IONIZATION CHAMBER :→

Principle :→ The basic principle of this method is that charged particles in motion produces ionization in the gas which vary with the nature and velocity of the charged particles.

Construction :→ The simplified schematic representation of pulse ionization chamber is shown in fig below. It consists of a cylinderical conducting chamber with a thin axial wire enclosed in a glass envelope containing some suitable gas like air or hydrogen at atmospheric pressure or at higher pressure (for detection of γ-rays). The central wire acts as anode and is insulated from the chamber walls. An external voltage V is applied between the walls of the chamber and central wire through a resistance. The chamber is made cathode and the will is made anode. Ionization chamber can be used to count single ionizing particles if the particle flux is so great that ions are produced more or less continously the chamber output is a steady current rather than a series of pulses.

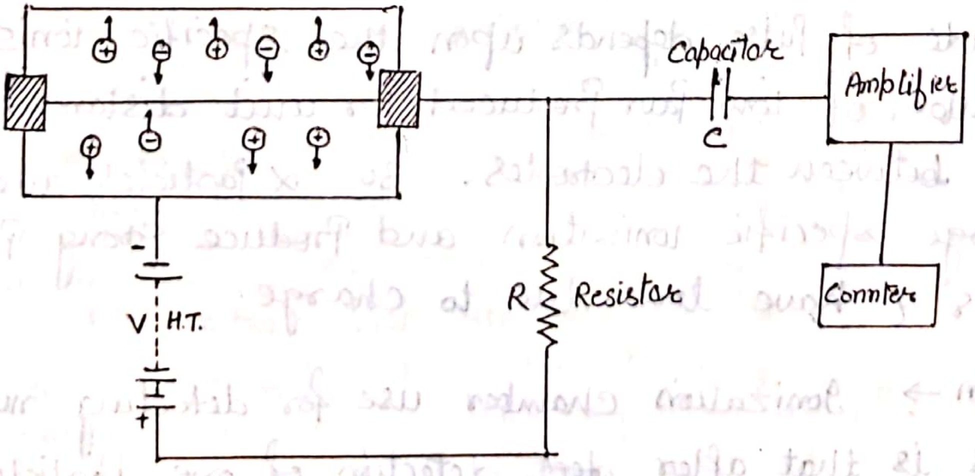
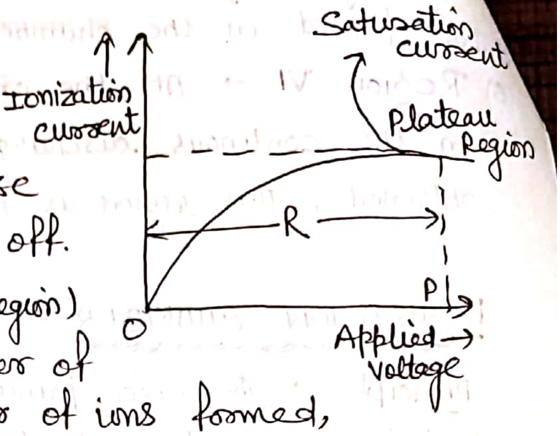


Fig 3 :→ Pulse ionization chamber.

Working :- when a voltage is applied between the electrod the ions drift along the lines of force producing an ioniza current. normally drift speed of electron 10^6 cm/sec, whose a ions drift very slowly.



when ionizing radiation enters the ionization chamber, so ionization current first increases with the increase in applied voltage and then levels off.

In the Region 'R' (called Recombination Region) of the voltage operation, the number of ions collected is less than the number of ions formed, At Point 'P' the applied voltage is sufficiently strong to prevent the Recombination of Ions. After being ionized the ions are pulled apart rapidly and almost all these ions are collected at electrodes.

The average Ionization current at Saturation $\propto ne$

or $I_{Sat.} = ne$ where $n \rightarrow$ number of Ion pairs formed per unit time by Radiation.

$e \downarrow$ electronic charge.

Ionization chamber measures the integrated effect of a large number of ionizing events.

