Fifth lecture

Dose Calibrator QC

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An ionization chamber is an instrument constructed to measure the number of ions within a medium. It usually consists of a gas filled enclosure between two conducting electrodes (the anode and cathode). When gas between the electrodes is ionized by any means, such as by gamma rays or other radioactive emission, the ions and dissociated electrons move to the electrodes of the opposite polarity, thus creating an ionization current which may be measured. Each ion essentially deposits or removes a small electric charge to or from an electrode, such that the accumulated charge is proportional to the number of like-charged ions. A voltage potential that can have a wide range from a few volts to many kilovolts can be applied between the electrodes; depending on the application. Ionization chambers are widely used in the nuclear industry as they provide an output that is proportional to radiation dose.

The **ionization chamber** is the simplest type of gas-filled radiation detector, and is widely used for the detection and measurement of certain types of ionizing radiation, including X-rays, gamma rays, and beta particles. Conventionally, the term "ionization chamber" refers exclusively to 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. Gaseous ionization detectors include ionization chambers and devices that use gas multiplication, namely the proportional counter and the Geiger counter.

Ion chambers have a good uniform response to radiation over a wide range of energies and are the preferred means of measuring high levels of gamma radiation. They are widely used in the nuclear power industry, research labs, radiography, radiobiology, and environmental monitoring.

A gas ionization chamber measures the charge from the number of ion pairs created within a gas caused by incident radiation. It consists of a gas-filled chamber with two electrodes; known as anode and cathode. The electrodes may be in the form of parallel plates (Parallel Plate Ionization Chambers: PPIC), or a cylinder arrangement with a coaxially located internal anode wire.

Principle of operation

A voltage potential is applied between the electrodes to create an electric field in the fill gas. When gas atoms or molecules between the electrodes are ionized by incident ionizing radiation, ion-pairs are created and the resultant positive ions and dissociated electrons move to the electrodes of the opposite polarity under the influence of the electric field. This generates an ionization current which is measured by an electrometer circuit. The electrometer must be capable of measuring the very small output current which is in the region of femtoamperes to picoamperes, depending on the chamber design,

The electric field is sufficiently strong to enable the device to work continuously by mopping up all the ion pairs, preventing the recombination of ion pairs which would diminish the ion current. This mode of operation is referred to as "current" mode, meaning that the output signal is a continuous current, and not a pulse output as in the cases of the Geiger–Müller tube or the proportional counter.[1] Because the number of ion pairs produced is proportional to the energy of the incident radiation,

Chamber types

1- Free-air chamber

This is a chamber freely open to atmosphere, where the fill gas is ambient air. The domestic smoke detector is a good example of this, where a natural flow of air through the chamber is necessary so that smoke particles can be detected by the change in ion current. Other examples are applications where the ions are created outside the chamber but are carried in by a forced flow of air or gas.

2-Vented chamber

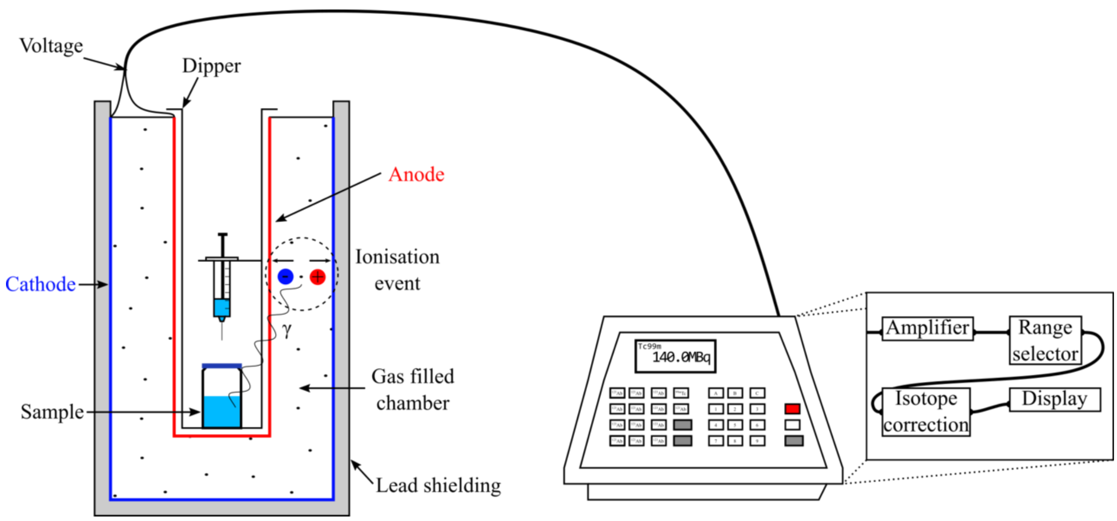
These chambers are normally cylindrical and operate at atmospheric pressure, but to prevent ingress of moisture a filter containing a desiccant is installed in the vent line.[2] This is to stop moisture building up in the interior of the chamber, which would otherwise be introduced by the "pump" effect of changing atmospheric air pressure. These chambers have a cylindrical body made of aluminium or plastic a few millimetres thick. The material is selected to have an atomic number similar to that of air so that the wall is said to be "air equivalent" over a range of radiation beam energies. This has the effect of ensuring the gas in the chamber is acting as though it were a portion of an infinitely large gas volume, and increases the accuracy by reducing interactions of gamma with the wall material. The higher the atomic number of the wall material, the greater the chance of interaction. The wall thickness is a trade-off between maintaining the air effect with a thicker wall, and increasing sensitivity by using a thinner wall. These chambers often have an end window made of material thin enough, such as mylar, so that beta particles can enter the gas volume. Gamma radiation enters both through the end window and the side walls. For hand-held instruments the wall thickness is made as uniform as possible to reduce photon directionality though any beta window response is obviously highly directional. Vented chambers are susceptible to small changes in efficiency with air pressure and correction factors can be applied for very accurate measurement applications.

