Upstream LNG Technology
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Lecture – 18
Pressure measurement in natural gas systems

Welcome. Today we shall learn about a few Pressure measurement techniques, which are used in the natural gas industries.

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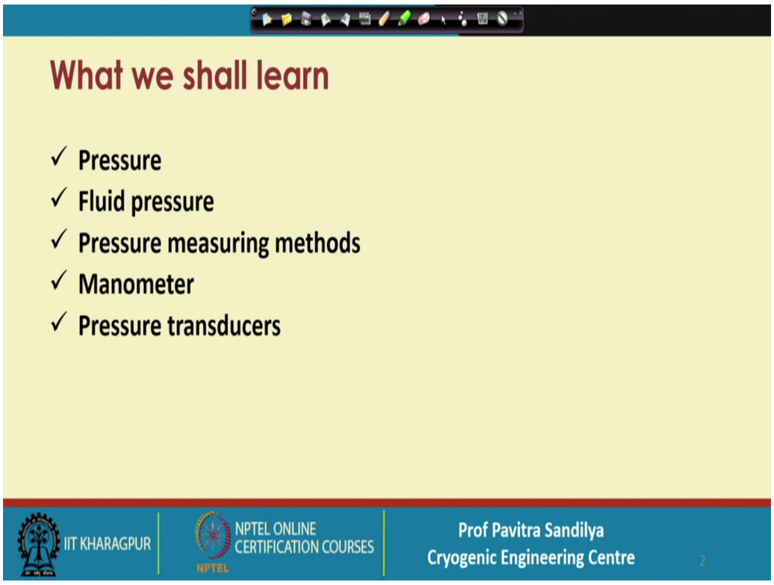

In this particular lecture we shall be learning about the, what is pressure the fluid pressure, the various pressure measuring methods related to natural gas and then something about manometer then some pressure transducer.

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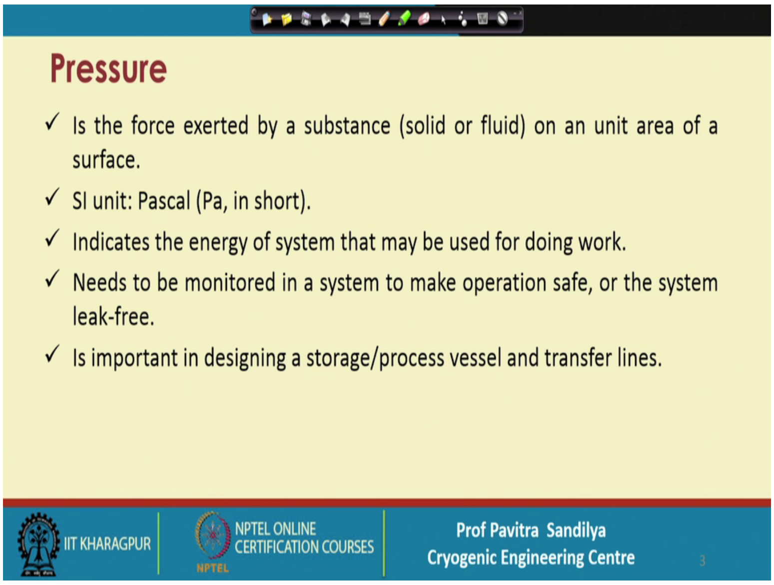

Now, first let us come to the pressure. Now, as we know the pressure is the force exerted by a substance the substance may be a solid or a fluid on an unit area of a surface. So, the SI unit of pressure is Pascal which is also the Newton per meter square, and it is given in short as Pa and pressure represents the energy that a system has to do some work. And we know that there are some various equipment like compressor; compressor takes in the pressure to takes in work to generate the pressure whereas, turbine reduces the pressure and it gives out work.

So, there everywhere you find that the pressure changes across a compressor or a turbine either to consume the work or to generate the work. Then we need to monitor the pressure in a system so, that we the system can be operated safely and without any leak whenever we are talking of any kind of storage or transfer. So, when we are whenever we are designing any kind of storage or process vessels and transfer lines, we have to take care of the pressure inside the things. Because in the storage vessel for example, if there is the pressure is certainly goes up beyond the design pressure, it may it explosion and in the process vessels many a times we are carrying out some kind of reactions on some kind of separations in process vessels.

So, we have to keep monitoring the pressure inside the vessel because the for a particular process takes place at a particular operating condition, and if the pressure fluctuates if the operating conditions goes away from the designed operating conditions, then we will not be getting the right performance. So, that is why we need to be very careful about the pressure inside the system and so we need to have some appropriate pressure measuring device.

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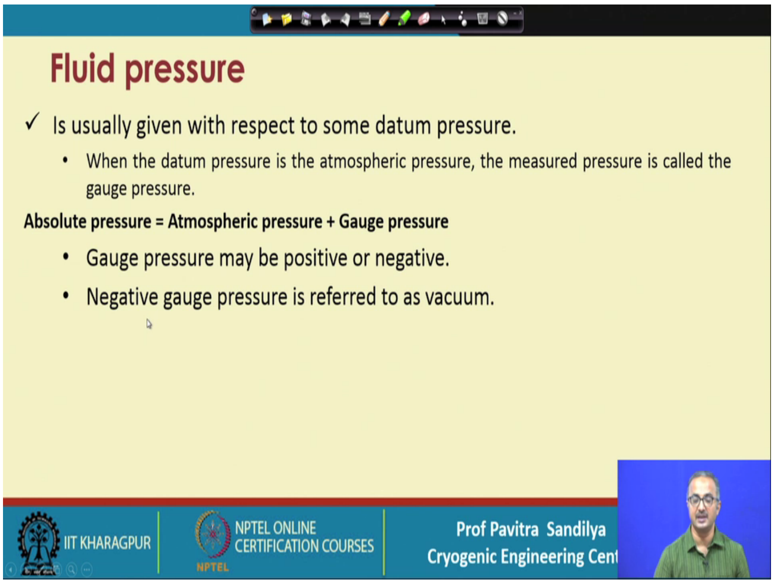

Now, let us look at what is fluid pressure. Now fluid pressure is generally represented a with respect to some kind of datum pressure and when the datum pressure is the atmospheric pressure though we call it the gage pressure. And so, we have this thing that absolute pressure is equal to the atmospheric pressure plus the gauge pressure. The gauge pressure may be positive or negative, and if we have negative gauge pressure we call it vacuum.

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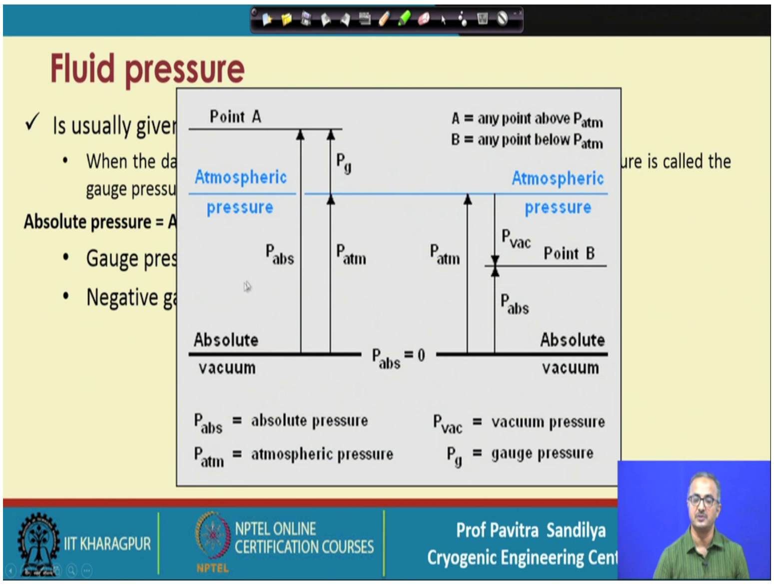

And this can be demonstrated from this particular figure. Here what we see that there is this atmospheric pressure and there is one point A. The point A has a pressure which is higher than the atmospheric and here we call it Pg and the absolute pressure is the P atmospheric plus P g, where P g represents the gauge pressure. And somewhere near the bottom we are showing some kind of absolute pressure that is 0 pressure. And we can have various types of units for that here we are showing atmospheric, atmosphere bar there are various kind of units sometimes represent pressure in terms of the millimeter of mercury, sometimes in terms of inches of mercury, millimeter of water inches of water column. So, there are various types of units that are there for the pressure measurement and here in this particular figure we see the vacuum pressure.

