**Chemical Process Instrumentation**
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**Lecture – 30**
**Pressure Measurement**

Welcome to lecture – 30. So, this is the last lecture on pressure measuring instruments. As of now, we have talked about pressure measuring instruments that are useful for measurement of moderate pressure, measurement of low pressures and measurement of very small pressures or high vacuum. So, today, we will talk about differential pressure cell, we will talk about certain accessories for pressure measurement and finally, we talk about how to select a pressure gauge for our application. So, today's class will conclude our ongoing discussion on pressure measuring instruments.

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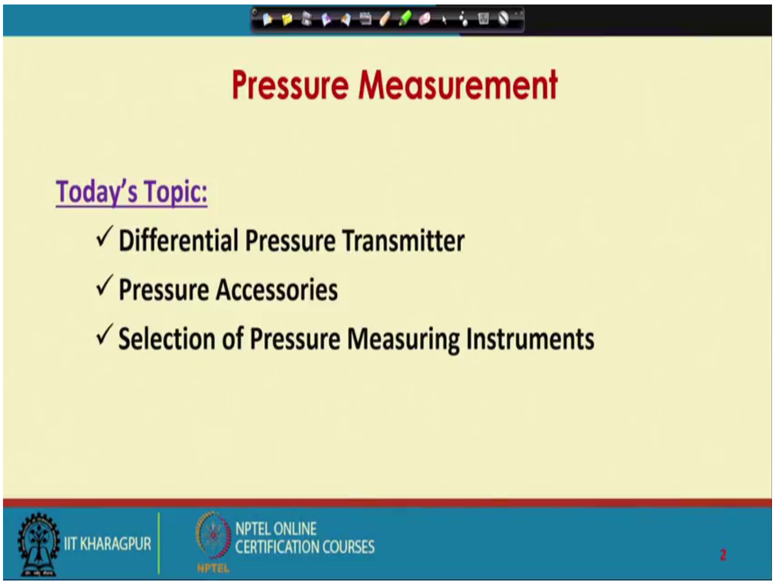


So, this is today's topic. We will talk about differential pressure transmitter, we will talk about some pressure accessories and we will talk about how to select a pressure measuring instruments for my application.

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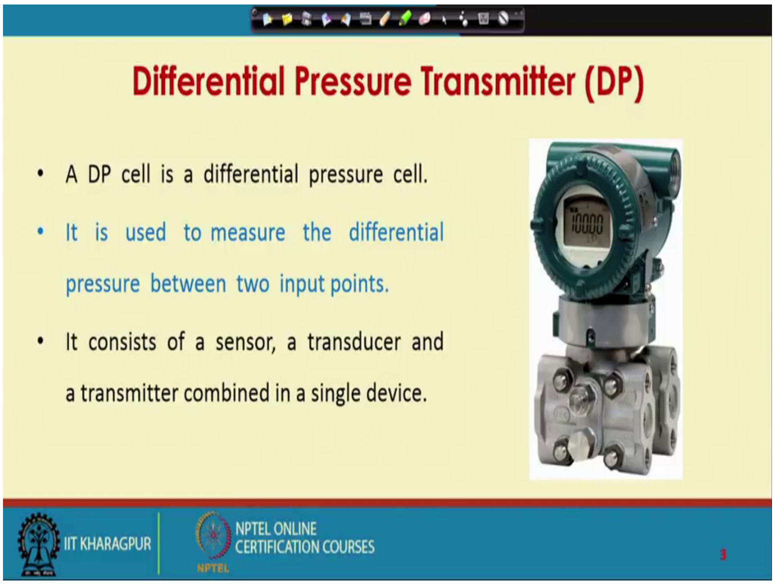


So, let us start our discussion with differential pressure transmitter known as DP cell, what you see is the photograph of a DP cell. So, DP cell is a differential pressure cell, so it measures delta P or difference between two pressures. So, you will see here that there will be connections for two different pressure sources. A DP cell is used to measure the differential pressure between two input points. It consists of a sensor a transducer and a transmitter combined in a single device.