3-Sealed low-pressure chamber

These are similar in construction to the vented chamber, but are sealed and operate at or around atmospheric pressure. These chambers also have the advantage of not requiring a vent and desiccant. To improve detection efficiency, they are filled with a noble gas because the highly electronegative oxygen in air easily captures free electrons, forming negative ions. The strength of the beta window limits the differential pressure from atmospheric pressure that can be tolerated, and common materials are stainless steel or titanium with a typical thickness of 25 µm.

4-High-pressure chamber

The efficiency of the chamber can be further increased by the use of a high-pressure gas. Typically a pressure of 8-10 atmospheres can be used, and various noble gases are employed. The higher pressure results in a greater gas density and thereby a greater chance of collision with the fill gas and ion-pair creation by incident radiation. Because of the increased wall thickness required to withstand this high pressure, only gamma radiation can be detected. These detectors are used in survey meters and for environmental monitoring.



Applications

1.Nuclear industry

Ionization chambers are widely used in the nuclear industry as they provide an output that is proportional to radiation dose They find wide use in situations where a constant high dose rate is being measured as they have a greater operating lifetime than standard Geiger–Müller tubes, which suffer from gas break down and are generally limited to a life of about 10^{11} count events. Additionally, the Geiger–Müller tube cannot operate above about 10^{4} counts per second, due to dead-time effects, whereas there is no similar limitation on the ion chamber.

2.Smoke detectors

The ionization chamber has found wide and beneficial use in smoke detectors. In an ionisation type smoke detector, ambient air is allowed to freely enter the ionization chamber. The chamber contains a small amount of americium-241, which is an emitter of alpha particles which produce a constant ion current. If smoke enters the detector, it disrupts this current because ions strike smoke particles and are neutralized. This drop in current triggers the alarm. The detector also has a reference chamber which is sealed but is ionized in the same way. Comparison of the ion currents in the two chambers allows compensation for changes due to air pressure, temperature, or the ageing of the source.

3.Medical radiation measurement

In medical physics and radiotherapy, ionization chambers are used to ensure that the dose delivered from a therapy unit or radiopharmaceutical is what is intended. The devices used for radiotherapy are called "reference dosimeters", while those used for radiopharmaceuticals are called radioisotope dose calibrators - an inexact name for radionuclide radioactivity calibrators, which are used for measurement of radioactivity but not absorbed dose. A chamber will have a calibration factor established by a national standards laboratory such as ARPANSA in Australia or the NPL in the UK, or will have a factor determined by comparison against a transfer standard chamber traceable to national standards at the user's site.

أسالة محلوله

Q_1-This is a chamber freely open to atmosphere, where the fill gas is ambient air that is…………..

A. Smoke detectors B.High-pressure chamber C. Vented chamber
D. Sealed low-pressure chamber E. Free-air chamber

Q_2- These chambers are normally cylindrical are………………..also operate at atmospheric pressure

A. Smoke detectors B.High-pressure chamber C. Vented chamber
D. Sealed low-pressure chamber E. Free-air chamber

Q_3- These are operate at or around atmospheric pressure has beta window this type is ……………….

A. Smoke detectors B.High-pressure chamber C. Vented chamber
D. Sealed low-pressure chamber E. Free-air chamber

Q_4-The efficiency of the chamber can be further increased by pressure gas its called………………….

A. Smoke detector B.High-pressure chamber C. Vented chamber
D. Sealed low-pressure chamber E. Free-air chamber

Q_5-The chamber contains a small amount of americium-241 its called………………….

A. Smoke detectors B.High-pressure chamber C. Vented chamber
D. Sealed low-pressure chamber E. Free-air chamber