Here total charge on capacitance is $Q = CV$

maximum ~~Height~~ value of Pulse Height $V_{max.} = \frac{Q}{C} = \frac{ne}{C}$

So $I_{Saturated} = \frac{dQ}{dt} = C\frac{dv}{dt}$

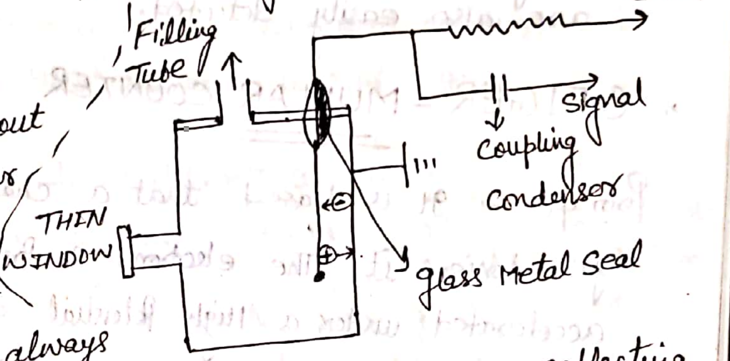
and Ionisation current for 'R' is $I = \frac{V}{R} = \frac{Q}{CR} = \frac{ne}{CR}$

The magnitude of pulse depends upon the specific ionisation (i.e number of ions pair produced per unit distance) and the distance between the electrodes. So α particles and proton have large specific ionisation and produce strong pulses But β & γ have low due to charge.

→ **Limitation** → Ionization chamber use for detecting nuclear Radiations is that after ~~deet~~ detection of one particle, the chamber has to wait for several milli seconds, before it is again ready to detect the next particle, so from this we cannot take High Counting Rates.

PROPORTIONAL COUNTER →

inciple → It is based on the Principle that when a Potential difference between the Central wire and the cylinder is Sufficiently high, the electrons Produced due to Ionisation Produces Secondary ions by collision with the gas and the Primary ionisation is multiplied by a factor depending upon the geometry of the apparatus and the applied voltage 'V'.



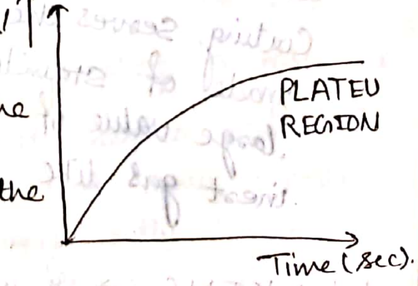
Construction → It Consist of a Hollow metallic cylinder of about '20 cm' long and '2 cm' in diameter with a fine tungsten wire (≈ 0·1 mm diameter) Running along its length see fig. The wire is always made (+ve) w.r.t the metallic cylinder tube and serves as a collecting electrode which is connected to the Pulse Amplifier. Here take Argon as a filter due to its High density but it has some long lived excited states. when those states are de-excited, the energy Released Rapidly may Produce discharges in the Counter. due to discharge So methane is added (90% Ar and 10% Methane).

Electric field Required for Producing Secondary ionization is given by

$$E = \frac{V}{r \log_e \frac{b}{a}}$$

where → a → Radius of the wire
b → Radius of the cylinder
r → distance of central wire from Radial electric field.
V → +ve Potential of the ~~cen~~ Central wire w.r.t cylinder.

WORKING → The electrons from the ion Pairs created any where in the Centre move Towards the Positively charged wire to give more ions and an 'avalanche' of ionisation in the central Part. Here Gas-multiplication of no. of electrons coming to wire for each initial electron between (10^1 to 10^3)



These electrons Come to the Central wire very Rapidly but the voltage Pulse developed at the Central wire is dependent on the motion of heavy ions, majority of which are created very near the Anode, So cancelling the effect of electrons.

and velocity of ions is Quite High as the ions are in a very strong field and the Pulse quickly achieves Half the value of the amplitude.

