Geiger Muller (GM) counter

Topics covered:

- Basic principle of GM counter
- Construction of GM Counter
- Working of GM counter
- Quenching of GM Counter
- Characteristics of GM counter
- Uses of GM counter
- Disadvantages of GM Counter
- References

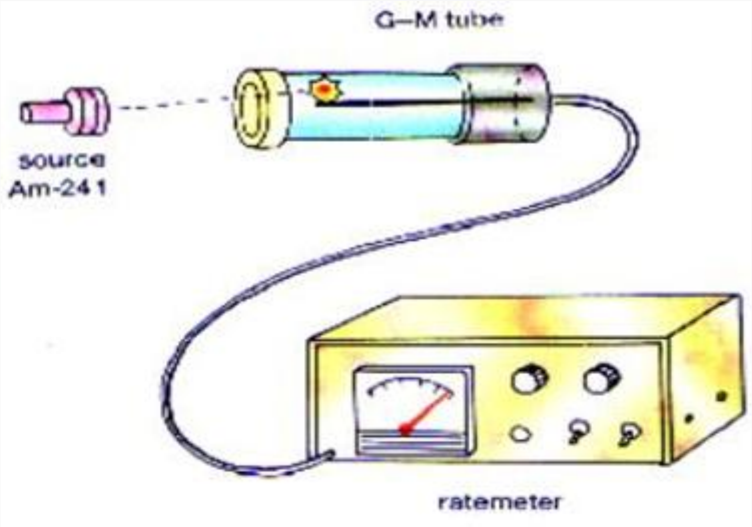
Geiger Muller (GM) counter

INTRODUCTION

- This counter was named after Hans Geiger and W. Müller, who invented it in the 1920s. It is sometimes called a Geiger counter or a GM counter or GM tube
- This is most commonly used portable radiation instrument.
- Although useful, cheap and robust, a counter using a GM tube can only detect the presence and intensity of radiation.
- Geiger counters are used to detect ionizing radiation, usually alpha and beta radiation and other types of radiation like low energy X-rays, etc.
- The Geiger counter used widely in as radiation dosimetry, radiological protection.
- In wide and prominent use as a hand-held radiation survey instrument, it is perhaps one of the world's best-known radiation detection instruments.

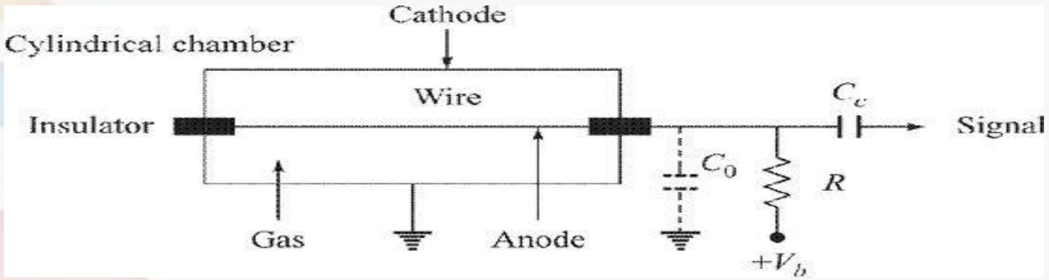
Geiger Muller (GM) counter

Principle



It works on the principle that nuclear radiations while passing through the gas contained in GM counter ionize it.

Construction of Geiger Muller (GM) counter.



- The schematic diagram of a GM counter is identical to that of a proportional counter
- In majority of the cases, the GM tube is cylindrical in shape.

- This cylinder is either made up of a conducting metal like copper or of glass, in which a metallic cylinder is supported which acts as a cathode
- Anode is generally made up of tungsten wire which stretches in the centre of the tube and is isolated from the cylindrical tube. The thickness of this wire is generally 0.02 to 0.05 mm.
- Depending upon the requirement, the GM tubes are available in a variety of sizes. The diameters of the tubes vary from 0.3 cm to about 15 cm while their lengths vary from 1 cm to 100 cm.
- Commercially available GM tubes are filled with 90% argon (as the filling gas) and 10% ethyl alcohol (as the quenching gas) or 0.1% either chlorine or bromine (as the quenching gas) and the rest is neon or argon gas.
- A thin glass, mica or polymer window (~10 μm) isolates the gases present in the GM counter from the atmosphere.