Again we say this is the atmospheric pressure and this P vac represents the negative gauge pressure or the vacuum pressure. So, the absolute pressure is equal to the atmospheric pressure minus this negative gauge pressure or the vacuum pressure. So, this is the absolute pressure. So, this is the vacuum pressure and this is the more than atmospheric pressure.

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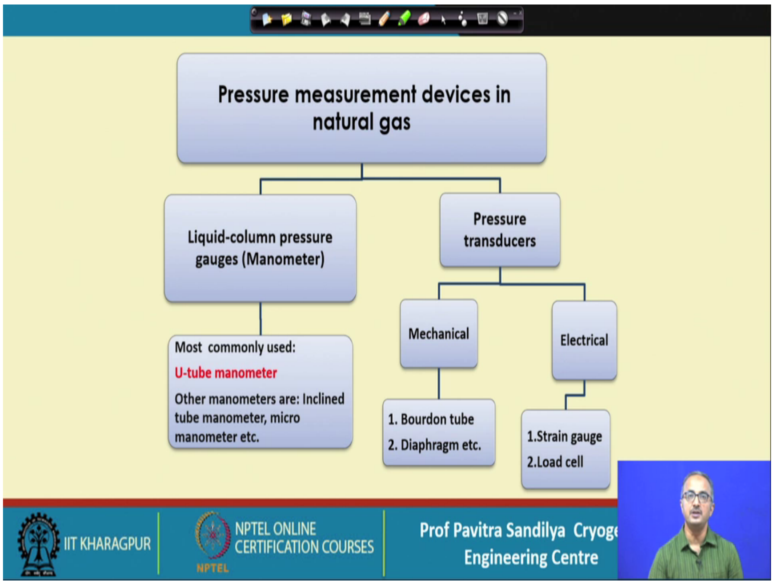

Now, we shall be looking into a few types of the pressure measuring device cells, which are related to the natural gas processing. So, broadly all the measuring devices for pressure are divided into two types, one is the liquid column measuring gauges and there is the pressure transducer. Generally the liquid column pressure gauges incorporate some kind of fluid and this particular liquid column pressure gauges is also called manometer and there are various types of manometers available depending on the pressure ranges we need to measure.

The U-tube manometer is very common and in the natural gas industries, we use the U-tube manometer because of the large pressure differences we find in the pipelines or the storage vessels.

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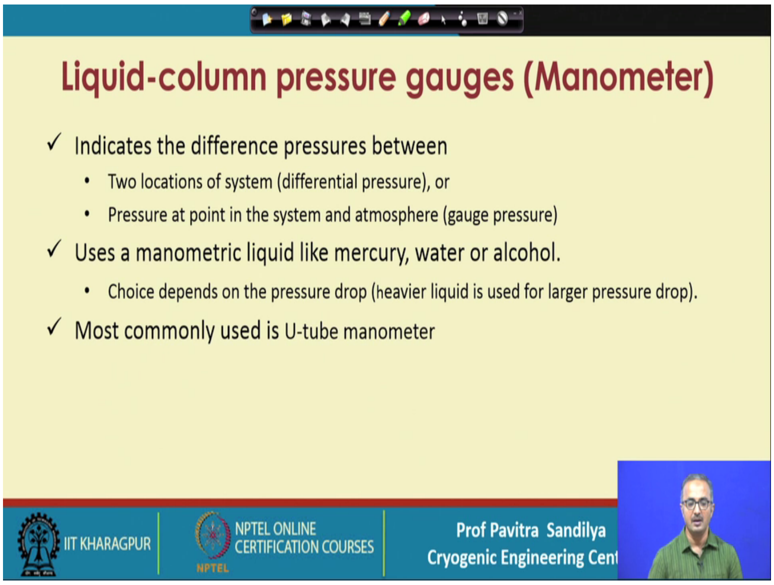

So, let us look into the manometer, first let us see that what it represents. The manometer can be used to find out the pressure difference between two locations or we call it the differential pressure. A manometer may also be used to find out the absolute pressure in a given system by putting one of exposing one of is limps to the atmosphere. So, which we will see that in our next slide how it is based now as I told you that we use different types of manometric liquids like mercury, water or alcohol depending on the pressure difference expected.

So, we use generally heavier liquid if the pressure difference is large; if the pressure difference is small then we use lighter liquid because in that case we shall be giving we shall be getting the difference in the liquid level more, if you are using lighter liquid for small pressure difference.

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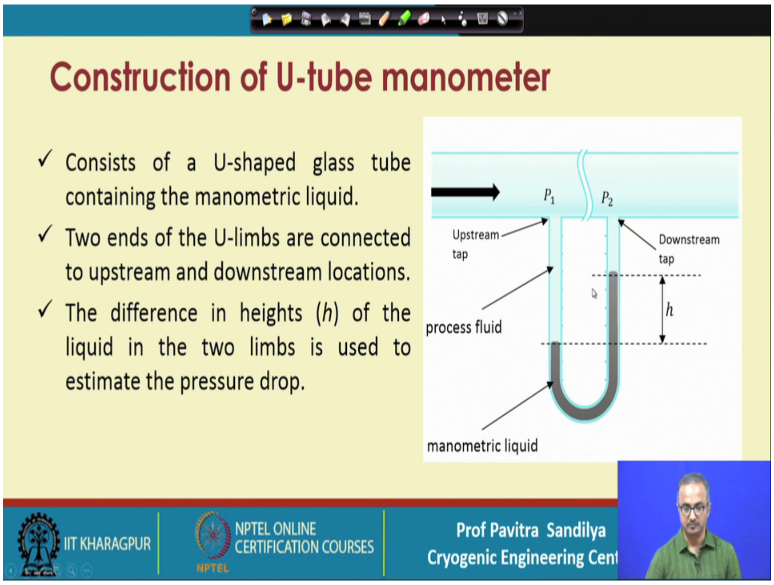

Now, let us look at how a U-tube manometer looks like. Here it is that we have a U-tube manometer it looks like U. So, that is why the name U-tube. So, in this case we find there are two limbs and these two limbs are placed in the pipeline where we want to measure the pressure difference, in this figure we find that the flow is taking place from left to right.

So, we have in this manometer some manometric fluid that is liquid and some process fluid which is also passing through the pipeline. And the two ends of the manometer are put on the one on the upstream side and one on the downstream side. And what we find because the pressure on the upstream side is more than the pressure at the downstream side we find that the, this liquid is pushed downwards more than the other on that other limb.

So, we find there is a difference in the heights of the manometric liquid in the two limbs and obviously, when there is no flow through the pipeline, these two limbs will be having the same liquid heights. So, here we see that the difference in the heights between the two limbs is h.