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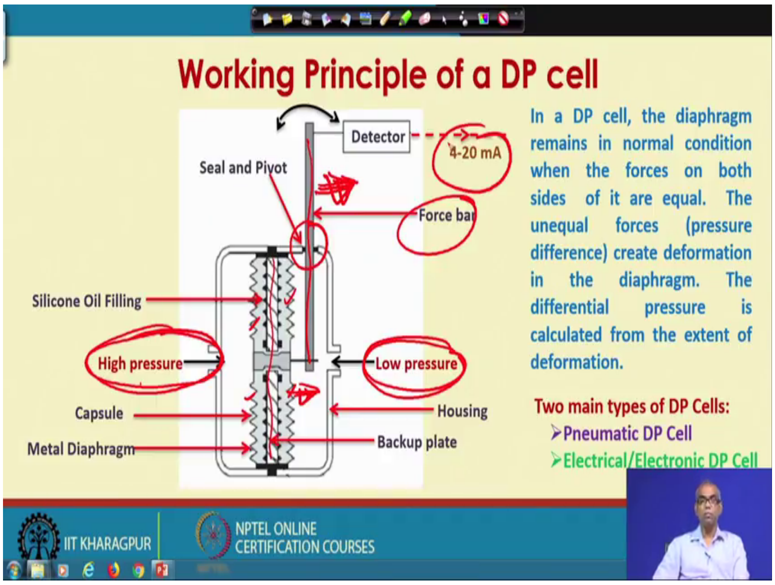

Now, let us try to understand the working principle of a DP cell. In a DP cell the diaphragm remains in normal condition when the forces in the both sides of it are equal. So, you have diaphragm in the capsules made of diaphragms we have talked about pressure capsules we have talked about measurement of moderate pressures. So, the diaphragm remains in normal condition when the forces on both sides of it are equal. So, these are the two pressure sources which is acting from both sides of the diaphragm. The unequal forces; that means, pressure difference create deformation in the diaphragm. The differential pressure is calculated from the extent of deformation.

So, essentially you have a diaphragm mounted in a chamber and you have two pressure sources which will be applied from both from both sides of the diaphragm. If these two pressures are equal the diaphragm will remain in its normal position, but, if they are different there will be a deformation of diaphragm here we are applying high pressure from this side, so, the diaphragm will deflect in this direction. Typically, this diaphragm will be filled with silicon oil. This will be useful for transmitting the pressure uniformly throughout the diaphragm capsules. So, the diaphragm capsules will be filled with silicon oil which is useful for transmission of pressure uniformly. There is a backup plate inside the diaphragm capsules. Now, these diaphragm capsule is attached to a force bar. So, this is the force bar this is connected to the diaphragm capsule.

Now, this is seal and pivot. So, as the diaphragm capsule deflects in this direction the force bar also makes the displacement. So, this displacement of this force bar can be read by a displacement transducers we have talked about several transducers capacitance type LVDT type. If a pneumatic transducer is also possible like we can take help of flapper nozzle systems. So, the displacement of this force bar can be will be considered as the measure of these difference between these two pressures, because the difference between high pressure and low pressure will cause a deflection in this diaphragm and that deflection will cause the displacement to this force bar. So, I can measure this displacement of this force bar using a pneumatic transducer or an electrical transducer and accordingly can get an output in the range of 4 to 20 milliampere, current if I am using electrical transducer, but I can also get output in the range of 3 to 15 PSI pressure if I am making use of flapper nozzle systems.

So, we can have two main types of DP cells; pneumatic DP cell and electrical or electronic DP cell. So, the output of the pneumatic DP cell will be in the range of 3 to 15

PSI pressure signal and the output of the electrical or electronic DP cell will be in the range of 4 to 20 milliampere current signal.

