Chemical Process Instrumentation
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Lecture – 25
Pressure Measurement: Moderate and High Pressure Measuring Instruments (Cont.)

Welcome to lecture 25. So, this is the last lecture of week 5 and also the last lecture for moderate and high-pressure measurements. So, today we will talk about electrical pressure transducers and also will talk about high pressure measurements.

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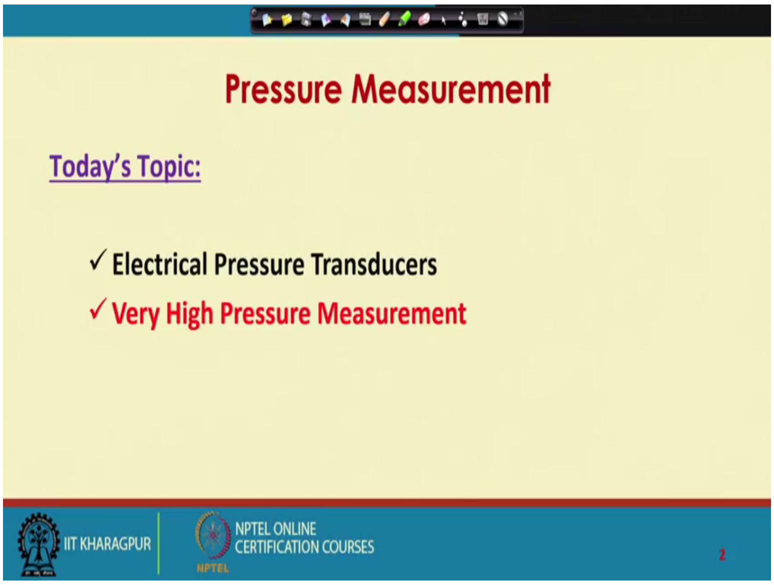

So, today's topic is electrical pressure transducers and very high-pressure measurement.

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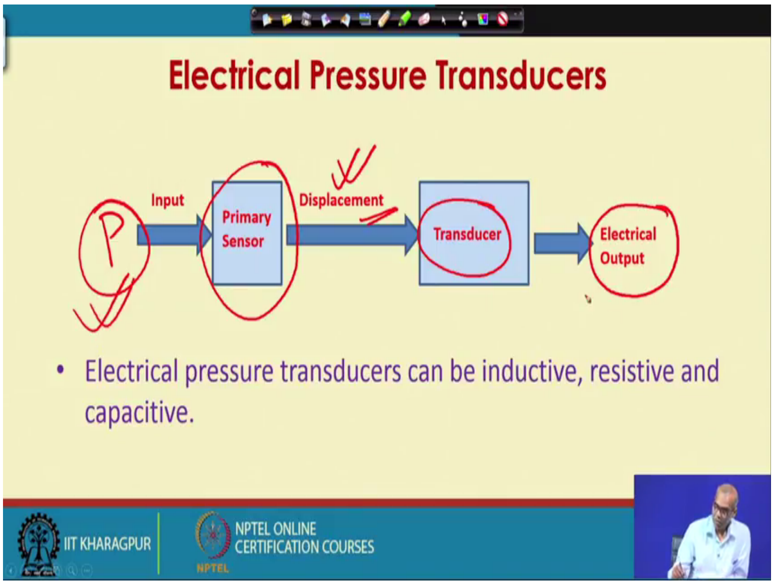

As we have discussed while talking about transducers, a transducer element usually gives us electrical signal as output and it becomes very convenient for the purpose of measurement. Now several pressure measuring instruments gives us displacement as output. Let us say, the elastic elements types such as bourdon tube, bellows, diaphragm, they all give displacement when pressure is given as input. So, elastic pressure elements gives us displacement or deflection as output when pressure is input.

Now, we have talked about electromechanical transducers, which receives displacement as input and gives us an electrical signal as output. For example, LVDT we have talked about, we have talked about capacitive transducers, we have talked about strain gauges etc. So, if I can combine an elastic pressure element such as bourdon tube or bellows or diaphragm with electromechanical transducers such as LVDT or strain gauge then, we can have an electrical pressure transducers.

So, if you look at this diagram let us say it is primary sensor is a bourdon tube or a bellows or diaphragm. So, I give pressure input I get displacement as output. Now I make use of an electromechanical transducers such as LVDT. So, which will receive this displacement as input and give me an electrical signal as output, finally, I have been able to convert this pressure signal to this electrical signal and as you know that, handling electrical signal is much more convenient than handling a displacement signal. So, this is the basic principles of electrical pressure transducers electrical pressure transducers can be inductive, it can be resistive, it can be capacitive or it can also be piezoelectric type. We have talked about transducer element in detail. So, we will briefly touch up on these inductive, resistive, capacitive and piezoelectric and pressure transducers. So, the basic idea is to make use of an electromechanical transducer to convert the displacement output of a pressure gauge to an electrical output.