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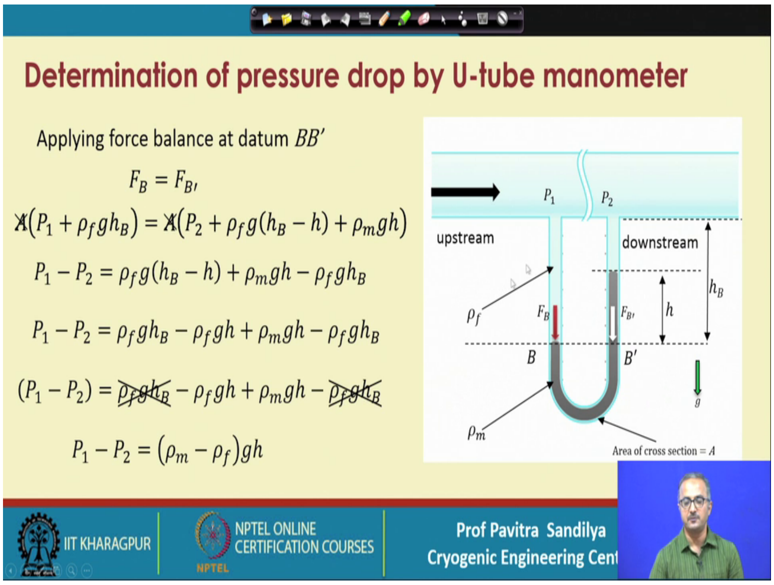

Now we shall see that how we can find out the pressure drop using this U-tube manometer. So, here we are showing that some datum B across which we are taking the pressure force balance. So, we shall be looking at the force acting on this plain BB prime and here we see that here this F B is the force which is acting on this limb and F B prime is acting on the other limb the downstream limb.

So, here we have the those two forces I have to be balanced, and when we are balancing the forces for this F B; what is happening? The forces due to this pressure P one plus the due to the hydrostatic height of this particular fluid; So, we are writing P 1 into A that is the force plus rho f g into h B into A. So, this is the total height h B that h B into A s the rho f h B h B into a is the force due to this particular process fluid. And on the right hand side we have thus P 2 into A due to the flowing liquid then we have this small height that is h B minus h into rho f into g plus this h B or h h into rho m into g into A.

So, this is how we are getting the various forces and which are acting on this plane BB prime. Now, after that this force balance we now make all these mathematical manipulations to ultimately get this particular equation, which gives us the pressure difference between the upstream and downstream side in terms of the density difference between the manometric liquid and the process fluid and the height difference in the liquid column inside the U-tube manometer.

So, once we know h once we know this density of the manometric liquid and density of the process fluid, we can find out the pressure difference between the upstream and the downstream of the flowing fluid.

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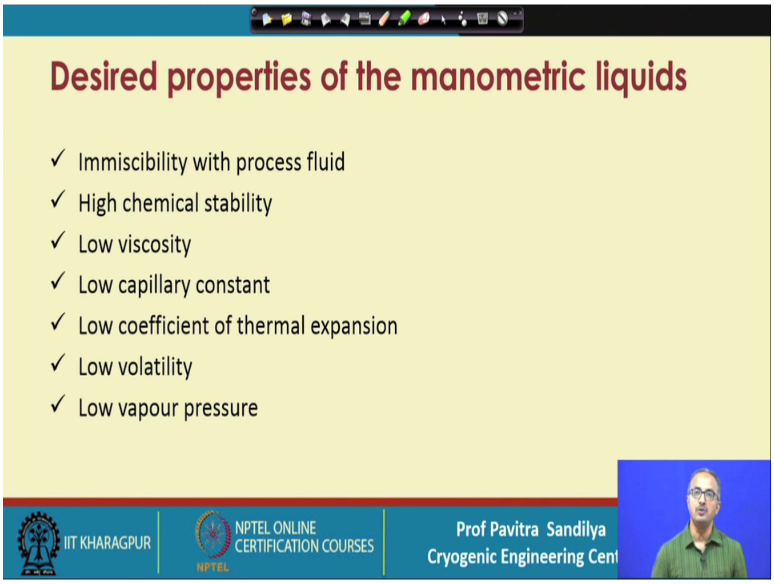

After learning about the method to find out the pressure difference, now let us look at the various desirable properties, which a monometric liquid should have based on these desirable properties we can choose the appropriate manometric liquid for a given application. Here first is that the immiscibility of with the process fluid; that means, the manometric liquid should not be soluble in the process fluid, then it should have high chemical stability, you should not get dissociated or it should not react with any other components with the process fluid or with the surrounding glasses. So, it should be chemically stable.

Then it should have low viscosity so, that it can move in the manometric limbs very easily, it should not be having, which should not be needing the pressure energy from externally otherwise we cannot measure the pressure drops properly. Then you should have low capillary constant it is also related to is free movement through the manometric limbs. Then we have low a coefficient of thermal expansion means in the range of the operation that with temperature, it should not expand or contract too much if it expands and contract it density will change.

So, we will not be getting the right value out or we have to keep on applying some correction for the densities if it expands or contracts. Then it should have low volatility you should not if it is highly volatile then what will happen it will evaporate, it will not be able to stay in the manometric limbs. So, which ex pound that this should not have high volatility and also to have low volatility low evaporation it should have a low vapor pressure because high vapor pressure leads to high rate of evaporation.

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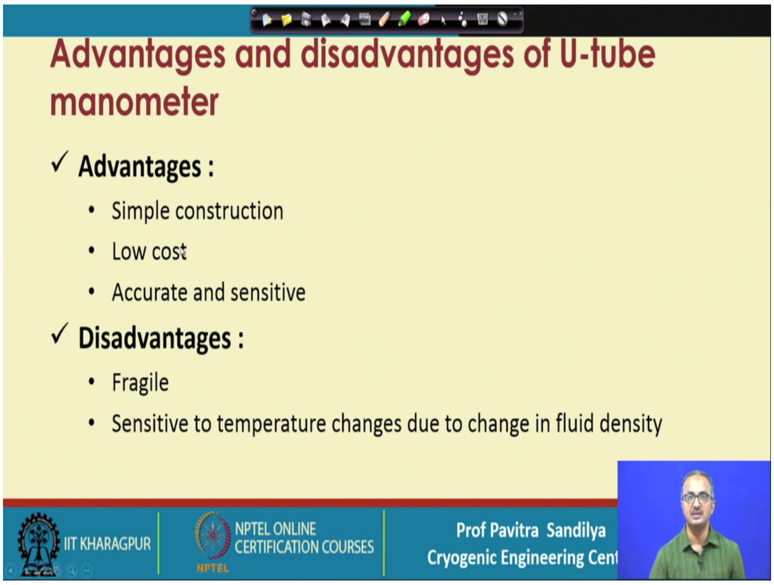

Now, let us see what are the advantages and disadvantages of the U-tube manometer. In the advantages we have that it is quite simple in its construction, it is also not very costly and it is fairly accurate and sensitive to the pressure changes. However, the disadvantages are that it is quite fragile because most of the times it is made from glass so, that we can see through it. So, it is fragile and it is also sensitive to temperature changes due to the change in the fluid density.