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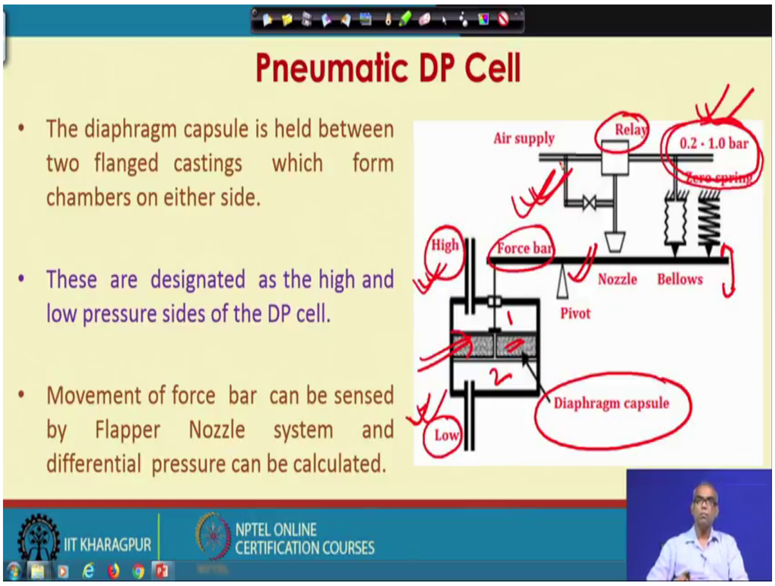


So, what do you now see is a schematic of a pneumatic DP cell. The diaphragm capsule is held between two flanged castings which form chambers on either side. So, you have the diaphragm capsule. So, these diaphragm capsules creates two chambers chamber 1, chamber 2. So, these two chambers are connected to two different pressure sources let us say this is connected to high pressure source, this is connected to low pressure source. So, the force bar is connected to the diaphragm capsules. So, as the diaphragm deflects there will be displacement of this force bar. This displacement can be measured by a flapper nozzle assembly. What you see is a flapper nozzle assembly with the relay, we have talked about this and we have seen that the relay increases the amount of air which is helpful in the measurement.

So, the output which is a 3 to 15 PSI air signal or 0.2 to 1 bar is measure of difference between these two pressures. So, these output pressure signal is the measure of difference between these two pressure sources. So, basically all I am doing is the deflection of these diaphragm capsules is causing a displacement in this force bar and that displacement is being converted to a pressure signal with help of a flapper nozzle system. So, this is briefly the working principle of a pneumatic DP cell.

So, the diaphragm capsule is held between two flanged castings which form chambers on either side. These are designated as the high and low pressure sides of the DP cell. Movement of force bar can be sensed by flapper nozzle system and differential pressure can be calculated. If you look at a DP cell you will see that it is writ10 there high pressure side and low pressure side. So, accordingly we will connect the high pressure source and the low pressure source to the DP cell. So, when the DP cell it iself it will be retained high pressure source connection and connections for low pressure source.

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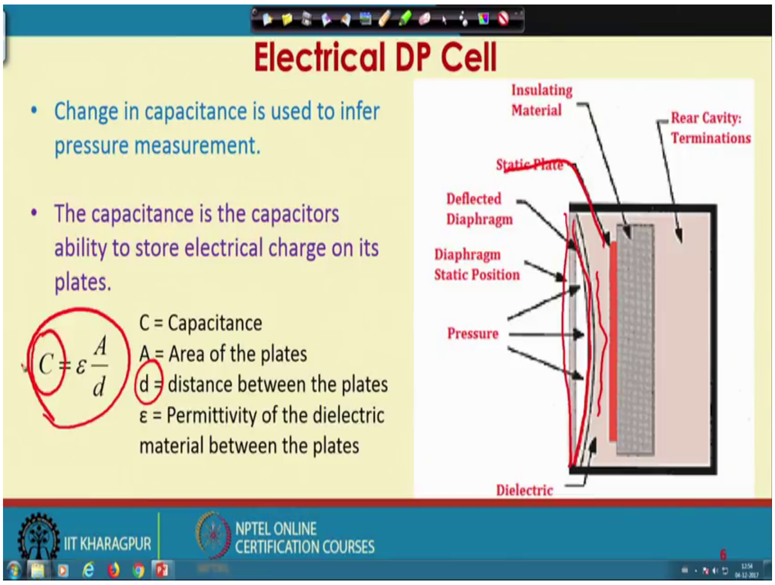


