**Geiger Counter**

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| **Geiger–Müller counter** |
| A "two-piece" bench type Geiger–Müller counter with end-window detector. |
| **Other names** | Geiger counter |
| **Uses** | Particle detector |
| **Inventor** | Hans GeigerWalther Muller |
| **Related items** | Geiger–Müller tube |

A **Geiger–Müller counter**, also called a **Geiger counter**, is a type of particle detector that measures ionizing radiation. It detects the emission of nuclear radiation — alpha particles, beta particles, or gamma rays — by the ionization produced in a low-pressure gas in a Geiger–Müller tube, which gives its name to the instrument. In wide and prominent use as a hand-held radiation survey instrument, it is perhaps society's best-known radiation instrument.

The original operating principle was discovered in 1908 in early radiation research. Since the subsequent development of the Geiger-Müller tube in 1928 the Geiger Müller counter has been a popular instrument for use in radiation dosimetry, health physics, experimental physics, the nuclear industry, geological exploration and other fields, due to its robust sensing element and relatively low cost. However there are limitations in measuring high radiation rates and in measuring the energy of incident radiation.

**Principle of operation**



Schematic of a Geiger counter using an "end window" tube for low penetration radiation.

Main article: Geiger-Müller tube

Geiger counter instruments consist of two main elements; the Geiger-Muller tube, and the processing and display electronics. The radiation sensing element is an inert gas-filled Geiger-Muller tube (usually containing helium, neon or argon with halogens added) which briefly conducts electrical charge when a particle or photon of radiation makes the gas conductive by ionization. The tube has the property of being able to amplify each ionization event by means of the Townsend avalanche effect and produces an easily measured current pulse which is passed to the processing electronics.

**Readout**

There are fundamentally two types of radiation readout; counts or radiation dose. The counts display is the simplest and is the number of ionizing events displayed either as a count rate, commonly "counts per second", or as a total over a set time period (an integrated total). The counts readout is normally used when alpha or beta particles are being detected. More complex to achieve is a display of radiation dose rate, displayed in a unit such as the sievert. This type of display is normally used for measuring gamma or X-ray dose rates. The G-M tube can only detect the presence of radiation, but not its energy; which determines the ionizing effect. Consequently, dose rate measurement requires the use of an energy compensated G-M tube, so that the absorbed dose displayed relates to the counts detected. The electronics will apply known factors to make this conversion, which is specific to each instrument and is determined by design and calibration.

The readout can be analog or digital, and increasingly, modern instruments are offering serial communications with a host computer or network.

There is usually an option to produce audible clicks representing the number of ionization events. This is the distinctive sound normally associated with hand held or portable Geiger counters. The purpose of this is to allow the user to concentrate on manipulation of the instrument whilst retaining auditory feedback on the radiation rate. The electronics also generates the relatively high voltage, typically 400–600 volts, that has to be applied to the Geiger-Muller tube to enable its operation.

**Limitations**

There are two main limitations of the Geiger counter. Because the output pulse from a Geiger-Muller tube is always the same magnitude regardless of the energy of the incident radiation, the tube cannot differentiate between radiation types. A further limitation is the inability to measure high radiation rates due to the "dead time" of the tube. This is an insensitive period after each ionization of the gas during which any further incident radiation will not result in a count, and the indicated rate is therefore lower than actual. Typically the dead time will reduce indicated count rates above about 104 to 105 counts per second depending on the characteristic of the tube being used. Whilst some counters have circuitry which can compensate for this, for accurate measurements ion chamber instruments are preferred for high radiation rates.

**Types and applications**



G\_M counter with pancake type probe



Laboratory use of a Geiger counter with end window probe to measure beta radiation from a radioactive source



A Geiger counter and metal detector combined for security use.

The application and use of a Geiger counter is dictated entirely by the design of the tube.

**Particle detection**

The first historical uses of the Geiger principle were for the detection of alpha and beta particles, and the instrument is still used for this purpose today. For alpha particles and low energy beta particles the "end window" type of GM tube is used as these particles have a limited range even in free air and are easily stopped by a solid material. The end window is designed to be thin enough to allow these particles through with minimal attenuation, and normally has a density of about 1.5 - 2.0 mg/cm2. For efficient detection of alpha particles the GM tube window should ideally be within 10mm of the radiation source due to the particle attenuation in free air. However, the G-M tube produces a pulse output which is the same magnitude for all detected radiation, so a Geiger counter with an end window tube cannot distinguish between alpha and beta particles. The "pancake" Geiger-Muller detector is a variant of the end window probe designed with a larger detection area, and is normally used as an alpha/beta contamination monitor.

High energy beta particles can also be detected by a thin walled "windowless" tube; which has no dedicated end window. Although the tube walls have a greater stopping power than an end window, they still allow these more energetic particles to reach the fill gas.

Geiger detectors are still used as a general purpose alpha/beta portable Radioactive contamination measurement and detection instrument, owing to their relatively low cost, robustness and their relatively high detection efficiency; particularly with high energy beta particles. However for discrimination between alpha and beta particles or provision of particle energy information, scintillation counters or proportional counters must be used. These instrument types can also have much larger detector areas, which means that

**Gamma and X-ray detection**

Geiger counters can be used to detect gamma radiation, and for this the windowless tube is used. However, efficiency is only about 1%, due to low interaction of gamma with the tube.