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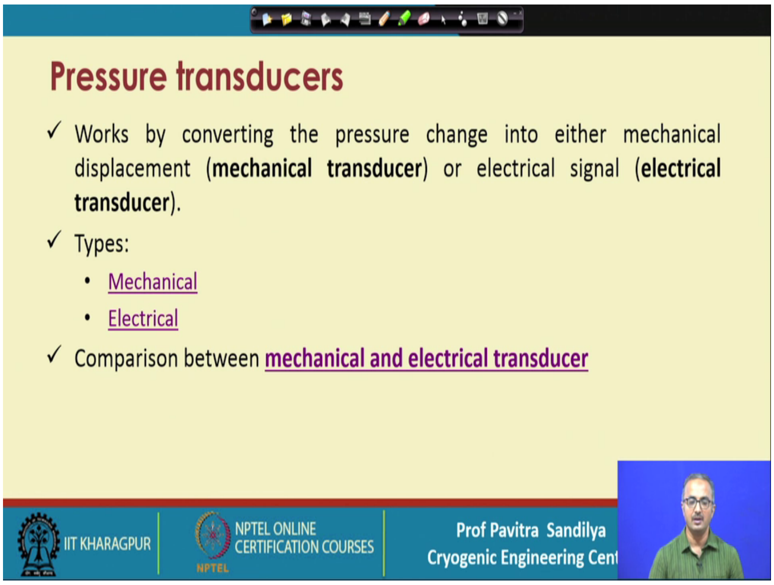

Now, next we come to pressure transducers now what are pressure transducers? They are some devices which work by converting the pressure change either into some mechanical displacement or some electrical signal. Now, when it causes some when the pressure change causes some mechanical displacement, we call it mechanical transducer and if the pressure change causes some kind of change in the electrical signal maybe in terms of the voltage or the current we call it electrical transducer. So, here we have two types of transducers mechanical and electrical first let us go to mechanical transducer.

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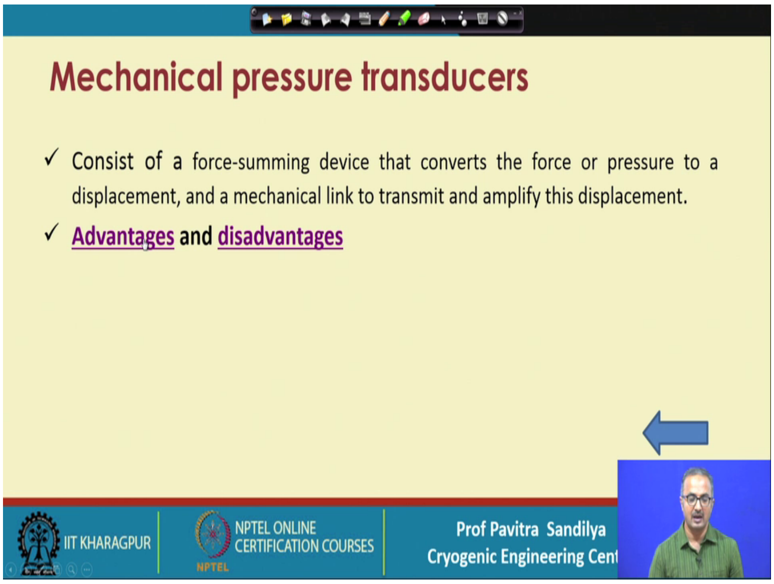

Again we shall be confining ourselves to a very few mechanical transducers. In these particular mechanical transducers what we have? We have some pre force summing device; that means, it will be taking all kinds of forces which are acting on the device, that will be converted to some kind of displacement through some mechanical link, to transmit and amplify the displacement.

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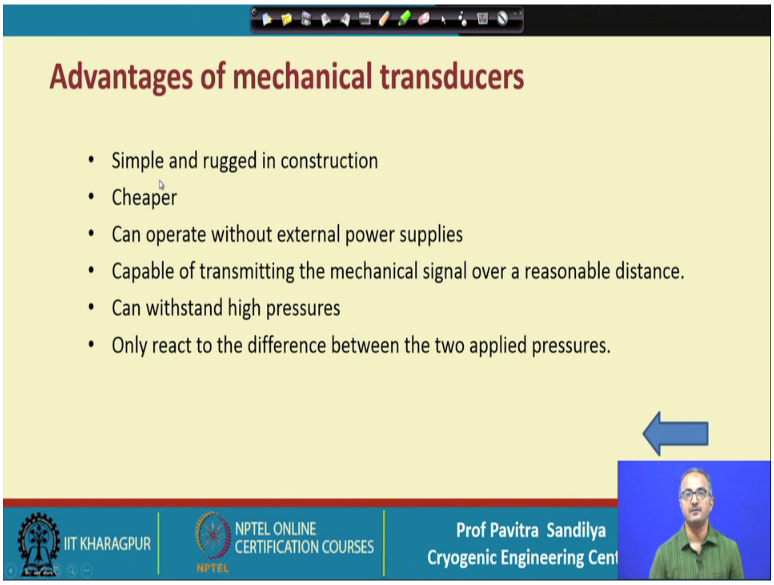

Then the advantages are that these mechanical transducers are quite simple in the construction and quite robust and rug it. And they are cheaper than the electrical transducer can operate without any external power supplies; in some transducers we need some external power supplies like electric current to operate them, but in this case we do not need any kind of external power supply.

Then they are capable of transmitting the mechanical civil signal or a reasonable distance; that means, they need not be fixed right at the place where we are staying we can observe them from a faraway place also and then they can withstand high pressures and only react to difference between the two applied pressures.

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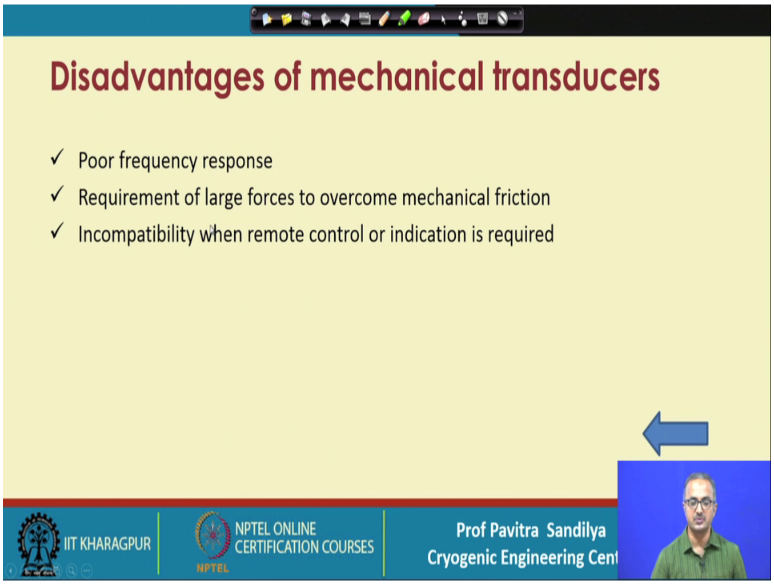

And coming to disadvantages of this mechanical transducers, we have they have poor frequency response; that means, they are having some kind of inertia in the when the pressure fluctuates too much. So, they cannot use cells the pressure properly if there is a lot of fluctuation and they require quite large forces to overcome some mechanical friction in the instrument and they are incompatible when remote control or indication is required.

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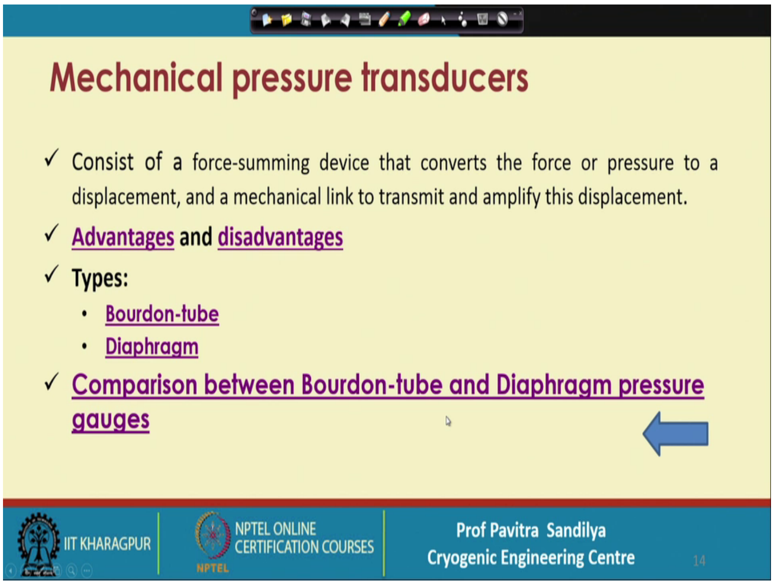

There are various types of mechanical pressure transducers we are just listing only two of them. One is the bourdon tube which is very common and which is also found in our laboratory or in the industries quite commonly and we have diaphragm. So, let us first look into the bourdon tube mechanical pressure transducer.

