RADIATION DETECTORS

Radiation instruments used as survey monitors are either gas ionization detectors (e.g. Ionization chamber or Proportional counter or Geiger-Müller chamber) or solid state detectors (e.g. scintillator or semiconductor detectors).

Gaseous ionization detectors

Gaseous ionization detectors are radiation detection instruments used in particle physics to detect the presence of ionizing particles, and in radiation, protection applications to measure ionizing radiation.

They use the ionizing effect of radiation upon a gas-filled sensor. If a particle has enough energy to ionize a gas atom or molecule, the resulting electrons and ions cause a current flow which can be measured.

A gas-filled detector is usually cylindrical in shape, with an outer wall and a central electrode well insulated from each other. The wall is usually made of tissue equivalent material for ionization chamber detectors. Depending upon the design of the gas-filled detector and the voltage applied between the two electrodes, the detector can operate in one of three regions, shown in figure 5.

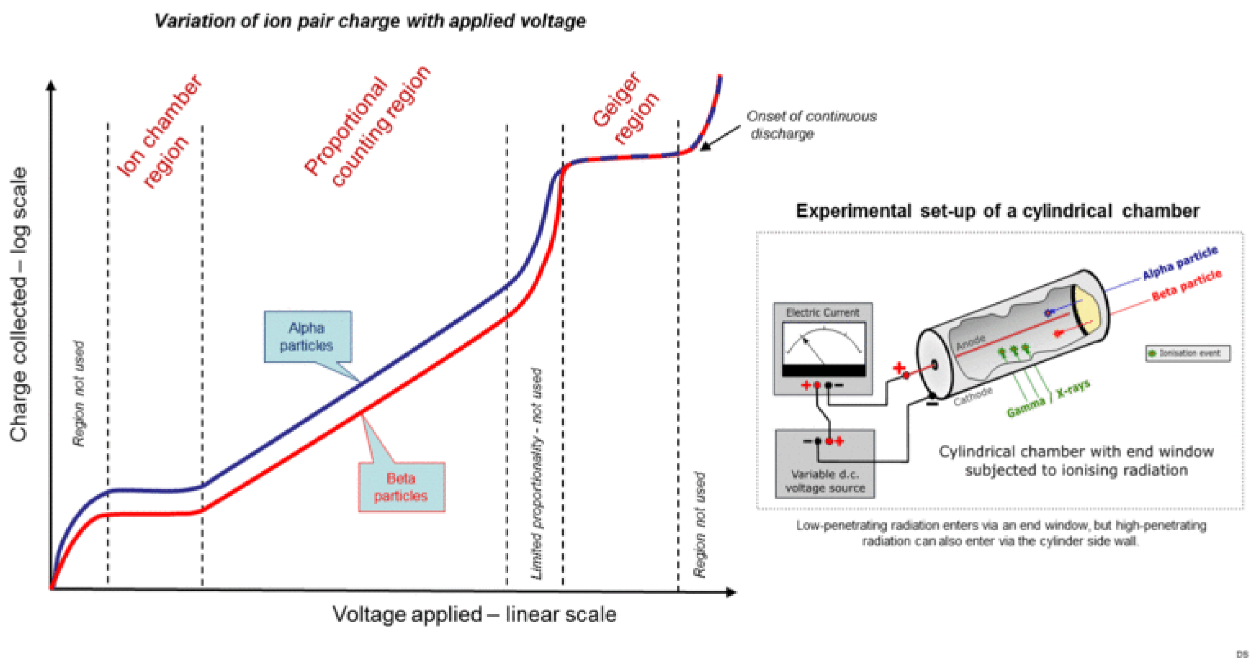
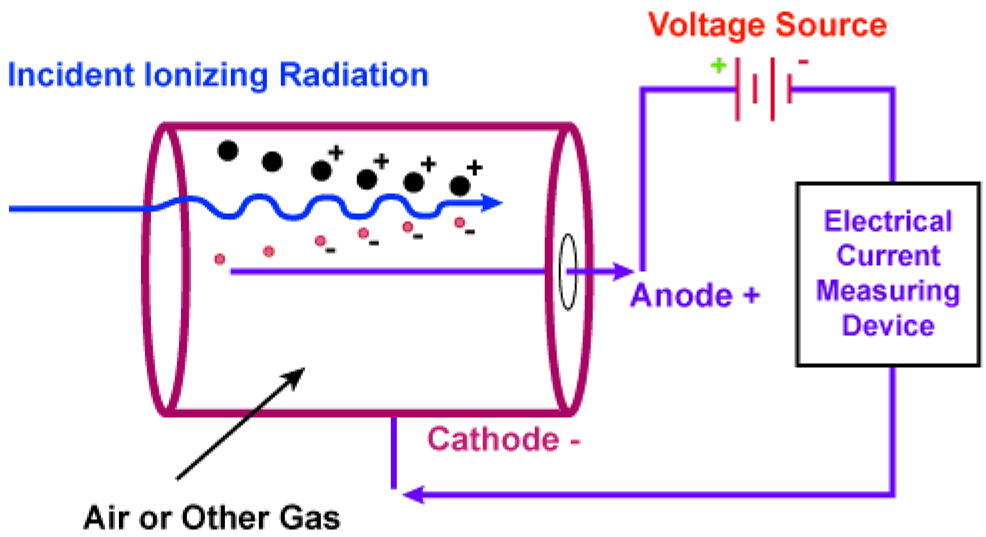


Fig 5: Various regions of operation of a gas-filled detector

Ionization chambers

The ionization chamber is the simplest of all gas-filled radiation detectors, and is widely used for the detection and measurement of certain types of ionizing radiation; X-rays, gamma rays, and beta particles. Conventionally, the term "ionization chamber" is used exclusively to describe those detectors which collect all the charges created by direct ionization within the gas through the application of an electric field. It only uses the discrete charges created by each interaction between the incident radiation and the gas and does not involve the gas multiplication mechanisms used by other radiation instruments, such as the Geiger-Müller counter or the proportional counter.