Shape of the Pulse in this counter is independent of the Position of ionising Track since the main Multiplication in High field in order to limit the multiplication, a Proportional Counter is filled 90% Argon and 10% Methan at atmospheric Pressure. Methane helps in limiting the multiplication by absorbing Photons emited by electron

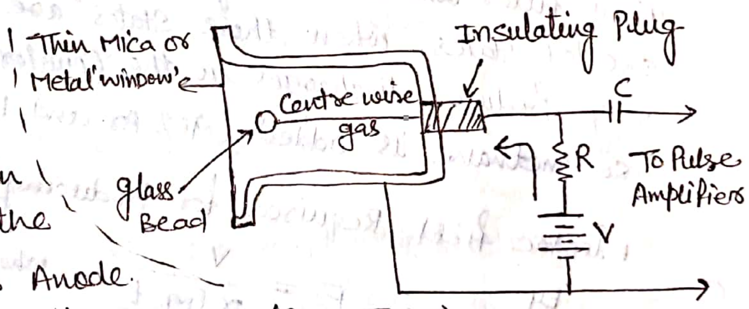
→ This counter useful for measurement of soft Radiations such as β-Rays, mesons, and fast Protons. Slow and heavy Particles are also easily detected.

* GEIGER – MULLAR COUNTER (G. M. COUNTER) →

Principle → It is based that a charged Particle Passing through a gas, ionises it, The electrons so Produced during the ionisation get accelerated under a High Potential and Produce further ionization This ionization is called indirect ionization and ultimately a large number of electrons are Produced which are collected By Positive feed back.

Construction →

The G.M Tube Consists of a cylindrical metallic envelopes which acts as cathode. A Thin wire of Tungsten lying on the axis of the cylinder act as Anode.



(G. M- TUBE)

A glass Bead is used to Cover the free end of the wire in chamber. Bead used to avoid Corona discharging at the Sharp Point. A Thin mica window is Provided at one end of the chamber. So α and β Particles may enter the Chamber. In this counter, a cylindrical metal Coating inside a glass ~~env~~ envelope also used in Place of metallic cylinder. Then the inner metal Coating serves the Purpose of cathode. The Cathod Surface is made of stainless Steel or Nickel or any other material having large value of work-function. The G.M Tube is filled with an inert gas like Ar, Ne, He etc.

WORKING → If an ionizing Particle Produces a Trail of ion Pairs in the gas, the Resulting current Pulse would be larger than the originating from a single ion Pair, when Potential difference is eased. this variation in the size of the current pulse gradually isappears, ultimately it is found that the size of the current pulse becomes effectively independent of the initial density of ionization for quite a Range of Potential differences. The counter then gives a full avalanche of nearly constant size for any particle counted, in this Region, it is said to operate on the 'plateau' or in the 'geiger - Region'. in this Region counter sensitivity is highest and counting efficiency is independent of tube voltage over a Reasonable Range, this voltage is not critical.

→ Quenching → The +ve ions produced during an electron avalanche in a Geiger counter are subjected to same electrical forces as electrons. because of their much larger masses they have small acceleration, and considered as being virtually stationary during the electron avalanche. After this avalanche these (+ve ions) which are principally formed close to the central wire, move outwards towards the cathode. when they reach it some time later, they have considerable energies and some of them will Release electrons as they bombard the cathod surface. so second avalanche is started, and succession of discharge will follow. it should be stopped otherwise a single event will be counted Twice. So +ve ion cloud should be eliminated. around the wire is called 'Quenching'.

If 'λ' be the mean free path then for the Avalanche to start

$$E_a\lambda = \frac{V\lambda}{a\log_e\left(\frac{b}{a}\right)} = I \text{ (ionisation Potential)}.$$

Here b → inner radius of the cathod cylinder

a → Radius of central wire,

E_a → Ionisation Electric field.