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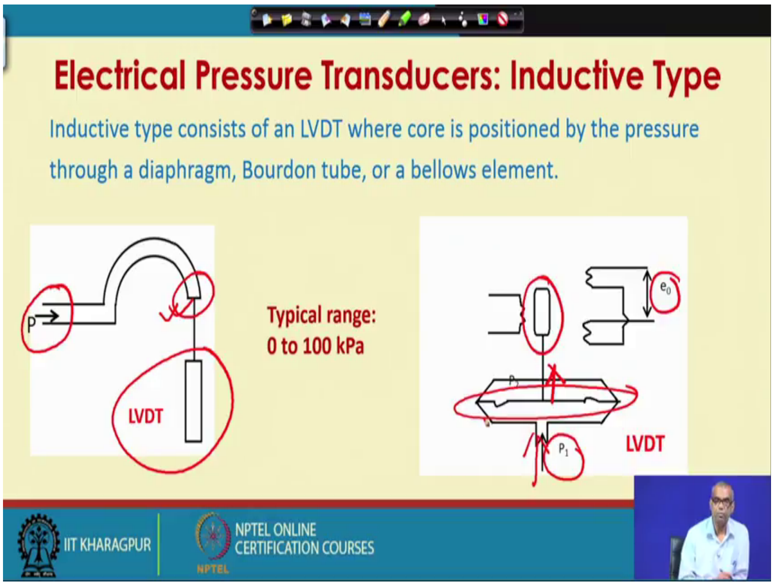

Now, let us talk about first inductive type electrical pressure transducer. Inductive type electrical pressure transducer consists of an LVDT or linear variable differential transformer where core is positioned by the pressure being applied through a diaphragm, bourdon tube or bellows element. So, you apply pressure here, in this bourdon tube we have learnt in previous classes that there will be deflection of this tip of the bourdon tube.

Now I make use of LVDT to convert this displacement to an electrical signal. Similarly, I have this diaphragm when I apply pressure gauge pressure here, this diaphragm deflects. Now this core of LVDT is attached to the diaphragm. So, as the core shows displacement, the output voltage will be a measure of the displacement of the core which in turn is a displacement of the diaphragm which is in turn is a measure of pressure.

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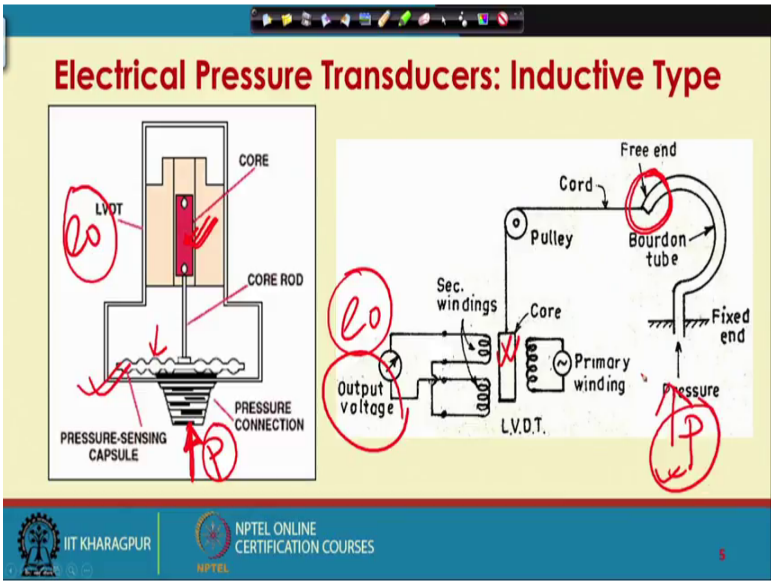

This is the better picture of diaphragm based electrical pressure transducers and bourdon tube based electrical pressure transducers. So, here you have this diaphragm or those capsules. So, you have formed pressure sensing capsule using diaphragms. You take 2 diaphragms and join at the periphery. So, you form a capsule.

Now, this is the connection for the pressure here, the core of the LVDT is connected to this pressure sensing capsule. Now when I apply pressure here, this capsule receives the pressure and it will show deflection. So, this displacement will cause a movement of the core of the LVDT. So, the LVDT will produce an electrical signal of voltage it will produce and that will be dependent on the pressure being applied. So, I can directly calibrate the output voltage of LVDT with this pressure.

This 2 can be directly related similarly, you have bourdon tube here you apply pressure inside the bourdon tube the free end will show displacement, see that displacement is used to move this LVDT core. So, in this when you apply pressure inside the bourdon tube, this shows displacement accordingly the core of the LVDT goes up or comes down depending on the magnitude of the pressure and depending on that you will get an output voltage. So, this output voltage is related to this pressure.