Electrical DP cell; in case of electrical DP cell, the output will be an electrical signal. A capacitance type transducer can be used here. Change in capacitance is used to infer pressure measurement. You know that the capacitance is the capacitor's ability to store electrical charge on it is plates and we are now familiar with this equation, which says the capacitance is directly proportional to the area of the plates, is directly proportional to the distance or gap between the plates, and the proportionality constant is the permittivity of the dielectric material that exists between the two plates.

So, this is the diaphragm static position and this is the deflected diaphragm. You have a static plate here and in between you have this dielectric medium. So, here the distance between the two electrode change and accordingly the capacitance will change.

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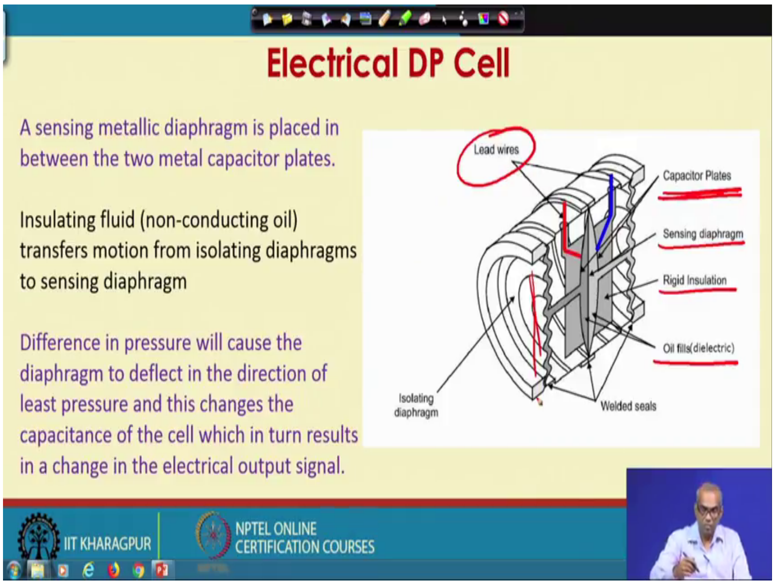


So, once again, you see a schematic of electrical DP cell. You can see two capacitor plates, in between you see a sensing diaphragm. You have insulation and you have oil fields which works as dielectric medium these are the wires coming out from the two capacitor plates. A sensing metallic diaphragm is placed in between two metal capacitor plate. So, we have two metal capacitor plates and in between a sensing diaphragm is placed. Insulating fluid which is a non conductive oil transfers motion from isolating diaphragms to sensing diaphragm. So, I have isolating diaphragms which will receive the pressure of the fluid and transfer it on to the sensing diaphragm. Difference in pressure will cause the diaphragm to deflect in the direction of least pressure and this changes the capacitance of the cell which in turn results in a change in the electrical output signal. So, again it is basically causing the distance d different.

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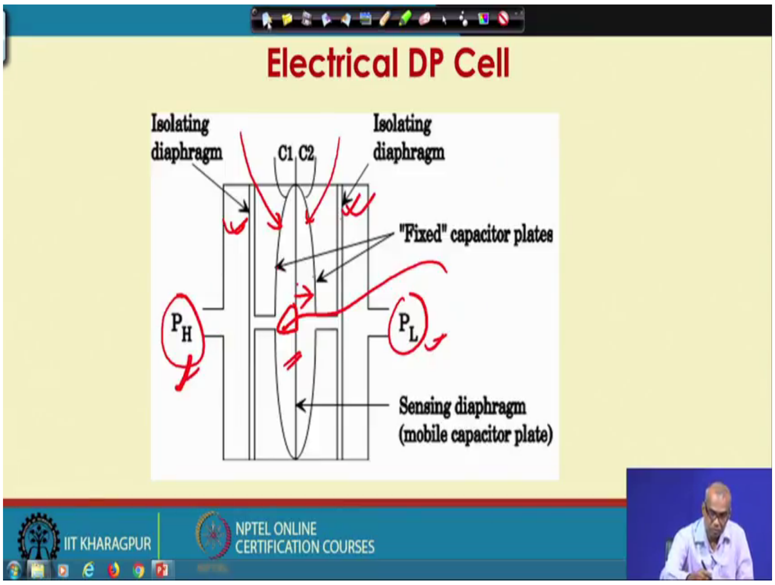