→ Following quenching methods are used →

① External quenching method →

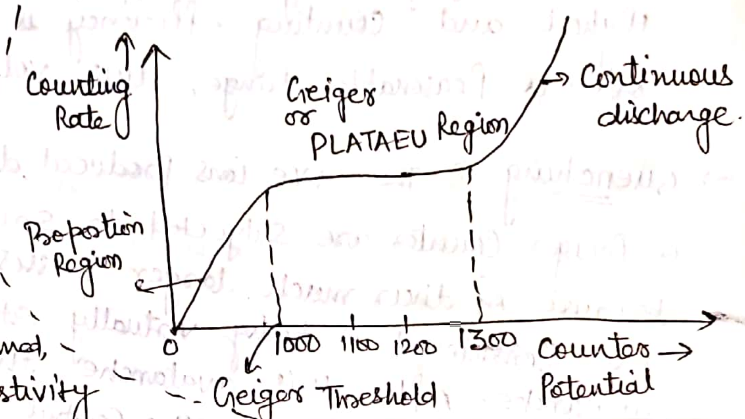
Ⓐ when large pulse occurs, the momentary voltage drop across the Resistance lowers the Geiger tube voltage sufficiently to extinguish the discharge. since it Results in a Relatively long time interval after one pulse before the counter recovers sufficiently to detect a new particle. so following Period one count during which the counter is insensitive called 'dead time' of the counter.

It is also possible to quench the discharge internally by introducing into the counter tube a small quantity of a Polyatomic gas such

as ethyl alcohol. This quenching agent Prevent the Release
electrons from the Cathod Surface by Positive ion Bombardme

② Self quenching →

For internal quenching a Partial Pressure of about 1 cm of ethyl alcohol is commonly used, such internally quenched Counters operate with potential difference of 1 to 2 thousand volt. also quenching agent ~~Methane~~ Halogen gas, chlorine or neon gas taken.



If voltage is low, a single initial ion pair does not produce a full avalanche although some gas amplification still occurs. The size of the current pulse at the Anode is then proportional to the number of ions initially formed, So a detector of finite sensitivity will Record the large pulses but miss the small ones, resulting a low count Rate, Counters operating in this Region can be used to differentiate between different types of particles, with Higher tube voltages, the count Rate increases and then becomes constant for a Range of potential differences, This Range called 'Plateau Region'.

When the voltage is Raised above this Plateau or Geiger Region, the quenching action is incomplete and one initial Particle may give Rise to more than one count. The count Rate increases due to these spurious output pulses and at slightly Higher voltages, the Counter goes into continuous discharge. This Region of voltage is of no practical use and damage to the tube may be ensured.

→ above counter used to detected α, β, γ Particles.

→ EFFICIENCY OF COUNTING → $\eta = \frac{N_0}{N}$

Here N_0 → no. of observed counts per time
N → No. of Ionizing particles which passed through the counter during that time.

→ Dead Time and Recovery Time → The Counter Remains dead till the '+ve' ions have moved sufficiently away from the avalanche sites to put the wire back to Geiger Threshold Potential. The Counter is insensitive to further ionization pulse.

Time during which the Counter voltage dropped below the Threshold voltage due to the Presence of slowly moving cloud of Positive ions towards anode is called dead or inactive time, and the time after which the original Pulse level is Restored is called Recovery time.

Let $t \rightarrow$ dead time of G.M Counter.
$N_0 \rightarrow$ Number of Counts Per minute.

So N_0t will Correspond to inactive Part of that minute, and $(1-N_0t)$ will be the active Part of that time.

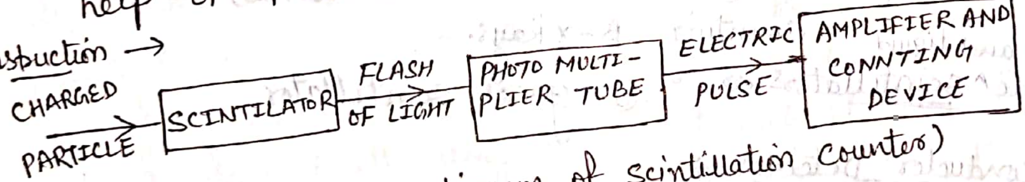
So $$\eta = \frac{N_0}{N} = \frac{1-N_0t}{1} \Rightarrow N = \frac{N_0}{1-N_0t}$$
$$N_0 = N - NN_0t$$

order of dead time $t = 500\,\mu sec$.