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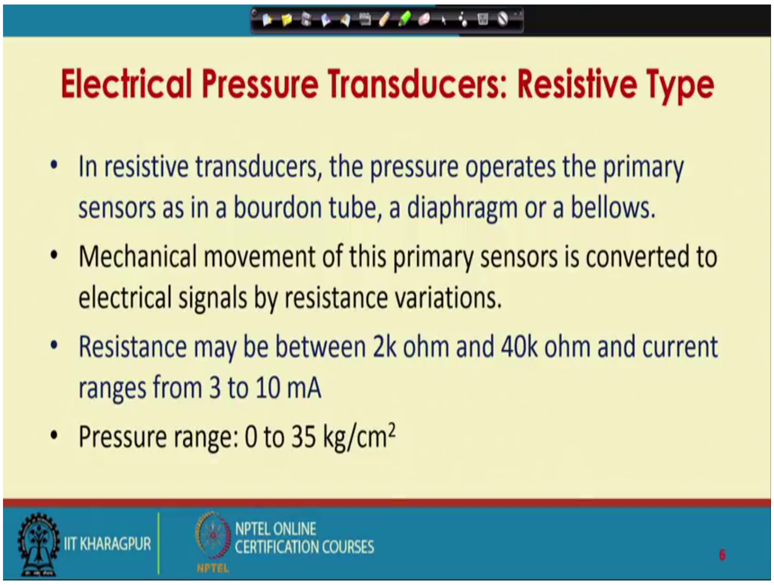

Next, let us talk about resistive type electrical pressure transducers. We talked about inductive type now will talk about resistive type. In resistive transducers the pressure operates the primary sensors as in a bourdon tube a diaphragm or a bellows. Mechanical movement of this primary sensor is converted to electrical signals by resistance variation.

So, here the electro mechanical displacement transducer works on the principle that, the resistance will change will measure the displacement by measuring the change in resistance. Resistance vary between 2 k ohm and forty k ohm and current ranges from 3 to 10 milli ampere the typical pressure range is 0 to 35 k g per centimetre square and indicative range.

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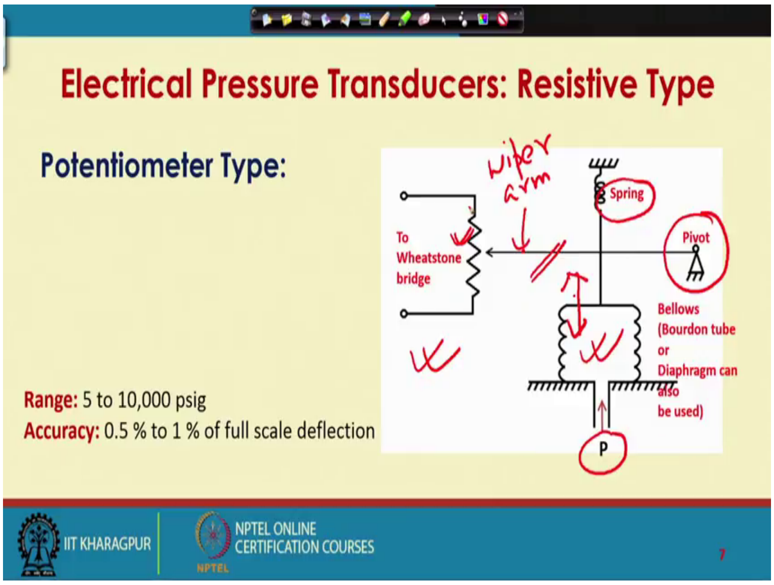

So, the first resistive type electrical pressure transducer will talk about is a simple potentiometer type.

It consists of a precision potentiometer, this is the wiper arm you have a bellows here. The bellows is connected to this wiper arm. We are also attached a spring here and this wiper arm is pivoted. So, when I apply pressure inside the bellows, the sealed end of the bellows will show deflection as there is deflection the wiper arm will change the location here as it does, there will be a voltage output from the wheat stone bridge. So, initially you get a null point and then when you apply pressure, the balance will be destroyed because the wiper arm has changed the position. So, the output voltage is a measure of the pressure that you are applying inside the bellows. So, this way you can convert the bellows to a resistive type electrical pressure transducer.

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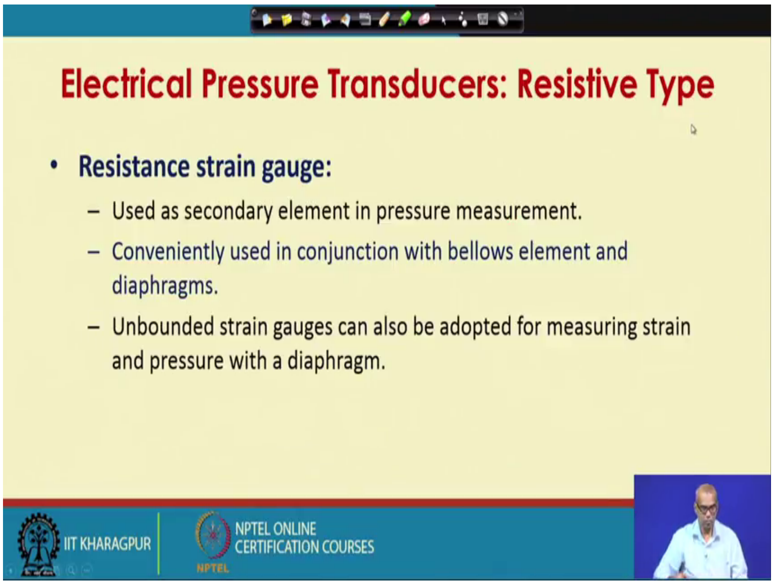

The typical range is 5 to 10000 psig and the accuracy is 0.5 percent to 1 percent of full scale deflection.