Working of Geiger Muller (GM) counter

- The charged particles entering the GM tube ionize the gas producing *primary ionization.*
- The electrons librated in the primary ionization are accelerated towards the central anode wire. Because of high potential present on the wire, the electrons may gain sufficient energy to cause further ionization of the neutral gas molecules (known as secondary ionization).
- This leads to a chain of ionizing events and is known as Townsend avalanche.
- Besides these processes, there is a possibility of excitation of molecules and atoms. Such excited molecules and atoms, while de-exciting, may emit ultra violet (UV) or visible photons. These photons again lead to the production of electrons due to ionization of gas atoms or molecules or due to photoelectric interaction with walls of the counter. Each such librated electron would again cause a Townsend avalanche.
- Such a series of avalanches would lead to discharge in the tube called Geiger discharge, forming of dense envelop of electron–ion pairs distributed around the anode. The voltage applied to anode collects all the electrons pertaining to single event leading to Geiger discharge.

Quenching of Geiger Muller (GM) counter

- During the Geiger discharge, there is a dense envelop of ions and electrons around the anode. The electrons would drift towards the anode and positive ions would drift towards the cathode.
- The positive ions drifting towards the cathode having ionization potential greater than the work function of the cathode material lead to exchange of electron from the cathode and become neutral.
- The excess energy may be dissipated with the emission of either a photon or an electron from the cathode the latter process take place only if excess energy is greater than the work function of the cathode material.
- This again initiates another Geiger discharge. The result of this is that the tube would always be in continuous Geiger discharge and hence is not able to measure any radiation.
- If measurements are made in the state of continuous avalanching, then the counter will confuse between two pulses, one due to continuous avalanching and the other due to fresh event. Hence to remove the state of confusion or to improve the resolving power of G.M. counter, the continuous avalanche is known as **quenching**.

Quenching of Geiger Muller (GM) counter

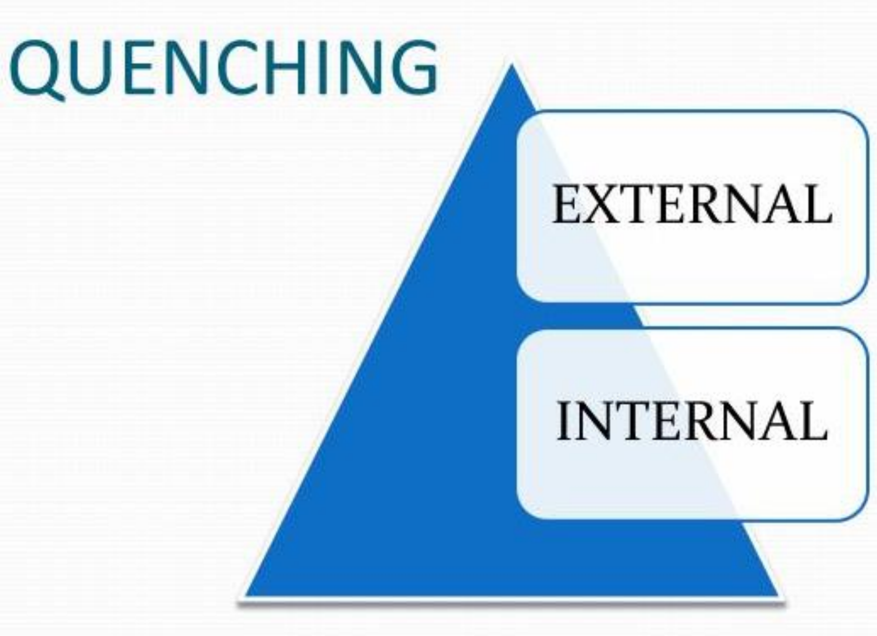
To overcome this problem, the concept of quenching is introduced. There are two types of quenching:

1. Self (Internal) Quenching : The quenching or suppression, by adding a quenching agent (alchohol or some polyatomic gas)

a. Organic quenching

b. Halogen quenching

2. External Quenching: by using an external load resistance in series with the tube



Organic Quenching of Geiger Muller (GM) Counter

- A suitable quenching agent should have ionization energy less than that of counter gas and should be such that it dissociates itself rather re-emit energy on absorption of excitation energy.
- In organic quenching, a small quantity of organic gas having a complex molecular structure is added.
- This prevents the continuous Geiger discharge by charge transfer collision principle.
- The positive ions on their path collide with organic molecules to get neutralized. This makes only ions of organic gas to reach the cathode and get neutralized.
- Any excess energy released would lead to dissociation of organic molecules. Thus, multiple Geiger discharge could be avoided.
- A typical filling of organic quenched GM tubes is 90% argon and 10% ethyl alcohol.
- The ionization potential of ethyl alcohol (11.3 ev) is lower than that of argon (15.7 eV). As a result, argon ions (on their journey to cathode) are all neutralized by acquiring an electron from the alcohol molecule and alcohol ions formed. Now only alcohol ions reach the cathode and neutralized by acquiring electrons from the cathode and again form largely excited molecules. These excited alcohol molecules usually prefer decomposition rather than photon emission and hence no photons are available to start the production of secondary electrons from cathode and the possibility of continuous avalanching is removed.

