^{137}Cs	0.510	10.4	20.7	41.4	103.5	207.0	414.0	1035.1
^{204}Tl	0.760	15.4	30.8	61.7	154.2	308.5	617.0	1542.5

PRICE LIST
SPRING - SUMMER 2011

GEM 400 RADIOACTIVITY MONITOR £395.82 + VAT = £475.00
(We're making these as fast as we can, see website for stock availability)

GEM 500 RADIOACTIVITY MONITOR £599.98 + VAT = £720.00
(Should be back in production by the end of the Summer)

GEM 100 RADIOACTIVITY MONITOR £695.81 + VAT = £835.00
(Should be back in production before the end of the Autumn)

There is no VAT if we post the item to an address outside the European Union, or if we post it to an EU address outside the UK *and* you give us your VAT number (we *will* verify that it matches both the company and the delivery address before sending the goods).