So, once again a simpler schematic for that. So, I have high pressure source, low pressure source. So, this is one isolating diaphragm, this is another isolating diaphragm, in between I have two capacitor plates and in within these between these two capacitor plates I have a sensing diaphragm. Two capacitor plates are fixed and I have this in between sensing diaphragm which can deflect. Here, this part is full with a non conduction oil which will work as dielectric medium. So, this is high pressure. So, this sensing diaphragm will deflect in this direction. So, as the diaphragm moves from it is initial position the capacitance will be different this will get and electrical signal as output which is a measure of difference between high pressure and low pressure.

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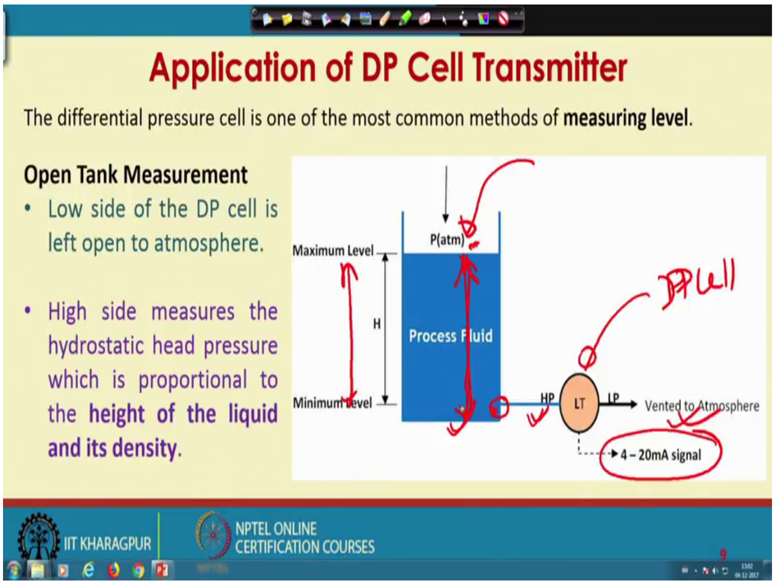


The differential pressure cell is one of the most common methods for measuring level. Let us now look at few application of DP cell transmitter, we will talk about pressure level measurement in detail later. For the time being let us take a look how a DP cell can be used to measure liquid levels. The differential pressure cell is one of the most common methods for measuring level. You may be interested measuring level in an open tank or in an closed tank. What do you see on the screen is measurement of liquid level in an open tank.

Low side of the DP cell is left open to atmosphere. High side measures the hydrostatic head pressure which is proportional to the height of the liquid and it is density. So, I am interested in measuring this liquid level and the tank is open to atmosphere. So, atmospheric pressure is acting here. We have the DP cell; the high pressure side of the DP cell is connected to the bottom of the tank; that means, this much of hydrostatic head is being fed to the DP cell from the high pressure side. The low pressure side is left open to atmosphere.

So, the output of the DP cell will be a difference between pressure here and the pressure here, this pressure is atmospheric pressure. So, this is related to density of the liquid and the height of the liquid you know the well known formula p equal to rho g h. So, the output of the DP cell which may be 4 to 20 milliampere current signal for electrical DP cell can be taken as a measure of the hydrostatic pressure head which in turn is related to the height of the liquid given the information on density of the liquid.