Halogen Quenching of Geiger Muller (GM) Counter

•The organic quenched GM tubes are characterized by short life time and are not suitable for operation in very high fields which leads to large count rate. To overcome this, the technique of halogen quenching was introduced.

•This involves the addition of small quantity of halogen gas such as chlorine or bromine. A typical filling is about 0.1% of chlorine to argon or neon.

•The quenching action is the same as that of the organic quenching process. The diatomic halogen gas molecules also get dissociated in quenching but get recombined to replenish the gas molecules and thus the counter life gets extended.

Charecteristics of Geiger Muller (GM) Counter

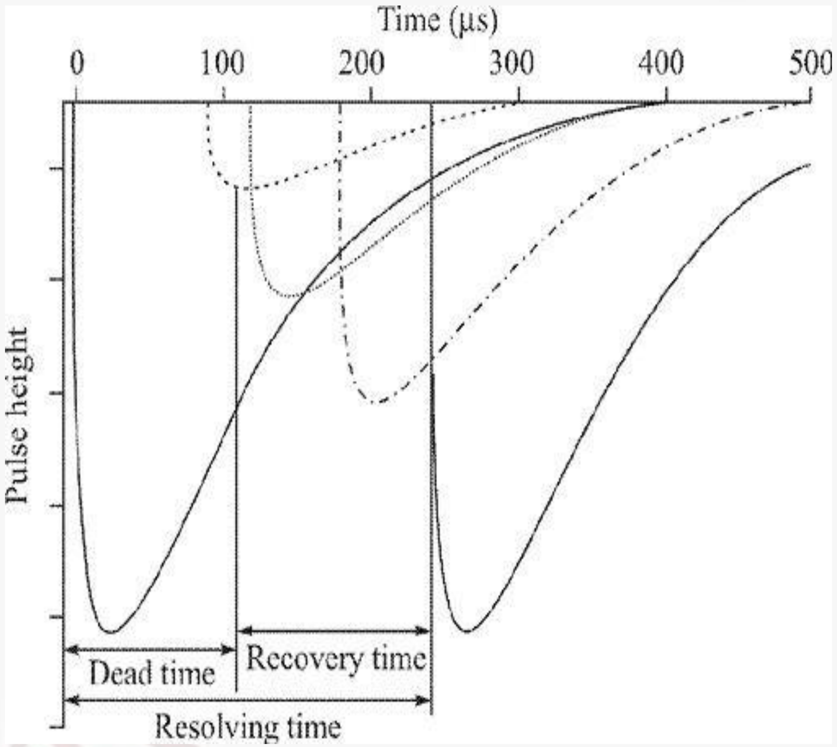
Dead Time:

- The positive ions take considerable time to reach the cathode compared to electrons. The reason is that the mobility of electrons is about 1000 times greater than that of positive ions.
- Due to low drift velocity of positive ions, there is a formation of cloud of positive ions.
- The electric field of these positive ions forms a sheath of positive ions (space charge) close to the anode and reduces the intense electric field sufficiently. Thus, approaching electrons do not gain sufficient energy to start new avalanches.
- The detector is then inoperative (dead) for the time required for the ion sheath to migrate outwards far enough for the field gradient to recover above the avalanche threshold. The dead time of a Geiger tube is defined as the time between the initial pulse and the time at which a second Geiger discharge (regardless of its size) can be developed. In most Geiger tubes, this time is of the order of 50–100 μs.
- Dead time is the time immediately following the introduction of a particle during which the counter tube is insensitive for detection of another particle.

Charecteristics of Geiger Muller (GM) Counter

Recovery time:

- After the dead time is over, some of the electrons and +ve ions recombine form neutral atoms.
- During this time, when a new ionizing radiation enters the tube, pulses of lower amplitude are formed, which cannot be counted by the counter.
- The total time taken for the tube to recover to its fully sensitive state to give the next pulse is called *resolving time*.
- The sum of the *dead time* and *recovery time* is called *Resolving time (Paralysis time)*.



- During the dead time, no new pulses are formed. However, during the recovery time, pulses of lower amplitude are formed, which are not counted by the counting system. It is only after the recovery time that the pulses of larger amplitude are formed, capable of getting counted.