The advantages are a good uniform response to gamma radiation and accurate overall dose reading, capable of measuring very high radiation rates, sustained high radiation levels do not degrade the fill gas. The disadvantages are 1) low output requiring sophisticated electrometer circuit and 2) Operation and accuracy easily affected by moisture.

Proportional counters

In the proportional region, there is an amplification of the primary ion signal due to ionization by a collision between ions and gas molecules (charge multiplication). This occurs between successive collisions, the primary ions gain sufficient energy in the neighborhood of the thin central electrode to cause further ionization in the detector. The amplification is about 103–104-fold. Proportional counters are more sensitive than ionization chambers and are suitable for measurements in low-intensity radiation fields. The amount of charge collected from each interaction is proportional to the amount of energy deposited in the gas of the counter by the interaction.

The advantages are the ability to measure the energy of radiation and provide spectrographic information, discriminate between alpha and beta particles, and that large area detectors can be constructed. The disadvantages are that anode wires delicate and can lose efficiency in gas flow detectors due to deposition, the efficiency and operation affected by ingress of oxygen into fill gas, and measurement windows easily damaged in large area detectors.

Geiger–Müller counters

The discharge spreads in the GM region throughout the volume of the detector and the pulse height becomes independent of the primary ionization or the energy of the interacting particles. In a GM counter detector, the gas multiplication spreads along the entire length of the anode. Gas-filled detectors cannot be operated at voltages beyond the GM region because they continuously discharge. Owing to the large charge amplification (nine to ten orders of magnitude), GM survey meters are widely used at very low radiation levels (e.g. in areas of public occupancy around radiotherapy treatment rooms). They are particularly applicable for leak testing and detection of radioactive contamination. GM counters exhibit strong energy dependence at low photon energies and are not suitable for use in pulsed radiation fields. They are considered indicators of radiation, whereas ionization chambers are used for more precise measurements. GM detectors suffer from very long dead times, ranging from tens to hundreds of milliseconds. For this reason, GM counters are not used when accurate measurements are required of count rates of more than a few hundred counts per second. A portable GM survey meter may become paralyzed in a very high radiation field and yield a zero reading. Ionization chambers should, therefore, be used in areas where radiation rates are high.

The advantages are that they are a cheap and robust detector with a large variety of sizes and applications, the large output signal is produced from the tube which requires minimal electronic processing for simple counting, and it can measure the overall gamma dose when using an energy compensated tube. The disadvantages are that it cannot measure the energy of the radiation (no spectrographic information), it will not measure high radiation rates due to dead time, and sustained high radiation levels will degrade fill gas

Solid state detectors

Scintillator detectors

Detectors based on scintillation (light emission) are known as scintillation detectors and belong to the class of solid state detectors. Certain organic and inorganic crystals contain activator atoms, emit scintillations upon absorption of radiation and are referred to as phosphors. High atomic number phosphors are mostly used for the measurement of γ rays, while plastic scintillators are mostly used with β particles (figure 6).

- Scintillating phosphors include solid organic materials such as anthracene, stilbene, and plastic scintillators, as well as thallium, activated inorganic phosphors such as NaI(Tl) or CsI(Tl).
- A photomultiplier tube (PMT) is optically coupled to the scintillator to convert the light pulse into an electric pulse. Some survey meters use photodiodes in place of PMTs.

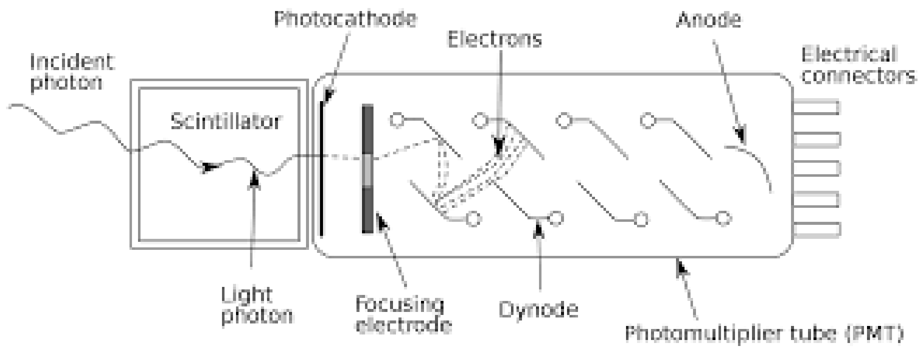


Fig 6: Scintillator detectors

Semiconductor detectors

Bulk conductivity detectors are formed from intrinsic semiconductors of very high bulk resistivity (e.g. CdS or CdSe). They act like solid state ionization chambers on exposure to radiation and, like scintillation detectors, belong to the class of solid state detectors. Extrinsic (i.e. doped with trace quantities of impurities such as phosphorus or lithium) semiconductors such as silicon or germanium are used to form junction detectors. They too act as solid state ionization chambers on the application of a reverse bias to the detectors and on exposure to radiation. The sensitivity of solid state detectors is about 104 times higher than that of gas-filled detectors, owing to the lower average energy required to produce an ion pair in solid detector materials compared with air (typically one order of magnitude lower) and the higher density of the solid detector materials compared with air (typically three orders of magnitude higher). These properties facilitate the miniaturization of solid state radiation monitoring instruments.

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