Introduction

Ionizing radiation that is associated with radioactivity cannot be directly detected by our senses. Ionization is the process whereby the radiation has sufficient energy to strip electrons away from atoms. The ionization results in the formation of free electrons and an ionized atom that has lost some of its orbital electrons. Examples of ionizing radiation include particles such as alpha and beta particles, and photon radiation such as x-rays and gamma rays. Neutrons and protons can also cause ionizations. Since radiation can be harmful to our health, we need detectors that are capable of sensing the presence and intensity of radiation and convert it into an electrical signal to provide suitable alarm. Geiger-Müller tubes are gas-filled radiation detectors that are useful, cheap and robust. A GM tube basically detects the presence and intensity of radiation (particle frequency, rather than energy). Geiger counters are used to detect radiation (usually gamma and beta radiation, but some models can also detect alpha radiation).Geiger-mueller counters respond to the commonly encountered types of radiation, namely, alpha and beta particles as well as gamma and x-radiation. In general, GM counters cannot determine the type, energy, or vectors of the detected radiation. Generally they are used for detecting and measuring radioactivity that consists of low level beta particles and gamma-ray radiation. It has high sensitivity, versatility with various types of radiation, wide variety of shapes and windows, large output signal and reasonable cost.

Hans Geiger first developed these detectors for detecting ionizing radiation in 1908. In 1928, based on suggestions from his colleague Walther Muller, he refined the design to create the Geiger-Muller tube, upon which most contemporary Geiger, or Geiger-Muller, counters are based.

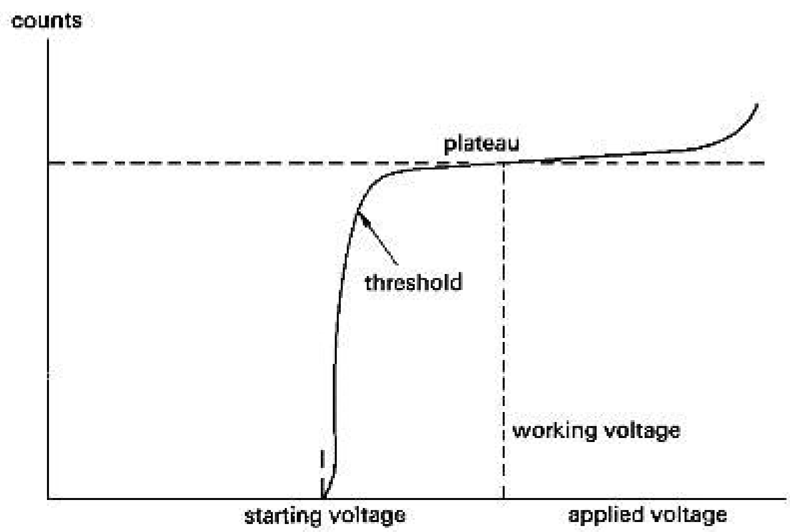
GM detectors are of three types: end-window, pancake and the side-wall detector. The end-window detector employs a thin wall at its end to allow most alpha and beta radiations to enter the detector without being stopped. This detector can also measure gamma/x-ray radiation. The pancake detector also has an end-window, with a wider diameter which permits faster detection. A side-wall tube can detect beta and gamma or x-ray radiation using an aluminum or stainless steel outer wall that can slides or rotates to selectively expose the actual detector to the radiation. The window can either be opened or shut so that beta and gamma/x-ray radiation above some energy can be detected. When shut, the window permits the detection of only gamma or x-ray radiation.

Principle of Operation

The Geiger counter is a gas-ionization device. The basic design consists of a metal tube, often with a glass or mica window at one end. At the center of the tube runs a wire with a strong positive charge. The tube is sealed and filled at low pressure with an inert gas such as argon, helium or neon with some gases added. In the absence of radiation, the detector does not conduct charge. Whenever ionizing radiation passes through, however, an electric signal is generated because the metal casing of the Geiger-Muller tube acts as a cathode, and the central wire is the anode. The anode transfers the pulses of current through a resistor, where they are converted to pulses of voltage. The voltage pulses are then recorded by a counting device. Finally, an oscilloscope, LED screen, or other display conveys the particle count to the user.

In a GM counter, the avalanche produced near the anode wire spreads along its entire length. That is why the output signal is independent of the magnitude of the triggering event. After the ionizing event creates electrons and positive ions, the electrons are collected very quickly while it takes a longer time for the ions to move slowly. When the discharge is quenched, the space charge sheath surrounding the anode moves towards the cathode. After it reaches sufficient distance from the anode, the voltage is sufficient to re-establish the threshold for Geiger action. If another ionizing event occurs immediately after this, a second pulse is recorded. In the circuit, the collector electrode is maintained at high voltage above the ground but this is blocked by a capacitor from the counter input. The cathode is maintained at ground potential for safe operation.