The second resistive type electrical pressure transducer will talk about is resistance strain gauge we have talked about resistance strain gauge, when you talked about transducer elements. Resistance strain gauge is used as secondary element in pressure measurement. So, the strain gauge is the electromechanical displacement transducer here. It can be conveniently used in conjunction with bellows element as well as diaphragms unbounded strain gauges can also be adopted for measuring strain and pressure with a diaphragm.

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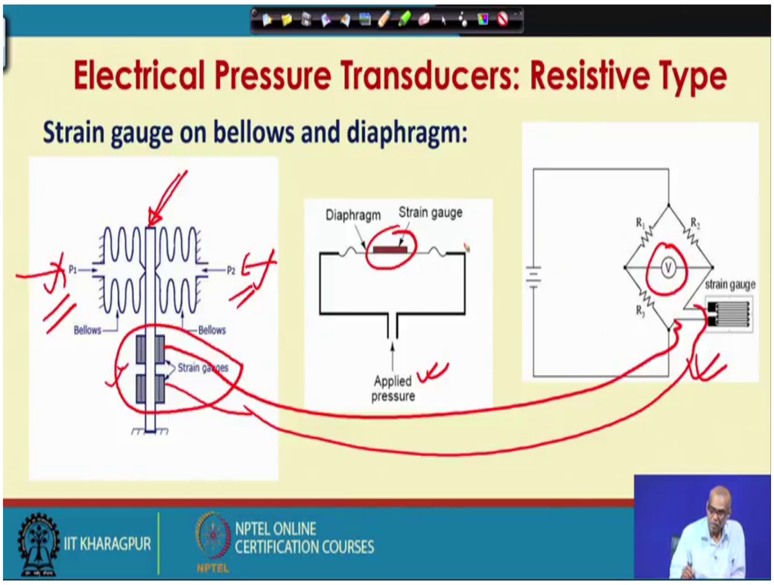

So, this is first, let us consider which is a schematic of measurement of resistance, change in the strain gauge by Wheatstone bridge. So, what we do is, we have attached this strain gauge to one arm of the Wheatstone bridge. You know the strain gauge measures the strain or of a small displacement. So, that strain gauge is bounded to a sample, the sample is under strain. So, the strain gauge is also under strain. So, there will be change in resistance. So, when you initially you establish the balance in the Wheatstone bridge then, you apply strain to the strain gauge the balance will be destroyed and this output voltage will be non-0 output voltage and that will be a measure of the strain in the strain gauge.

Now, how do I make use of the strain gauge? To measure pressures or how do I use a strain gauge? To convert a bellows or a diaphragm to a resistive type electrical pressure transducer let us first look at this, we have taken 2 bellows elements for measurement of differential pressure. You could have taken a single bellows element as well for measurement of gauge pressure or if you seal one end seal this bellows element and completely evacuate it then, you will measure absolute pressure.

Now so, you have 2 bellows elements for 2 pressure applications and these 2 bellows elements are joined together by this link. I attach strain gauge here now when I apply pressures, in this bellows element and this bellows element this link will show a displacement. So, this attached strain gauge will feel a strain. So, it will change it is resistance, that change in resistance has to be measured using this Wheatstone bridge. So, basically this goes to this arm of the Wheatstone bridge. So, initially you establish a balance in the Wheatstone bridge then you apply pressure, this link shows a displacement which cause a strain in the attached strain gauge now the resistance of the strain gauge were changes. So, there will be a non-0 voltage output from the Wheatstone bridge which is a measure of difference between these 2 pressures.

So, that way we can convert a bellows element to a resistive type strain gauge resistive type electrical pressure transducer that uses a strain gauge similarly, you can attach a strain gauge on the diaphragm. So, when you apply pressure these diaphragm shows deflection. So, that will cause a strain in the attached strain gauge. So, there will be change in resistance in the strain gauge where which can be read using Wheatstone bridge principle.

So, here also, we convert this diaphragm gauge to an electrical pressure transducer.

