Transducers For Instrumentation
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Lecture - 28
Radiation Sensors: Gas Filled Detectors

Hello, welcome to the course Transducers for Instrumentation. Today we will discuss about the radiation sensors. So, as the name says radiation sensors, we are going to measure the radiation which is happening from outside environment and we want to measure how much radiation is received using some sensors. So, as we know the radiation is nothing but the electromagnetic wave which is coming in and as the electromagnetic wave is nothing but the stream of photons. So, we have photons which are high in energy. So, when these photons strike or interact with some other matter, they produce certain kind of effects on that matter.

For example, it ionizes certain gases or it kind of give out some electron hole pairs in semiconductor. So, these kind of effects actually happens when a high energy photon strikes with certain media and this is what we want to measure how much ionization or how much how many photons are received in a particular cavity or in a particular volume and we want to convert that quantity into a measurable electrical signal. So, this is what the radiation sensor actually does. So, we are going to start today the radiation sensor. So, radiation sensor, there are three types of detectors that are most commonly used. So, before that radiation sensor is nothing but the sensors used to measure radiation. And there are three types of detectors which are mainly used. So, we have the radiation sensor, the radiation sensor, the radiation sensor, the radiation sensor. The first one is the gassed field detectors. The second is scintillators. And the third one is the solid state detectors. And these gas field radiators detectors are further of three types. The first one is ionization chamber. The second is proportional counters. And the third one is the geyser counter or geyser-muller counter. In short, we call it GN as well. So, here we have radiation detectors which are of three types. One is the gas field detectors, the other is scintillators and the third is the solid state detectors which are composed of for example, some semiconductors like silicon based or some organic material based detectors. Those are those falling the semiconductor or the solid state detectors.

The first one is gas field detectors. As the name says, there is a gas field in a cavity and we measure based on the property change of this gas. So, these gas field detectors are further of divided into three types. One is the ionization chamber. The second is proportional counters. And the third is the GM detector or GM counter or the geyser detector. So, these are of three types gas field detectors. Basically, all these three work on the similar kind of principles but based on the applications and the voltage applied they differ in the functionality. So, we have gas field detectors which we are going to discuss first now. So, the first is gas field detectors and as the name says when the gas in the detector comes in contact with radiation it reacts with the gas becoming ionized. And the resulting charge is 0. So, here we have gas field detectors where we have a cavity and in that cavity we place a certain gas along with two electrodes cathode and anode and we apply a voltage difference across these these two electrodes. When ionized ionization radiation comes in means the high energy photon comes in it reacts with the gas it reacts with what the gas is filled in that cavity and when it reacts this ionizes the gas ionizes means the it creates the charges in the gas filled in the cavity and because we have applied a potential difference this charge will be accumulated on these cathode and anode and that charge how much charge is developed by this ionization this can be measured using some electrical instrument like a emitter or voltmeter. So, that charge we can measure which is proportional to how much radiation is coming and reacting with the gas. So, this is how this gas field detector works and as we said there are three types one is the ionization chamber the second one is the proportional counters and the third one is the gm counters.

So, there are three types let us discuss the first one in detail. So, this works on the same principle, but this operates at a low voltage. So, this is anode and the measure measurement from the primary ions only. So, let us see the structure of these ionization chamber. We have a cavity where we fill a gas. So, let us say this is a cylindrical cavity. This is filled with a certain amount of gas and in this we place two electrodes let us say this is the electrode at the center and there is one electrode on the edge we call it anode and this is cathode and inside the cavity we have filled gas. Inside these electrodes are connected to the variable DC voltage source. So, we have two terminals. The other terminal we connect to anode through a meter or current meter or so, so that we can measure how much charge is actually developed.

So, this is a typical structure of this gas filled detector. We have this cavity filled with the gas and there is a DC voltage source where we apply a known DC voltage across anode and cathode. Now, when the energetic particle comes from outside and passes through this cavity that is going to knock down the gas particles because of this its high energy breaks that these kind of particles the gas atoms. It ionizes the gas and when the gas gets ionized because we are applying it certain DC voltage across anode and cathode they will move towards these electrodes they will be based on the polarity if it is positive it goes to the negative side. So, when this gas gets polarized one, we assume that one photon give rise to one kind of pair of electron hole though it is not electron hole it is actually the gas which dissociates which ionizes and one unit of charge in the gas.