So, basically your DP cell is used. Your DP cell is used to measure the level of the liquid by attaching the DP cell at the bottom of the tank, then you make use of the delta p equal to rho g h formula.

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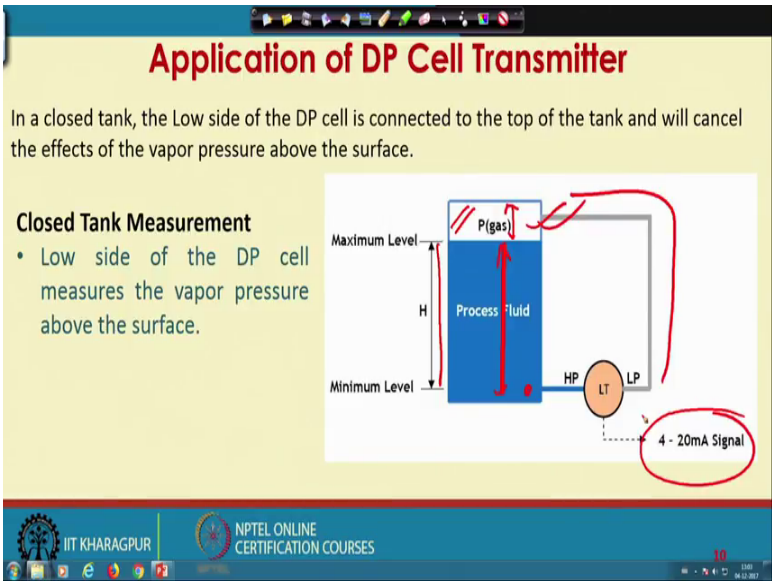


You can also use a DP cell to measure the level of the tank, which is not open to atmosphere, which is a closed one; so, the level of the liquid in a closed tank. So, this is the level of the liquid in the closed tank and upper part let us say you have some gas with some pressure. So, here the low side of the DP cell is connected to this gas above the liquid and the higher side of the pressure is connected to the bottom of the tank. This is obvious choice, because at the bottom of the tank you have this hydrostatic head plus this. So, again the output of the DP cell 4 to 20 milliampere current signal can be used to measure the hydrostatic pressure head. So, low side of the DP cell measures the vapor pressure about the surface.

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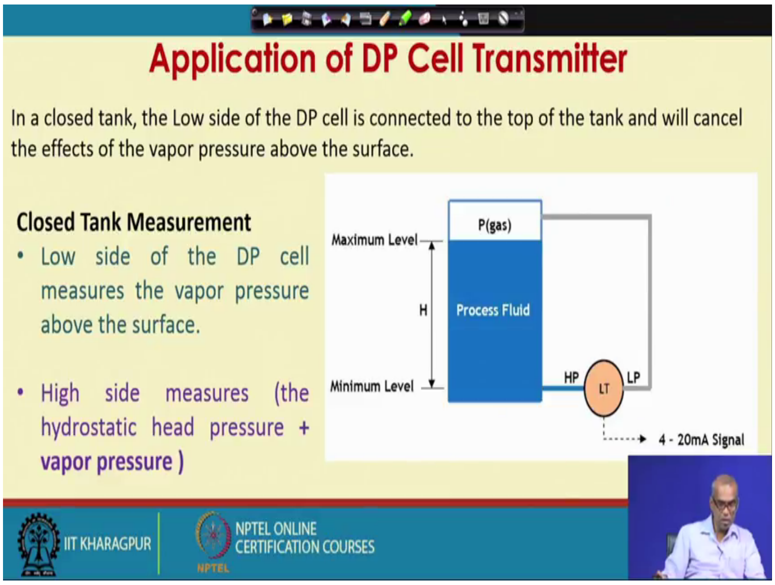


High side measures the hydrostatic head pressure plus vapor pressure. So, combining this I can measure the hydrostatic head and if I know the density of the liquid I can measure the liquid or height of the liquid in the tank.