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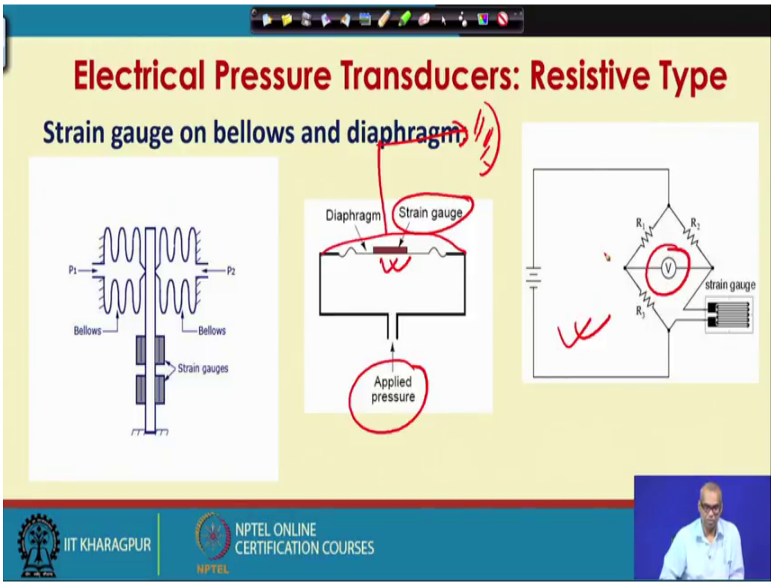

Note if you do not use this strain gauge, you will perhaps read the deflection of the strain gauge by attaching, a pointer against a attaching a pointer and scale to this diaphragm. But, if you put a strain gauge on the diaphragm, you can measure the change in resistance due to application of pressure by using a Wheatstone bridge principal and we will get electrical signal voltage as output, which becomes more convenient for measurement purpose.

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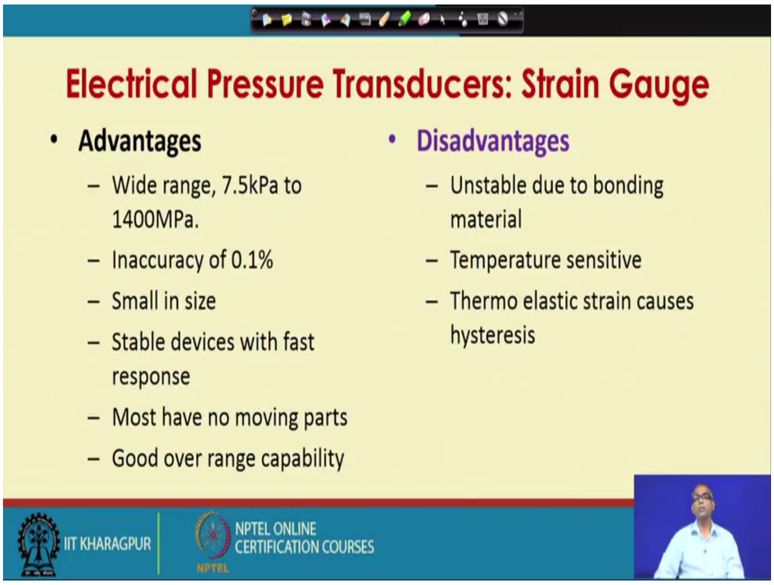

There are certain advantages of strain gauges; advantages are wide range 7.5 kilo pascal to 1400 mega pascal. So, electrical pressure transducers based on strain gauges have wide range 7.5 kilo pascal to1400 mega pascals in accuracy of 0.1 percent, small in size, stable devices with fast response usually they do not have any moving parts, good over range capability.

However, there are certain disadvantages as well, the strain gauge is unstable due to bonding material, it is temperature sensitive, because change in ambient temperature will cause a change in resistance of the strain gauge resistance wear, but we have learnt about temperature compensation in the strain gauge what we do is we add an identical strain gauge to the adjacent arms of the Wheatstone bridge and that strain gauge will not be under strain.

It is an identical strain gauge, you take an identical strain gauge attached to the adjacent arm of the Wheatstone bridge and that strain gauge will not be under strain. So, that way you compensate the effect of change in ambient temperature.

Thermoelastic strain causes hysterisis. So, these are some disadvantages of electrical pressure transducer based on strain gauge.

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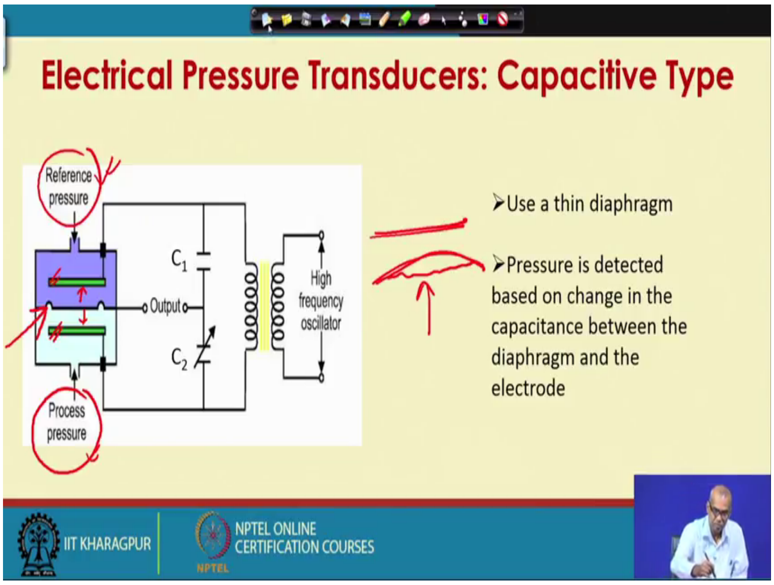