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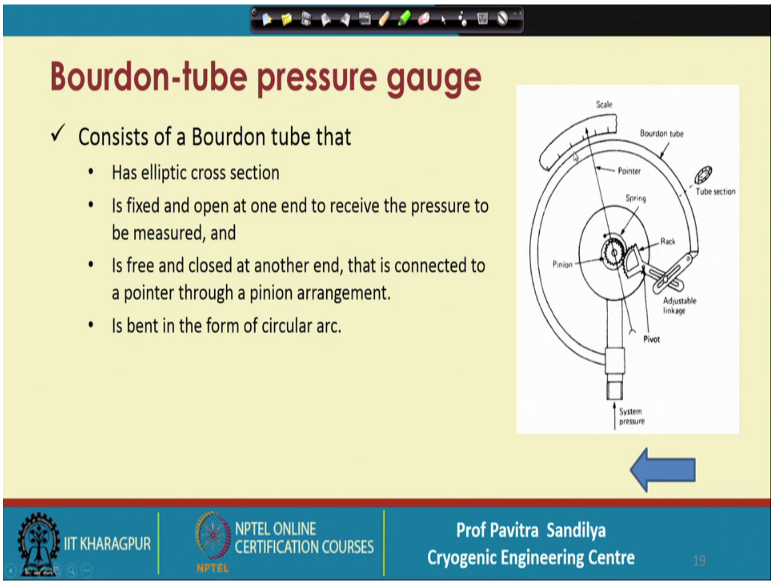

In this bourdon tube what we have that as we see in this particular figure, we have some the bourdon tube the vertical tube this tube is there this tube is then has elliptical cross section and is fixed at one end, and from this fixed end it receives the pressure signal. The other end is free to move and it is closed. So, the other end is closed and the one end is open and fixed other is free and closed and what happens? When this is when this pressure is sensed this particular tube tends to stretch out or becomes more circular.

So, when some stretch out what happens? On the other end from the other end through pinion connection there is a pointer is there, and this pointer will change its position as per the expansion of the bourdon tube and this pointer spans over the over the from particular calibrate scale.

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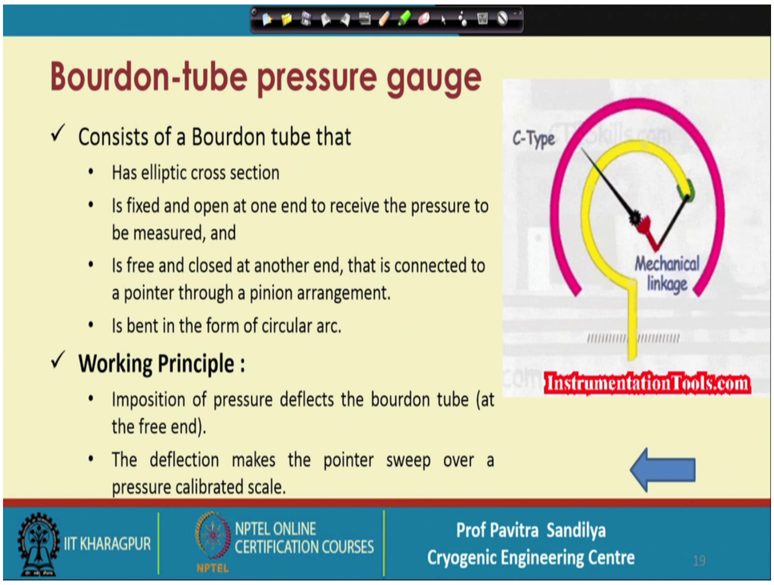

And here in this particular figure we see that how the pressure at this at the unit pressure will stretch this board and tube and how the pointer is going to move on the pre calibrated scale due to some pressure change at this end. So, this is how a c type bourdon to work and there are many other type of bourdon gauges we are just looking at a typical bourdon gauge. Then we have another type of mechanical pressure transducer that is the diaphragm type.

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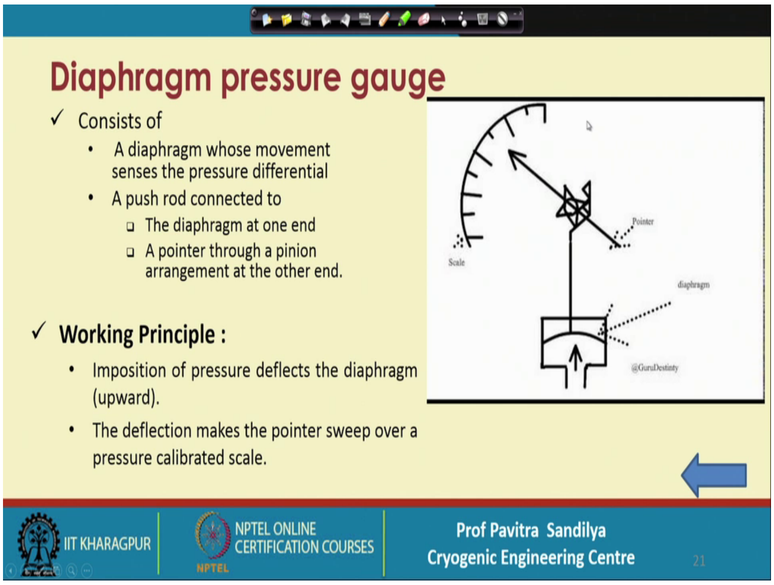

Now, in this diaphragm type what we have that, here we have a diaphragm. So, the here we have a diaphragm and there is a again like the bourdon gauge, we have another pointer here. So, what how it works that, whenever there is a pressure on the diaphragm this pressure to the pannier element this will again cause a movement to this pointer. So, depending on the pressure coming to the diaphragm this pointer will move on the left hand side or the right hand side. So, this is how the diaphragm pressure gauge works. Now, let us make a quick comparison of the bourdon tube with the diaphragm pressure gage.

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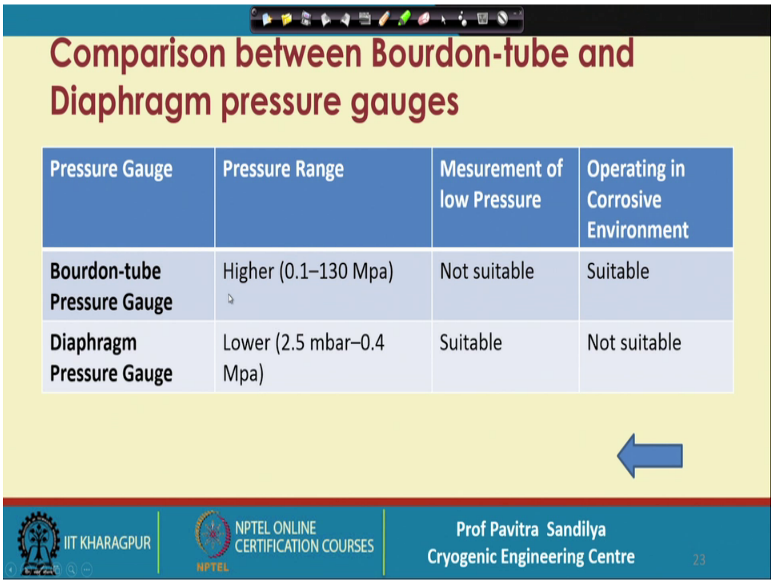

Here we see that the bourdon gage can go for a higher pressure range about one atmosphere to about 1300 atmosphere and then it is, but while the diaphragm gage goes for a lower pressure range we can see it is goes from go up to milibar pressure range, then if we want to measure low pressure we will go for the diaphragm type. And it this bourdon gage can operate in corrosive environment whether the diaphragm is not suitable for corrosive environment.