* The Scintillation Counter →

Principle → It is based on the Principle that nuclear Radiations on falling over a fluorescent material like (ZnS), Produces light flashes called Scintillations which are detected with the help of Photomultiplier tube.

Construction →



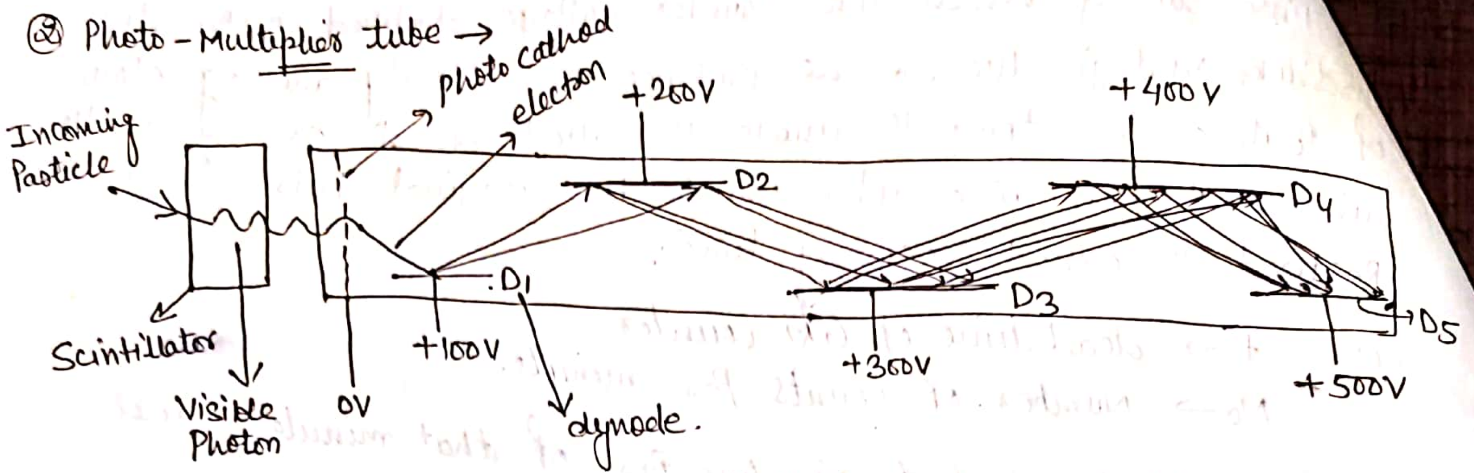
(Block diagram of Scintillation Counter)

① Scintilator → The Passage of a charged Particle through the scintillating material causes some of the Scintillator atoms to become excited, As the electrons in these excited atoms Return to their ground States, Photons are emitted, The number of Photons will depend on the energy lost by the charged Particle Traversing the Phosphor, so total Intensity of the light flash will depend on the energy given up by the charged Particle.

Example Ⓐ Caesium Iodide activate with Thallium in Crystalline form is very Popular as a Phosphor for the detection of Protons and α-Particles.

Ⓑ Sodium Iodide activate with thallium for the detection of α & γ Rays.

② Photo-Multiplier tube →



The Photons from the scintillator strike the Semi-Transparent Photo Cathode in Photo multiplier tube and cause photoelectric emission. electrons Produced at the Photo cathod can be accelerated from it towards the first dynode 'D1 which is +ve with respect to cathod. from D1 creat Secondary emission of electrons. Practically its order is (4). its mean secondory$^{(4)}$ electrons emitted Per incident electron. So from D2 electrons are (4^2) from D3 (4^3) and from (D10) (4^{10}) and last dynode called Collector (D11). or Photo multiplier.

→ Types of scintillators →

① Thalium Activated NaI or Cesium Iodide; ② Zinc Sulphide

③ organic Phosphors → (Anthracene and Stilbene). useful for Counting β-γ Rays.

④ Plastic and liquid scintillators ⇔ ⑤ gases scintillator