The typical counting rate characteristics of a thin-window GM tube are shown in the figure below. The threshold indicates the voltage (minimum pulse-height) allowed by the discriminator. The slight positive slope of the plateau is due to the fact that as the applied voltage is raised, the sensitive volume of the detector increases slightly. The operating voltage of the counter is usually chosen as the mid-value of the plateau length so that the count rate remains more or less constant even if the voltage varies slightly.

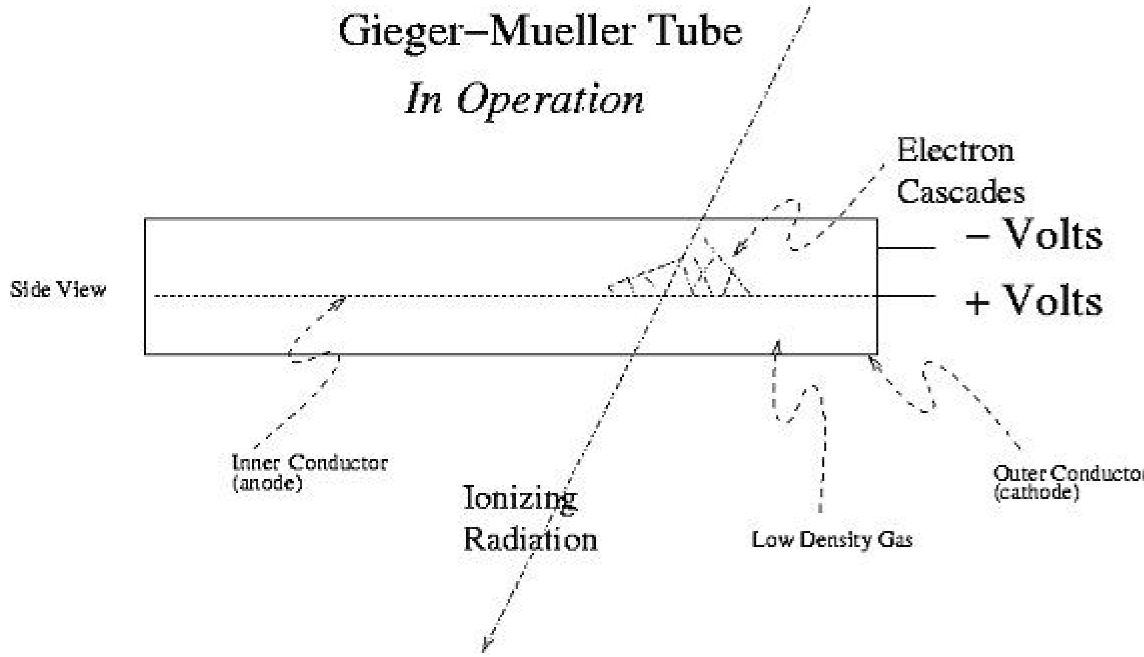


Courtesy: www.practicalphysics.org

Sensitivity

Most GM tubes will detect gamma radiation, and usually beta radiation above about 2.5 MeV. Geiger-Müller tubes will not normally detect neutrons which do not ionize the fill-gas. However, neutron-sensitive tubes can be produced with their insides coated with elemental boron or is filled with boron trifluoride/helium-3 gas. The neutrons interact with the boron/helium nuclei, producing charged particles and electrons. These charged particles then trigger the usual pulse-generating mechanism.

Typical energy of beta emitters ranges from 0.15MeV (carbon-14) to 1.7MeV (phosphorus-32) and a window thickness of about 30mg/sq.cm is adequate for good transmission. While the intrinsic efficiency of GM counters is about 1 for beta particles, it is only 0.01-0.03 for gamma rays since only a small fraction of gammas are detected. In monitoring beta activity, GM counters produce high count rate even at low radiation levels. This is because almost every beta particle that enters the detector window generates a pulse. It should be remembered that even in the absence of any radiation source, GM counters may produce a background pulse rate of about 70 clicks per minute, due to cosmic ray background. It is possible to distinguish between beta and gamma radiation by interposing a thin absorber between the radiation source and the detector. We can expect a sharp decrease in the count rate in the case of a beta source.



Courtesy: Department of Physics and Astronomy
Youngstown State University

GM tubes can record radioactivity levels over several orders of magnitude. The sensitivity can be lower for high energy gamma radiation because the density of the gas in the device is usually low, allowing most high energy gamma photons to pass through undetected (lower energy photons are easier to detect, and are better absorbed by the detector. X-ray Pancake Geiger Tubes work on such principle). Geiger detectors are favored as general purpose alpha/beta/gamma portable contamination and dose rate instruments, due to their low cost and robustness. Geiger tubes can be used to measure neutrons, by the use of boron trifluoride gas and a plastic moderator that slows down the neutrons. This creates an alpha particle inside the detector and thus neutrons can be counted. GM tube is a type of gaseous ionization detector with an operating voltage in the Geiger plateau.