This is a capacitive type electrical pressure transducers. So, in case of capacitive type electrical pressure transducers, the electromechanical displacement transducer is a capacitive type transducers. So, will attach a bellows element or a diaphragm element with a capacitive type transducer, so that the diaphragm or the bellows can be converted to a capacitive type electrical pressure transducers.

So, you have this diaphragm and you have 2 different pressure sources acting. Now depending on this 2 pressures the diaphragm will go in this direction or will come in this direction then the pressure can be detected based on the change in the capacitance between the diaphragm and the electrode. So, the capacitive type electrical pressure transducers use a thin diaphragm. We apply pressures then the pressure is detected based on change in the capacitance between the diaphragm and the electrode.

If you use only one pressure source what I can do is? I can keep one electrode fixed and one diaphragm which will change it is position. So, one electrode fixed and another diaphragm, let us say this is diaphragm. So, with application of pressure this diaphragm will change position. So, the capacitance between this electrode and this diaphragm will change. So, the displacement can be converted to an electrical signal.

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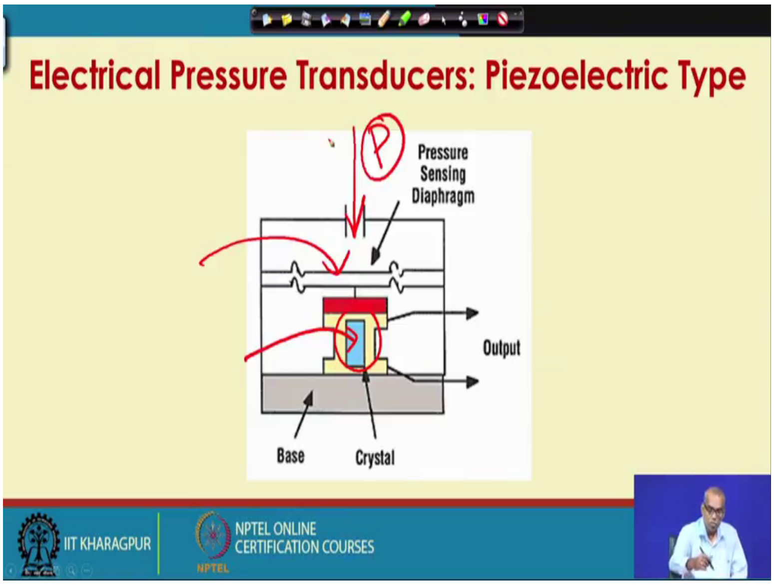

Piezoelectric electric type electrical pressure transducers again, this is the piezoelectric crystal, this is the diaphragm. So, when you apply pressure, the diaphragm receives the pressure, a force will be developed and this forces is transferred onto this piezoelectric crystal. So, there will be charge produced on the surface of the crystal and by measuring that, we can measure the pressure.

So, output of the piezoelectric crystal which is an electrical signal, can be related to this pressure. So, make use of a diaphragm. Let, the pressure act on the diaphragm a force will be developed, a piezoelectric crystal is connected to the diaphragm. So, as the pressure is applied on the diagram diaphragm applies a force on the piezoelectric crystal and when the piezoelectric crystal senses force a charge is accumulated on the surface. So, there is the piezoelectric property. We have talked about when we talked about electrical sorry piezoelectric transducers. So, that way we can convert a diaphragm to an electrical pressure transducer which makes use of piezoelectric crystals.

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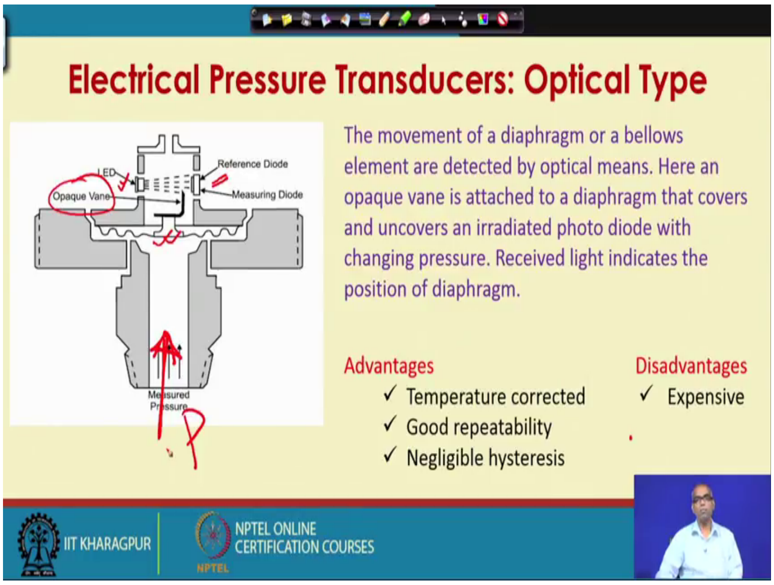