This charged particle now reaches an anode which we can measure using this electrical current how much electrical current is flowing through that kind of corresponds to how much of the photons are received in the cavity. So, we have this let us say some high energy photon comes in and this knocks down the gas particles ionizes the gas. This is high energy photon or the radiation. So, this is how these gas chambers actually work and they registers a measurement from primary ions primary ions means the how many photons are received those are the primary ions which when they convert it into the ionized gas that is called the primary ions. So, let us say 100 photons come in and they give rise to 100 charged particles in this cavity. So, those 100 are called the primary ions and this setup registers only that because those 100 charged particles will reach to anode and cathode and give rise to current which is proportional to 100 photons. So, that is why it registers a measurement from primary ions. Next is because it registers only from the primary ions the measurement that the detector records is directly proportional to the number of ions or pairs created. So, this the measurement shows that the detector records is directly proportional to the number of ion pairs created. This is particularly useful as a measure of absorbed dose over time.

They are also valuable for the measurement of high energy gamma rays. So, we have these ionization chamber where the measurement is being done only from the primary ions. So, the number of photons received they convert into the ion pairs and which is the measurement is going to be done. So, because of this we can say this measures the absolute number of photons and how much photons are received based on that our output reading is there. So, this kind of measurement is useful for a longer time. For example, we want to measure for in let us say 1 hour how much of radiation is being received. So, this kind of measurement can be done using an ionization chamber. So, we because the charge developed is directly proportional to how many photons are received. So, we can use this as a measurement for absorbed dose how much of dose is actually absorbed by the gas over a period of time. So, we take let us say 1 hour or 1 day or a finite amount of time.

In that finite amount of time how many photons or how many energetic particles are received and absorbed by the gas. So, this is what the measurement is and they are also valuable for high energy gamma rays that also ionizes the gas. So, for gamma ray detection this is also used these ionization chamber. So, these are the good points about ionization chambers. However, these chambers are not able to differentiate between different types of radiation. For example, one is the gamma radiation one is the x rays radiation both are ionization radiation. But when the rays come in and they ionize the gas we cannot detect by ionization chamber whether it is because of the gamma rays or because of the x rays. So, thus that detection is not possible using ionization chambers. So, we have ion chambers that are unable to discriminate between different types of radiation. Meaning, they cannot be used for spectroscopes. And they are also widely used in laboratories. To establish different standards. For calibration. And sometime they are little expensive than other kind of detectors. So, here these ion chambers they are not able to discriminate between different kind of radiation as we say it cannot differentiate whether the ionization is happening because of the x rays or because of the gamma rays.

So, if it cannot discriminate between different type of radiation we cannot use it for spectroscopy. Spectroscopy is something where we detect what kind of radiations are coming in. So, this kind of ionization chambers are not suitable for the spectroscopy measurements. They are widely used in laboratories because we measure the absolute number of photons how many photons are coming in which are being absorbed by the gas. So, they are very much used in reference standards to make to calibrate the instruments how many photons are actually received.

So, for calibration of those instruments these ion chambers are very much used. And depending upon the size if we want these kind of detectors in a bigger size then the cost actually goes up. So, they are little expensive than other kind of detectors. So, this is the first type of ionization chamber. Let us discuss the second type. The second type is proportional counter. So, proportional counters are also gas filled detectors and the configuration of these detectors is similar to what we just saw in the last slide. We have a cavity which is filled with the gas and we apply we have two electrodes in that cavity where we apply that the voltage. So, the proportional chamber differ from that is in proportional chamber we apply a little higher voltage in anode and cathode. So, that when a gas ionizes these ionized particles they further give rise to something called avalanche, but this avalanche is not a complete avalanche it is kind of a discrete avalanche.