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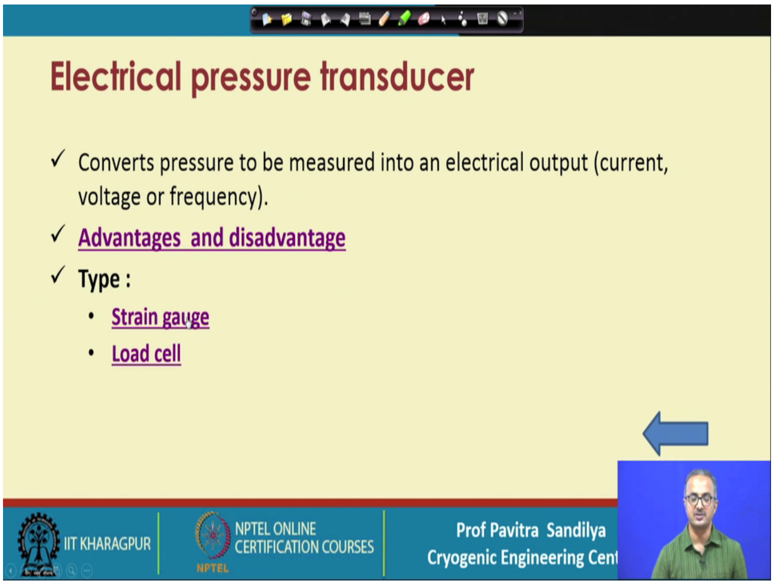

Next we come to electrical pressure transducer; in this the pressure sensed is converted into some kind of electric signal either in terms of current or voltage or some frequency. Now, what are the advantages and disadvantage.

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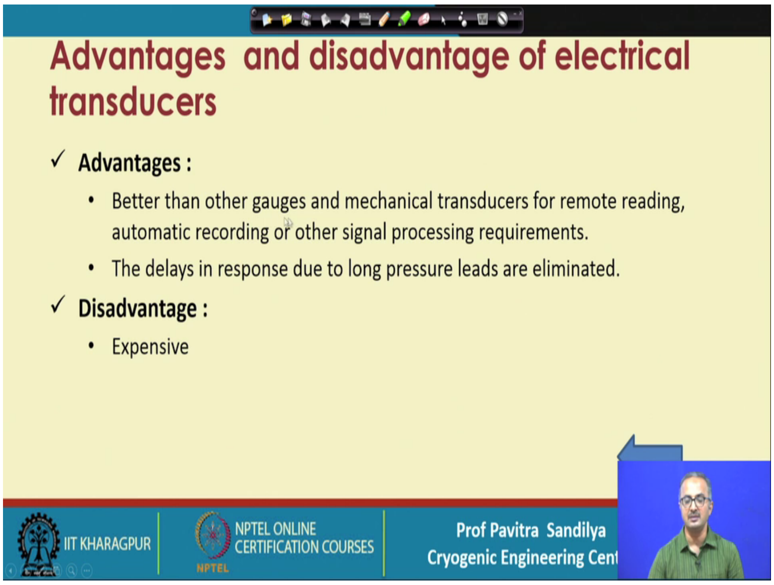

Let us see that advantage is they are better than the other gauges and mechanical transducer for remote reading or for automatic control or for signal processing. That means, if we want to have some automation in the industry, we cannot use the mechanical transducers we have to go for the elliptical transducer, because with them only we can capture the data and also whatever control actions or automations have to be done we can transmit those signals from the electrical transducer to our control room, which is not possible for the mechanical transducer.

And the delay in the response is also eliminated almost eliminated because it is electric signal. So, there is the response time is very small. So, that is these are the advantages of the electrical pressure transducer; however, the disadvantage is that basically they are quite expensive. Next we come to the various types of these electrics transducer; first we have the strain gauge.

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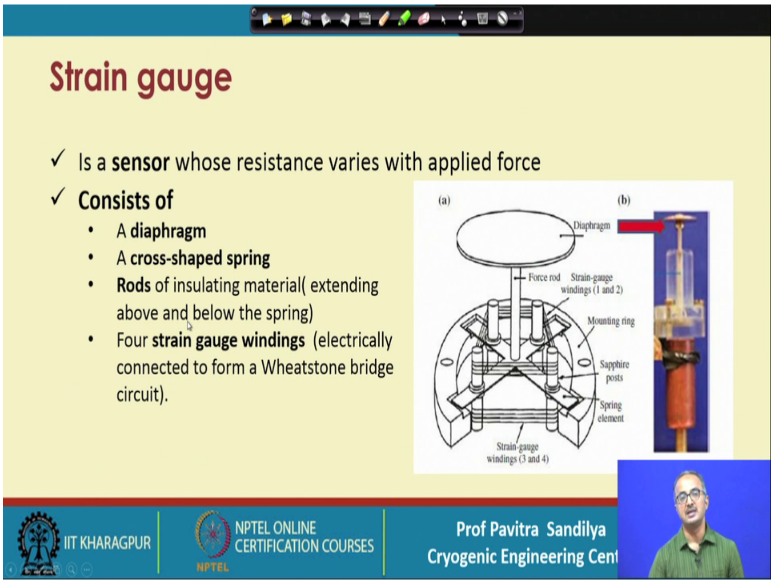

In the strain gauge what it says that it works on the straining that is the deformation of some element. Here we show the strain gauge type what we find in this figure is that we have a diaphragm, and then we have this cross shaped spring and then we have some rods over here, which will be displaced and we have the strain gauge windings.

So, these are the basic components of a particular strain gauge diaphragm, then cross cross ship spring, then these rods and the strain gauge windings. Now, how it works let us see that suppose from the diaphragm side, we are imposing some pressure.

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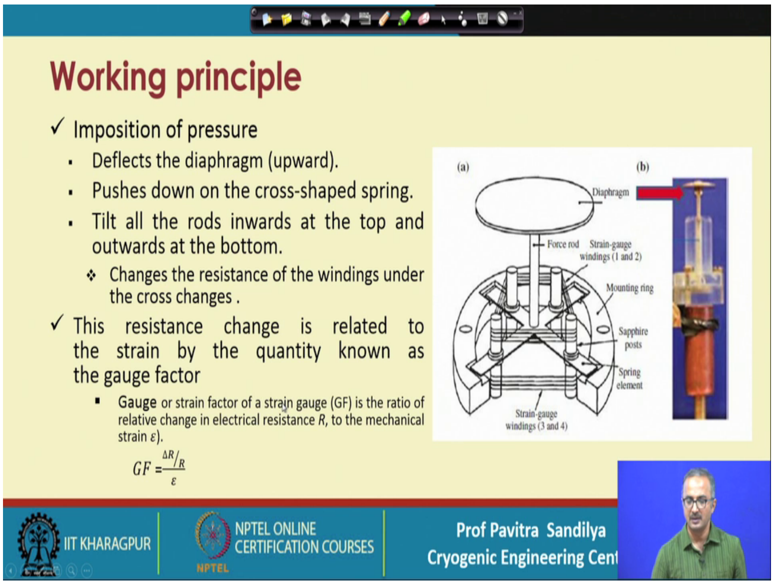

Now, because of this pressure what will happen, it will push this particular cross shaped spring downwards; and when is pushed down what will happen? These rods will be tilting inward at the top and they will be going towards the outward at the bottom side. And when these rods are getting tilted what will happen? They will also these strain gauges will also be getting some displacement and because of this resistance will change and this will send the signal to the some appropriate signal a data logger.