Next let us talk about electrical pressure transducers that are optical type. These are more recent electrical pressure transducers. Here, again we make use of a diaphragm or bellows as a primary sensor. Now, this is let us say a diaphragm and I apply the pressure to be measured here. Here you can see an optical vein an opaque vein is attached to the diaphragm. An opaque vein is used to the diaphragm now you have LED source here which emits light and you have photodiodes on the opposite side. You have a reference diode, you also have a measuring diode, there are 2 diodes.

Now as this pressure is applied the diaphragm will deflect. As the diaphragm deflects, the attached opaque vein when will also go up. So, that will cover some of the lights being emitted from LED. So, the photo diodes will receive less light. If you now decrease the pressure little bit, the opaque vein will come down little bit and then the photo diode will receive more light. So, the output of the diode will determine the position of the opaque vein and the position of the opaque vein depends on the deflection of the diaphragm.

So, finally, the output of the diode will determine the pressure that is being applied. So, the moment of a diaphragm or a bellows element are detected by optical means here an opaque vein is attached to a diaphragm that covers and uncovers an irradiated photo diode with changing pressure. Received light indicates, the position of the diaphragm and the position of the diaphragm is a measure of the pressure.

So, output of the photo diode can be directly calibrated in terms of pressure units. We have certain advantages of using optical type electrical pressure transducers. Such as, temperature corrected, good repeatability, negligible hysteresis; however, they are more expensive pressure measuring instruments. That completes our discussion on moderate pressure measuring instruments.

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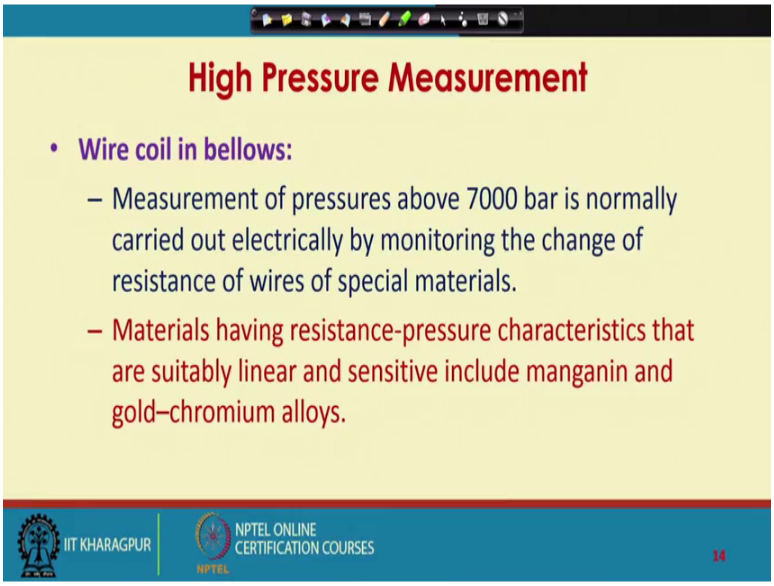

We will now talk about electrical high pressure measuring instruments.

High pressure measurement uses wire in wire coil in bellows. So, it makes use of an electrical coil in bellows. Measurement of pressures above 7,000 bar is normally carried out electrically by monitoring the change of resistance of wires of special materials. Materials having resistance pressure characteristics that are suitably linear or nearly linear and sensitive include manganin and gold chromium alloys.

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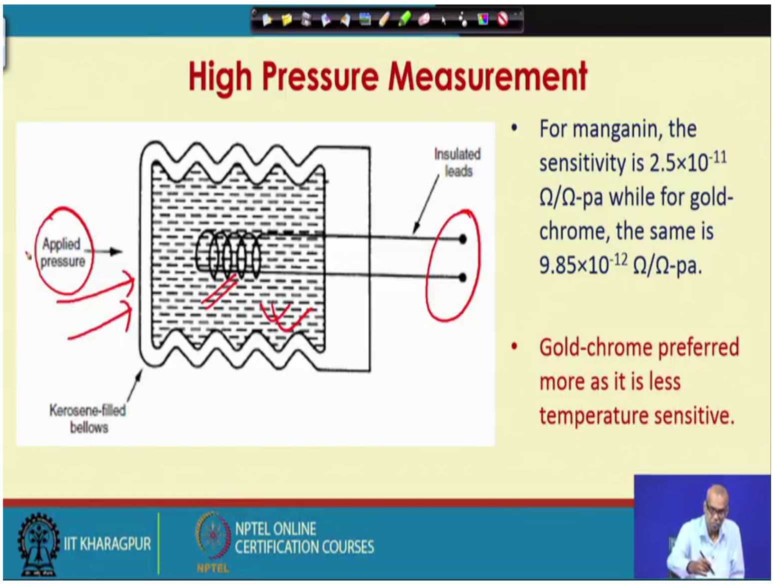