We do not apply so high voltage. So, that it goes purely into avalanche region. We apply the voltage only in certain range where the avalanche happens, but it does not happen very high. So, it is kind of a discrete avalanche we call and when a high energy photon comes in this is absorbed by the gas it creates charged particle. This charged particle start gaining energy from this high electric field or the high voltage what we apply here it acquires that and that energy and convert a avalanche which is limited in nature or we can say discrete avalanche. So, we have these proportional counters which operate at a slightly higher voltage expected such that discrete avalanches are generated. Each ion pair produces a single avalanche. So, that an output current pulse is generated which is proportional. To the energy deposited by the radiation. This is in the proportional counting region. So, here in proportional counter we apply a little higher voltage.

So, that these discrete avalanche comes into picture they get generated and each ion pair produces single avalanche. So, that an output current pulse is generated because of this avalanche because avalanche will suddenly release certain amount of charges which appear to be pulse at the output we measure in the electrical ah signal. So, this is this voltage is chosen. So, that the entire counter or the detector work in proportional counting region it means the avalanche are generated only in the discrete nature. Now, if we have radiation which is coming in we can differentiate between the radiations because whether it is a gamma ray where it is a kind of x ray radiation because these radiations are differ in terms of energy how much how much is the energy of these charged particles for the photon coming in. So, a high energy photon will give rise to a more stronger discrete avalanche and a lesser energy will give something like a lesser ah kind of avalanche. So, this counter proportional counter we can use for certain amount of spectroscopy which we cannot do in the earlier case where it was only measuring the amount of radiation not able to differentiate. Proportional counter however we can differentiate between the different types of radiation as well. measure energy of radiation and provide spectrographic information differentiate between alpha and beta particles alpha and beta particles. And the other advantage is the large area detectors can also be constructed.

So, in this type of detectors for example if we see the gas filled cavity where we have this gas filled in and we have the electrodes there. So, for example this is the one electrode which is let us say anode and in this gas-filled cavity this is the complete cavity full of gas. A high energy ray is coming like this. So, it ionizes the gas for example let us say this is the ionization is being happening here. So, this charged particle come this way and this is the avalanche region. This avalanche will give rise to multiple charged particles something like this one charged particle give rise to multiple charged particles. So, this is one avalanche let us say second it is ionizing here. So, this charged particle comes here and then start ionizing here 1 to 2, 2 to 4 and something like that. So, this is one avalanche and this is let us say the third avalanche which is happening here. This is let us say one avalanche 2 and 3. So, here in this figure we can see that a high energy wave high energy electromagnetic wave is coming in this red direction this that is high energy ionization.

So, this high energy particle is coming in this direction and the gas which is filled in this cavity that get ionized after ionization this charged particle move towards the anode, but it does not give rise to avalanche till the point it avalanche it reaches the avalanche region and the avalanche is happening only in this avalanche region which is enough only for a discrete avalanche is not like complete avalanche effect is a controlled avalanche effect and we call it let us say the discrete avalanche happening and here we see 1, 2, 3 these are based on the how many charged particles are created by ionization particle. So, this is how this proportional counter works. The disadvantage of this kind of proportional counter is these anode wires are little bit delicate and they lose efficiency in long term use of these proportional counter. So, the disadvantage are that anode wires are delicate and can lose some efficiency in detectors due to deposition. So, this is second type of counter which is proportional counter now we are measuring how much of charge is actually received in the cavity and which is and we are generating a controlled avalanche by applying a slightly higher voltage the voltage is not very high. So, that the complete avalanche is not happening the avalanche is happening only in a small region which is proportional to how many charged particles are actually generated by ionization particles.

So, this is proportional counter the third one is the GM counter or geyser counter we say in that geyser counter we apply much higher voltage compared to the proportional counter. So, that structure of GM counter or the geyser counter is exactly same only the difference is the voltage we apply if we apply a very high voltage the generated charged particle immediately creates a avalanche a sea of ah charged particles and this avalanche is generated throughout the gas and we cannot detect how many ionization particles are received because even a single ionization particle can create this avalanche because of very high applied electric field or the voltage.