So, what will happen this resistance change is related to the strain by some quantity known as the gauge factor. And what is gauge factor? It gauge factor is defined like this it is the ratio of the relative change in the electrical resistance to the mechanical strain; that means, this delta R is that change in the resistance due to the deformation or the tilting of these rods, and this is the original resistance and this is the actual strain that has taken place. So, with this gauge factor we can know that what is the actual pressure, that has been imposed by some calibration.

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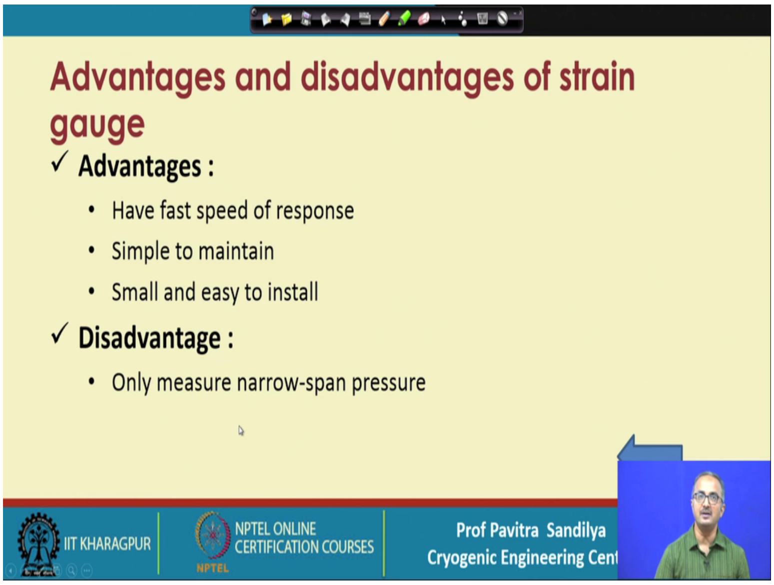

Now, the advantages of this kind of strain gauges are, that they are quite fast in response and they are simple to maintain, and they are their sizes are small and they can be installed easily. On the other hand we have the disadvantage as that they have the span or the range of pressure they can measure is small.

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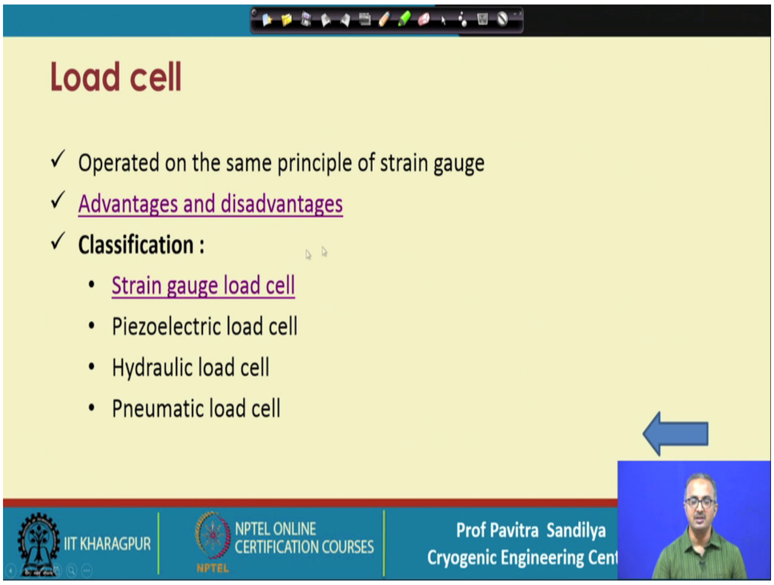

Next we go to the load cell; in this load cell we find that the operating principle is similar to that of the strain gauges.

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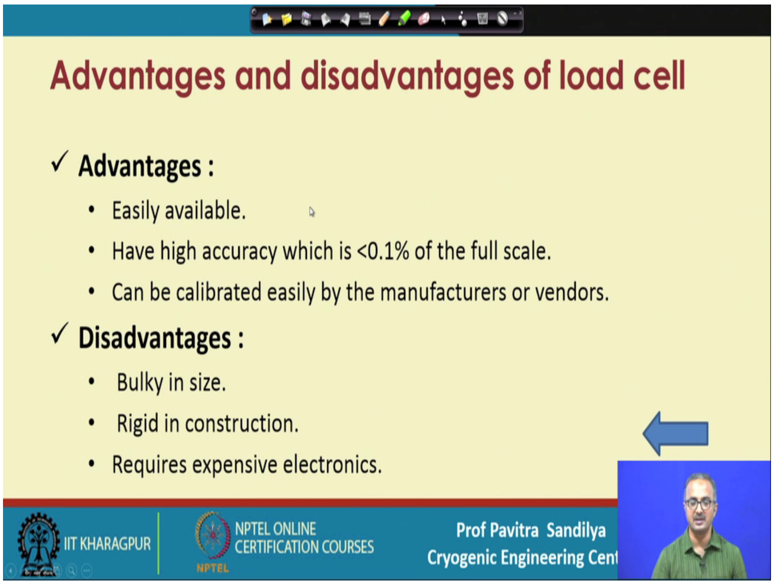

And first let us see the advantages that they are easily available, and they have quite high accuracy which is about even less than 0.1 percent of us full scale accuracy may be obtained, they can be calibrated easily by the manufacturers or vendors. On the other end the reified bulky and they are quite rigid they dot; that means, we do not have much flexibility in their installation and they require quite expensive electronics.

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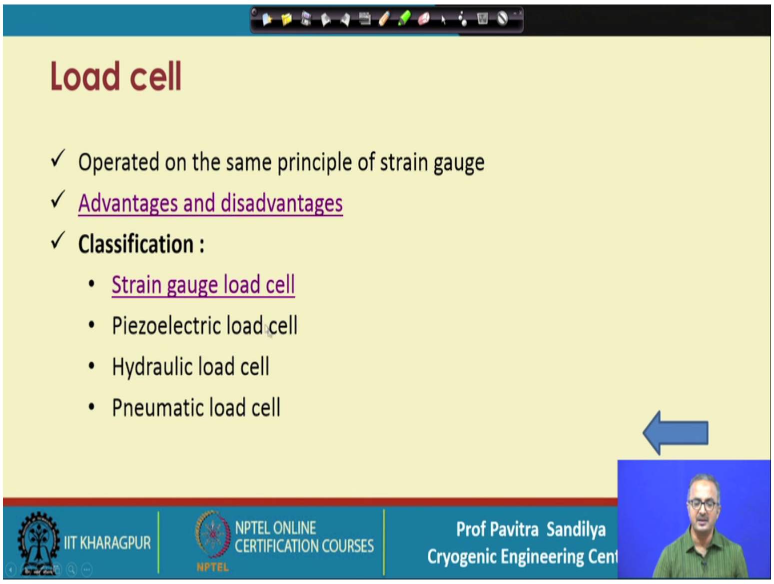

Now, there are various types of load cells available commercially strain gauge piezoelectric hydraulic load cell pneumatic, but essentially they are working principles are almost same. So, we shall be looking into only these strange gate load cell.