Quenching

The G.M. tube is designed to produce a single pulse when exposed to a single particle. Spurious pulses must be avoided and the device should recover quickly to the passive state. But the positively charged argon ions that strike the cathode become neutral argon atoms raised to an excited state; they do this by capturing electrons from the cathode. The excited atoms return to the ground state by emitting photons and these photons cause further avalanches. This causes spurious pulses. Introduction of pulse quenching mechanism is important because a single particle entering the tube is counted by a single discharge, and so it will be unable to detect another particle until the discharge has been stopped. This also helps prevent the tube damage by prolonged discharges.

External quenching technique uses electronic components to quickly discharge the potential between the electrodes. Self-quenching or internally quenched tubes can stop the discharge with a small amount of a polyatomic organic vapor or alternatively a halogen such as bromine or chlorine.

If a diatomic gas quencher is introduced in the tube, the positive argon ions, they move slowly towards the cathode and undergo multiple collisions with the quencher gas molecules. In this process they transfer their charge and some energy to the quencher. Thus neutral argon atoms would reach the cathode. The quencher gas ions in their turn reach the cathode, gain electrons and become excited. These excited atoms de-excite by molecular dissociation into neutral quencher molecules. In this process no spurious pulses are produced.

Tubes with halogen gas quenching were invented by Sidney H. Liebson in 1947. Here the discharge mechanism takes advantage of the metastable state of the inert gas atom to ionize the halogen molecule and produces a more efficient discharge which permits it to operate at much lower voltages, typically 400–600 volts instead of 900–1200 volts. Halogen quenching provides a longer life because the halogen ions can recombine unlike the organic vapor which can get gradually depleted by the discharge process.

Above a certain level of gamma or beta radiation, GM tubes can saturate, and the output of detected radiation will drop to zero until the level drops below this rate. Radiation events being random in nature, the saturation dropouts will occur intermittently as the level of radiation approaches this level. The level of radiation at which this occurs varies with the GM tube construction and design

Limitations

Problems can occur due to pulse overlap in GM tube operation. When a radiation event is detected by the GM tube while it is still in conduction, it will be masked by the first radiation event. The output pulse may possibly be prolonged or distorted, but the electronic circuitry will condition it into a pulse representative of a single radiation event. This can also be due to the electronic circuitry, where a second pulse is obtained from the GM tube before the first pulse has been processed. For this reasons, a geiger-mueller counter is ideal for detecting and measuring low level radiation.

The usual form of tube is an end-window tube. This type of tube has a window at one end through which ionizing radiation can easily penetrate. The other end normally has the electrical connectors. There are usually two types of end-window tubes: the glass-mantle type and the mica window type. The glass window type will not detect alpha radiation since it is unable to penetrate the glass, but is usually cheaper and will usually detect beta radiation and X-rays. The mica window type will detect alpha radiation but is more fragile.

Gamma-Scout® Design

The Gamma-Scout® component layout places the G-M tube at the top of the device. Progressive shielding covers the mica barrier, blocking out Alpha and Alpha/Beta particles at user option. With the tube configuration in this format, the Gamma-Scout® Geiger counter is directional, appropriate for a handheld measuring instrument.

The direct reading from a Geiger counter provides the count of particles detected, or counts per minute (cpm). Converting to other units may be misleading, since various designs will detect any given type of radiation. Nevertheless, a well-constructed and well-calibrated Geiger counter can offer several standard units of measurement, with the understanding that the readings apply only to the types of radiation that particular model is able to accurately detect. The Sievert and the rem are the most common measures of radiation dosage, with 1 Sievert (Sv) equal to 100 rems (R). A rem can be further divided into 1,000 millirems (mR or mrem). The U.S. Nuclear Regulatory Commission (NRC) states that a person in an occupation not involving radioactive materials is exposed to 100 mrem per year of normal background radiation, and should avoid more than 100 additional mrem per year.

The Geiger counter, sometimes referred to also as a Survey Meter, is distinguished from dosimeters; a dosimeter measures the amount all types of radiation, that is absorbed in a given time. In simplest terms, a Geiger counter is used to detect radiation in an area or on an object, while a dosimeter is used to monitor radiation exposure to a person over an extended period of time. For example, laboratory technicians who work with radioactive materials use film-badge dosimeters, which are worn for weeks or months, then processed to show the amount of radiation absorbed during that time. If the dosimeters indicate that a laboratory's personnel are receiving unexpected levels of radiation, a Geiger counter would be used to pinpoint the specific source of the unintended radiation.