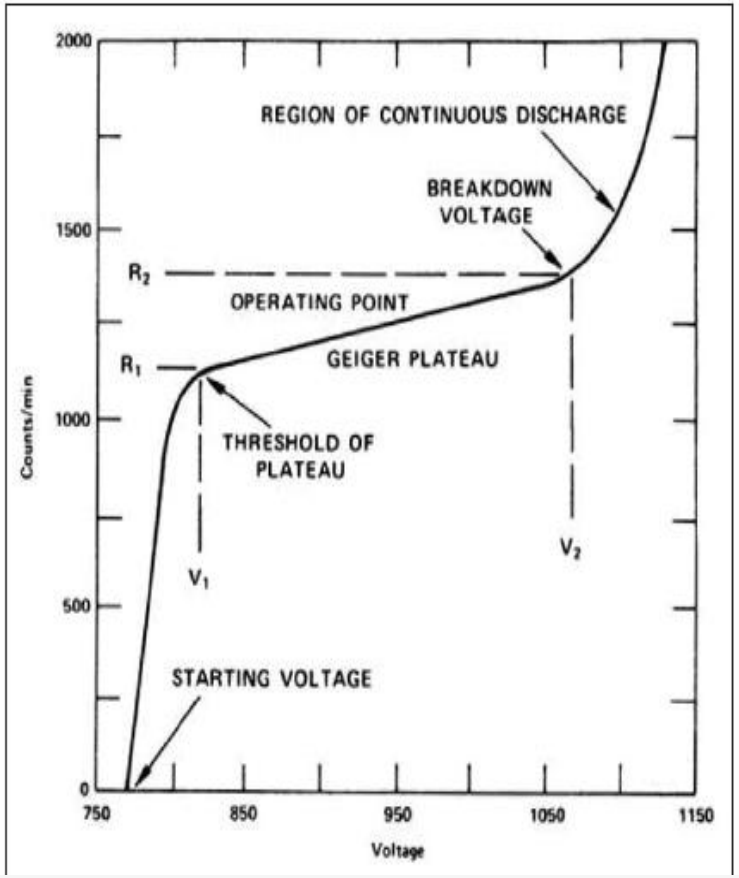
Charecteristics of Geiger Muller (GM) Counter

Geiger plateau:

•The potential difference at which the counting just starts is called threshold potential. The typical threshold potential depends upon the gas and its pressure in the counter. It generally varies between 400 and 900 volts.

•After a very sharp rise, the counting rate remains almost constant with increasing voltage. *This flat region, the plateau, where the number of counts recorded per second remains independent of applied voltage is called Geiger region*. The length of the plateau is about 100 to 300 volts.

•When the plateau region becomes shorter and steeper, it means that the GM tube is nearing the end of its useful life. If a Geiger–Müllar counter is operated in this region, it eliminates the need of a costly and highly regulated power supply.



Efficiency of Geiger Muller (GM) Counter

Efficiency of Counting (η)

It is defined as the ratio of number of observed counts per unit time (N_0) to the number of ionizing particles (N) which passed through the counter during that time i.e.,

$$\eta = \frac{N_0}{N}$$

where N_0 is observed counting rate and N is true counting rate

$$\eta = \frac{N_0}{1 - N_0\tau}$$

τ is paralysis time or resolving time and $N_0\tau$ inactive part of counting.

$$\text{The true counting rate} = \frac{\text{Observed counting rate}}{1 - \text{Observed counting rate} \times \text{Dead time}}$$

Uses of Geiger Muller (GM) Counter

1. It is very useful for counting β-particles. It can also be used for measuring intensity of γ-rays, X-rays and electrons.
2. It has output pulse height, independent of initial ionization.
3. It is also used to record the events involving high energy particles and cosmic rays.
4. It can detect even small activities, i.e., it is sensitive to the production of even a single ion pair (due to large multiplication factor)
5. It has a long insensitive time to allow entry of each particle.
6. It has long life (infinite life especially with halogen quenched counters)
7. It is one of the cheapest kinds of nuclear radiation detector

Disadvantages of Geiger Muller (GM) Counter

- They cannot be used to measure the energy of radiations.
- It is used for lower counting rates only
- Organic additive used for quenching is consumed after about 10^9 events and hence give a limited life to G.M. tube. The organic polyatomic counter gas does not require any additive quenching agent and increases the life of the tube.
- It cannot be used for counting α-particles due to their low energy as the window cannot be made thin enough to pass them
- It also has very less intrinsic efficiency for γ-ray detection.

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Thank you