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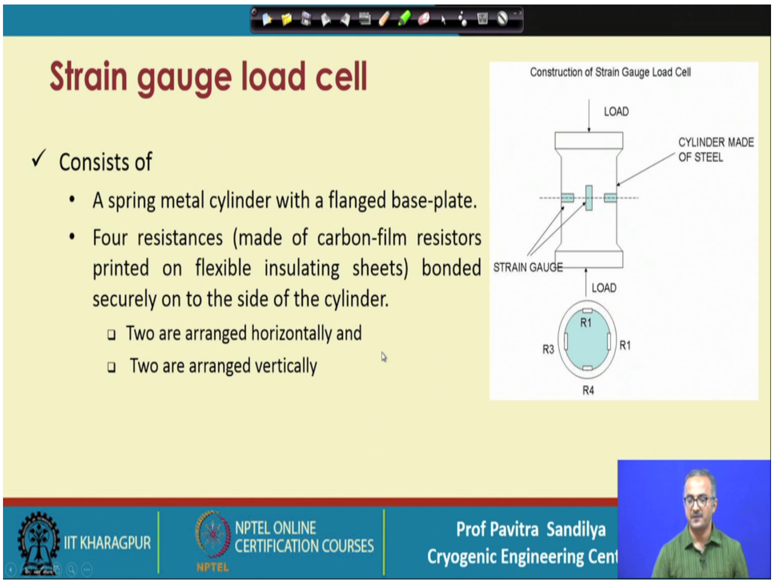

Here we find that how it works that first we see his construction. In the constitution we shall see that there is a metallic cylinder with some flange baseplate. And on this particular cylinder we are having four resistances; there two resistances are placed horizontally, and two resistances we are showing one resistance over here there is another resistance on the opposite side.

So, there are two resistances which are addressed horizontally and two resistance are addressed vertically. So, here in this top view if an we can see that these R 3 and R 1 are horizontally and R 4 R 1 are vertically.

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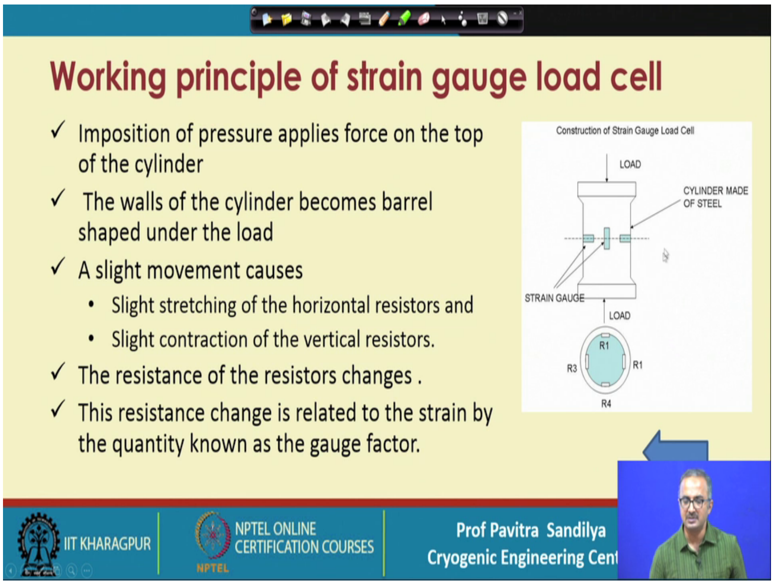

Now, what happens that whenever we are imposing some kind of a pressure on the top of the cylinder, this particular cylinder barrel where tends to deform and this cylinder means we are deforming it is not trying to bulge out. The when it shall bulge out what happens? These resistors change their positions and their resistances change. And these changes in the resistance of the resistors are recorded and they are related to the pressure imposed by some kind of gauge factor as we looked into the in kind of load cells. So, here we find that these strain gauges are working in a similar fashion as for the strain gauges the load cells are and still are similar in their functioning; now the we find.

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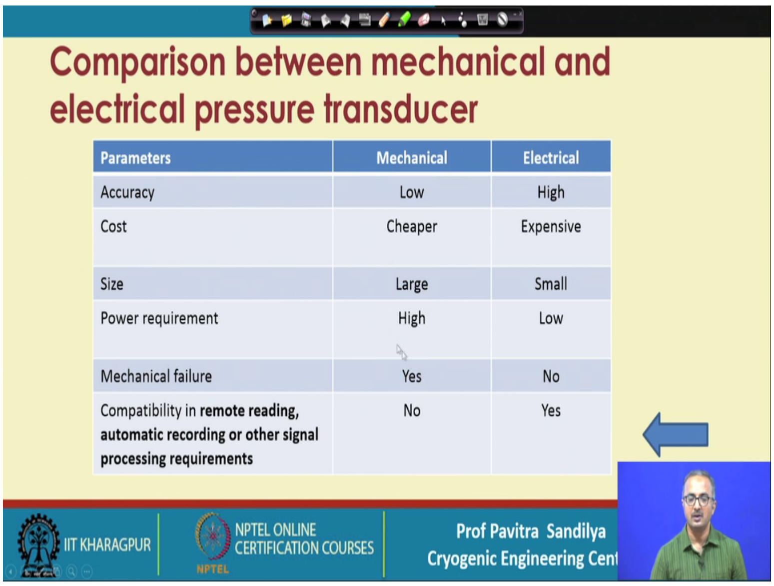

These are the comparison of the mechanical and electrical pressure transducer, that accuracy wise we find that electrical transducer are giving higher accuracy than the mechanical transducers. Cost wise of course, mechanical transducers are cheaper then electrical transducers, the size wise also the electrical transducers are smaller than the mechanical transducers. Power requirement is higher for mechanical transducer, because the pointer has to overcome some kind of frictional resistance, which is not the case with the electrical transducers.

Then mechanical failure is more in case of the mechanical than for electrical transducers, on the other hand for any kind of automation, control or signal processing electrical transducers are preferred to the mechanical transducers.

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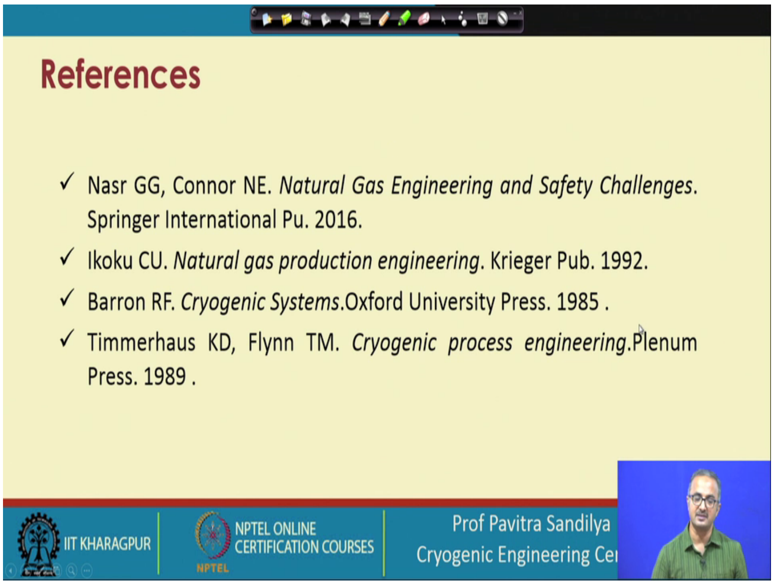

Now, these are the references which you may refer to for further details. Before this I would like to show you this is the thing this is the pressure transducer, here you can see there is a small hole over here which this we put in the in the transfer line wherever, there is some process fluid is passing. And on this particular hole we this fluid pressure is exerted and this particular portion is a transmitted portion through which this signal of the pressure is transmitted, and from here from this particular port we take the signal out electrical signal from the particular transducer.

So, this is how a pressure transducer looks like; and here I show you the strain gauges which are very very small these are very small there are strips are there, and these strips are pasted on wherever we want to measure the pressure drops and these strips will change the resistance and resistance is measured appropriately to get the pressure drops.

Thank you.