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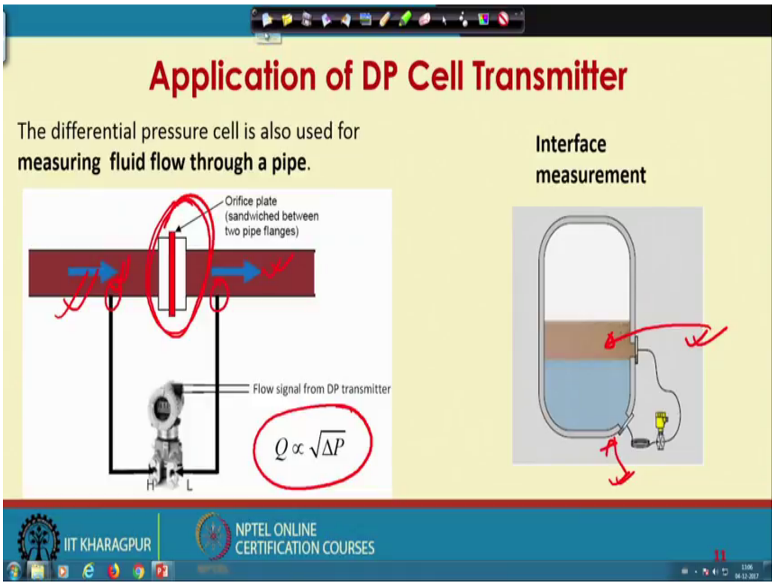


The differential pressure cell can also be used for measurement of fluid flow through a pipe. A fluid is flowing through this pipe. I have put an orifice plate we will learn more about orifice plate or orifice meter when we talk about measurement of flow. For the time being let us consider that the orifice plate works as a flow restrictor. So, we have put a flow restriction by putting an orifice plate here. So, there will be pressure drop across this orifice plate. So, the pressure here will be higher than the pressure here because there will be a pressure drop, in the direction of flow. So, I can take a DP cell attach the high side high pressure side here and the low pressure side here and then can measure the pressure drop across the orifice plate and can relate the flow rate with the pressure drop, because I know the relationship the flow rate is proportional to the square root of the pressure drop.

Similarly, it is also possible to locate the interface using a DP cell. These are two pressure sources which goes to DP cell higher side, lower side.

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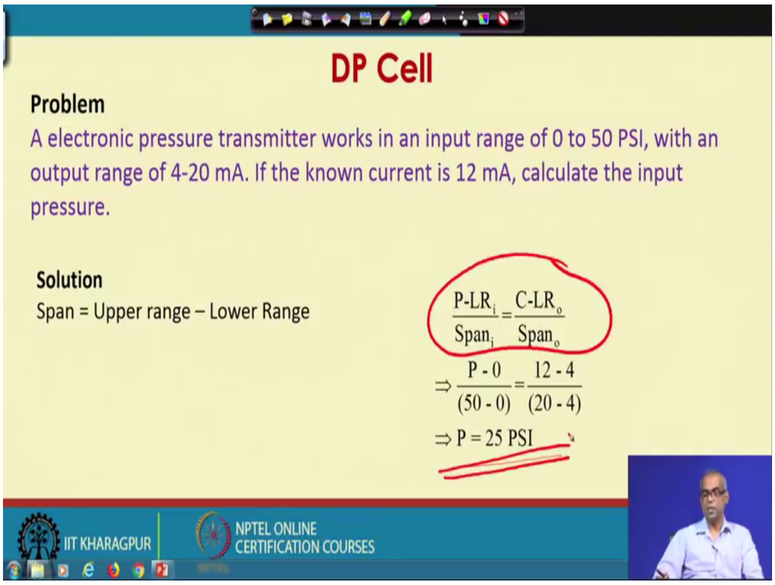


Let us take a quick look at a simple numerical problem on a DP cell. A electronic pressure transmitter works in an input range of 0 to 50 PSI with an output range of 0 to sorry 4 to 20 milliampere. If the known current is 12 milliampere, calculate the input pressure. Once again a electronic pressure transmitter works in an input range of 0 to 50 PSI with an output range of 4 to 20 milliampere. If the known current is 12 milliampere, calculate the input pressure.