So, what you do is, we take manganin or gold chrome where coil is formed and that is put inside a bellows and the bellows is filled with kerosene. So, these are the leads from the coil that is coming out. So, you apply the very high pressure here, the bellows will receive the pressure there is kerosene field inside. So, that will transmit the pressure to the electrical coil made of manganin or gold chrome. So, electrical resistance will change and change in resistance can be measured and that can be related to the pressure being applied. For manganin, the sensitivity is 2.5 into 10 to the power 11 while for gold chrome the same is 9. 85 into 10 to the power 12 please note the unit ohm pascal.

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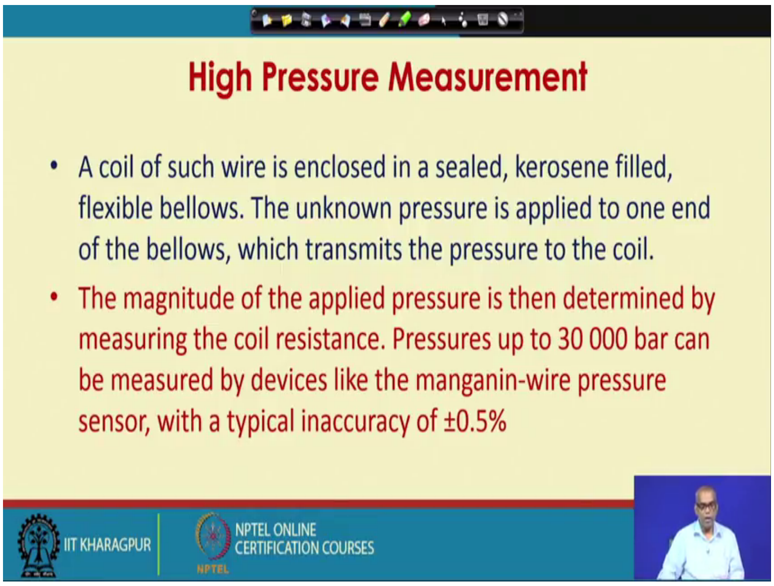

Gold chrome is preferred more, as it is less temperature sensitive. So, coil of such wire is enclosed in a sealed kerosene field flexible bellows. Such wire means, manganin or gold chrome alloy.

The unknown pressure is applied to one of the bellows which transmits the pressure to the coil. The magnitude of the applied pressure is then determined by measuring the coil resistance. Pressures upto 30000 bar can be measured by devices like the manganin wire pressure sensor with a typical in accuracy of plus minus 0.5 percent.

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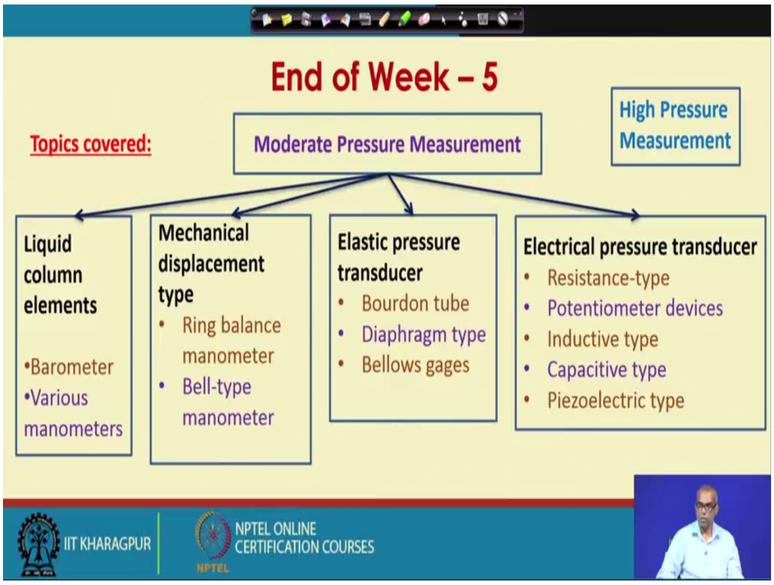

So, this is the end of week 5. So, the topics that you have covered are moderate pressure measurement, as well as high pressure measurement. Under moderate pressure measurement we have talked about barometers various manometers which come under liquid column elements. We have talked ring balance manometer bell type monometer which comes under mechanical displacement type.

We have talked about electrical pressure transducer such as bourdon tube diaphragm type bellows gauges and we have talked about electrical pressure transducer such as resistance type potentiometer devices inductive type capacitive type piezoelectric type and then, we also talked about high pressure measurement by manganin or gold chrome alloys through electrical methods.

So, this is end of week 5 and in the next week, we will talk about measurement of very low pressures or measurement of high vacuum.