So, that kind of measurement is used to detect for example single photon kind of detector if we want to measure whether a photon is coming or not some radiation is there or not we can use those GM counter if a single even a single photon comes in that ionizes the gas immediately we see a avalanche of charged particles and immediately we see a very high value of current flowing into these anode and cathode. So, these GM counters are used as a single photon detectors. So, let us discuss those GM counter or sometime called geyser molar or simply the geyser counter. So, they work on higher voltage. So, this voltage is selected such that. Each ion pair creates an avalanche. But, by the emission of UV photons.

Multiple avalanche are created. Along the anode wire. And at the gas volume. So, this ionizes from as little as single ion pair event. So, if we see the cavity view just like we saw last slide. We have this anode which is there in the gas filled cavity. And a high energy wave comes in. And even a single event occurs of ionization. Let us say this is the single event which occurs in the gas cavity. This single event give rise to the ionize the avalanche which is happening from 1 to 2, 2 to 4 and 4 to 8 something like this. And in between because of this very high applied field in the cavity, this also create other avalanche as well. So, let us say this particle which gains sufficiently high energy, it creates its own avalanche separate from this first avalanche. So, everywhere these avalanche are happening. These can also create some avalanche. So, at the end we get multiple avalanche happening in the cavity and that happens because we have applied a higher voltage between anode and cathode. This high voltage creates a very high electric field in the gas region. And these charged particles they accelerate because of this high electric field. And they gain energy from this high electric field when they acquire enough energy to knock down other gas particles as well.

So, they start their own avalanche as well. So, one even a one photon which is received from ionization particles, a single photon can give rise to multiple avalanche and in instant whole gas is getting ionized because of a single photon which is received. So, this kind of counter is used to detect whether a radiation is there or not because even a single photon comes in this gazer counter immediately ionizes all the gas and we receive its very strong pulse in the output the current pulse because of this so many charge. So, we the current pulse produced by the ionizing events. Which can generate which can derive the count rate or radiation and those. The advantage of these gm counters are they are cheap and very robust devices. The disadvantage is it cannot measure the amount the energy of radiation. So, again there is no spectroscopic information. Hence, no spectroscopic information. So, this is the gm counter where we have a instant avalanche happening even if it charge a single charge particle comes in the whole chamber of gas is actually ionized because of the avalanche. The advantages are they are very cheap and robust devices, but the problem is we cannot detect between different kind of radiation because any of the charge particle if it is coming from gamma ray or x ray or from any of the radii or any of the ionizing radiation a single rate ionization is creating a avalanche and after that we cannot detect whether it was this avalanche was generated by a gamma ray photon or a x ray photon.

So, this is the problem that we do not have any spectroscopic information from these gm counters. So, these are this is the third type of gas filled detectors which is the gm counter. If we classify based on this applied electric field or applied voltage then we have these three kind of radiation detectors which is gas filled. If we want to draw a graph based on the ion pair charge collection. So, let us say we have this graph where on the x axis we have the voltage applied and on the y axis we have rate of charge collected.

So, in the first region where the voltage applied is less let us say this is the lower region where we apply lower voltage and this region is where we apply a higher voltage. So, the first one is the ion chamber region. So, this is the region where this ion chamber region detector works. In medium applied voltage there is the proportional counting region and when the applied voltage is very high then we have a geyser region where we get sudden avalanche. So, this graph shows when we increase the voltage the first lower voltage is ion chamber region where the rate of charge collected is kind of constant and we cannot differentiate between the radiation this is ion chamber radiation.

Then we have a linearly increasing graph with the voltage and rate of charge actually collected is proportional to how much voltage we apply. This is the region for proportional region where we can detect whether which kind of radiation is coming into the gas cavity. The third is the higher voltage which is the geyser region or GM counter works. There again the instant avalanche comes in and we do not have any spectroscopic information we cannot detect whether the radiation is of this type of that or that type. But in GM counter even a single photon we can detect very easily which shows that whether radiation is present or not present. So, these are the three types of gas field detectors which we use for radiation detectors.

So, that is all for today.

Thank you.