The article on the Geiger-Muller tube carries an account of the techniques used to detect photon radiation. In summary, for high energy gamma this largely relies on interaction of the photon radiation with the tube wall material, usually 1-2 mm of chrome steel, to produce electrons within the wall which can enter and ionize the fill gas. This is necessary as the low pressure gas in the tube has little interaction with high energy gamma photons, and most pass through undetected. However, for low energy photons there is greater gas interaction and the direct ionization effect increases. As photon energies decrease from a high to a low level the dominance of wall effect gives way to a combination of wall effect and direct ionization, until direct gas ionization dominates. Due to the variance in response to different photon energies, thick walled steel tubes employ what is known as "energy compensation" which partially compensates for variations to increase the overall accuracy considered over a large energy range.

A typical design for low energy photon detection is a long thin-walled tube. This gives an additional gas volume, and thereby increased chance of particle interaction, but still allows low energy photons to enter the gas through the thin wall.

**Neutron detection**

A variation of the Geiger tube is used to measure neutrons, where the gas used is boron trifluoride or Helium 3 and a plastic moderator is used to slow the neutrons. This creates an alpha particle inside the detector and thus neutrons can be counted.

**Gamma measurement—personnel protection and process control**

The term "Geiger counter" is commonly used to mean a hand-held survey type meter, however the Geiger principle is in wide use in installed "area gamma" alarms for personnel protection, and in process measurement and interlock applications. A Geiger tube is still the sensing device, but the processing electronics will have a higher degree of sophistication and reliability than that used in a hand held survey meter.

**Physical design**

For hand-held units there are two fundamental physical configurations: the "integral" unit with both detector and electronics in the same unit, and the "two-piece" design which has a separate detector probe and an electronics module connected by a short cable.

The integral unit allows single-handed operation, so the operator can use the other hand for personal security in challenging monitoring positions, but the two piece design allows easier manipulation of the detector, and is commonly used for alpha and beta surface contamination monitoring where careful manipulation of the probe is required or the weight of the electronics module would make operation unwieldy. A number of different sized detectors are available to suit particular situations, such as placing the probe in small apertures or confined spaces.

Gamma and X-Ray detectors generally use an "integral" design so the Geiger–Müller tube is conveniently within the electronics enclosure. This can easily be achieved because the casing usually has little attenuation, and is employed in ambient gamma measurements where distance from the source of radiation is not a significant factor. However, to facilitate more localized measurements such as "surface dose", the position of the tube in the enclosure is sometimes indicated by targets on the enclosure so an accurate measurement can be made with the tube at the correct orientation and a known distance from the surface.

There is a particular type of gamma instrument known as a "hot spot" detector which has the detector tube on the end of a long pole or flexible conduit. These are used to measure high radiation gamma locations whilst protecting the operator by means of distance shielding.

Particle detection of alpha and beta can used in both integral and two-piece designs. A pancake probe (for alpha/beta) is generally used to increase the area of detection in two-piece instruments whilst being relatively light weight. In integral instruments using an end window tube there is a window in the body of the casing to prevent shielding of particles. There are also hybrid instruments which have a separate probe for particle detection and a gamma detection tube within the electronics module. The detectors are switchable by the operator, depending the radiation type that is being measured.

**Guidance on application use**

In the United Kingdom the HSE has issued a user guidance note on selecting the correct radiation measurement instrument for the application concerned. This covers all radiation instrument technologies, and is a useful comparative guide to the use of GM detectors.





The GM tube design used determines the types of radiation detected. This is a thin mica window type for detecting alpha and beta radiation. GM tubes without a window will not detect alpha.



GM detector with thin mica window pancake detector plugged into a microcontroller data-logger with Class 1 Bluetooth adapter sending radiation levels to a PC using radio signals

**History**

In 1908 Hans Geiger, under the supervision of Ernest Rutherford at the Victoria University of Manchester (now the University of Manchester), developed an experimental technique for detecting alpha particles that would later be used in the Geiger-muller tube. This counter was only capable of detecting alpha particles and was part of a larger experimental apparatus. The fundamental ionization mechanism used was discovered by John Sealy Townsend by his work between 1897 and 1901, and is known as the Townsend discharge, which is the ionization of molecules by ion impact.

It was not until 1928 that Geiger and Walther Müller (a PhD student of Geiger) developed the sealed Geiger-Müller tube which could detect more types of ionizing radiation and it became a practical radiation sensor. Once this was available, Geiger counter instruments could be produced relatively cheaply because the large output pulse required little electronic processing to give a count rate reading, which was a distinct advantage in the thermionic valve era due to valve cost and power consumption.

Modern versions of the Geiger counter use the halogen tube invented in 1947 by Sidney H. Liebson. It superseded the earlier Geiger tube because of its much longer life and lower operating voltage, typically 400-600 volts.