So, basically what is being asked is 0 PSI is related to 4 milliampere current, 50 PSI is related to 20 milliampere current, then 12 milliampere is, what? So, span is the difference between upper range and lower range. So, let us just make use of this. Let us consider corresponding to 12 milliampere current the pressure in PSI is P. So, P minus 0 by 50 minus 0 is 12 minus 4 divided by 20 minus 4, which will give you P equal to 25 PSI.

So, basically you are asking that if 0 PSI corresponds to 4 milliampere current 50 PSI corresponds to 20 milliampere current and what is implicit here is that the interpolation is linear. So, 12 milliampere current corresponds to what PSI pressure? One thing which is not directly related to this numerical problem I would like to point out is, see that we are saying that 0 PSI pressure is connected to 4 milliampere and 50 PSI is related to 20 milliampere; that means, the lower end of the pressure is related to the lower end of the current signal we shall take as 4 milliampere is 4 to 20 milliampere. So, all the pressures will mapped between this 4 milliampere at the lower end to 20 milliampere at the higher end.

So, why do I take 4 milliampere current signal why not 0 as the lower end? This is purposefully done so that 0, output from the electrical devices or the transducer is not coming for a faulty operation, that means, 4 to 20 milliampere output from the transducer is considered as lower end and upper end. I could have, if I take 0 milliampere current output as the lower end I may not be able to differentiate whether that 0 milliampere current is actually 0 milliampere current or a faulty operation. So, purposefully we have taken a non zero reference, a non zero number as a lower end.

So it is 4 milliampere as it has been chosen as lower end. So, if it is 4 milliampere I know I am talking about lower end of the pressure signal. So, if it is 4 milliampere current I know for sure that it is not a faulty operation. So, that is why we consider 4 to 20 milliampere as the range for current signals for an electrical transducer.

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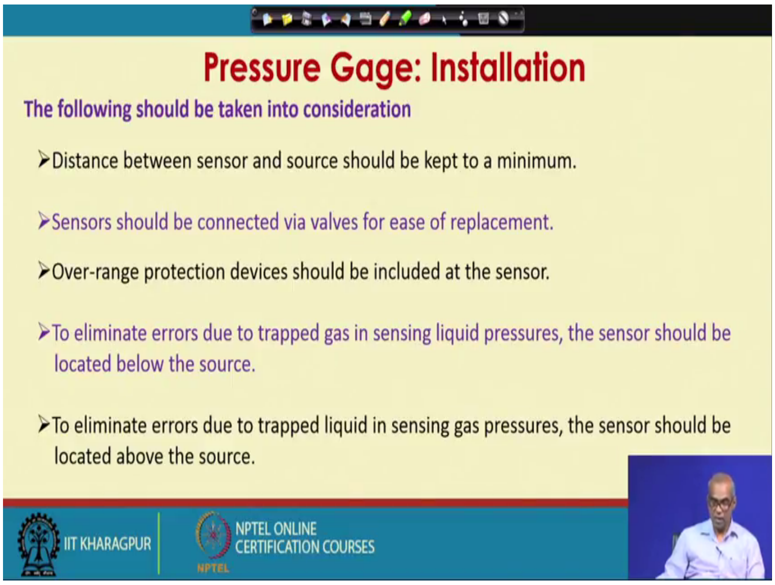


Now, let us briefly talk about certain important aspects of pressure gage installation. The following should be taken into consideration; distance between sensor and source should be kept to a minimum. Sensors should be connected via valves for ease of replacement. Over range protection devices should be included at the sensor. To eliminate errors due to trapped gas in sensing liquid pressures the sensor should be located below the source. To eliminate errors due to trapped liquid in sensing gas pressures, the sensor should be located above the source.

So, note these two last two points when the pressure sensors should be located below the source where you are sensing liquid pressure and, the sensors should be located about the source where you are sensing gas pressure.

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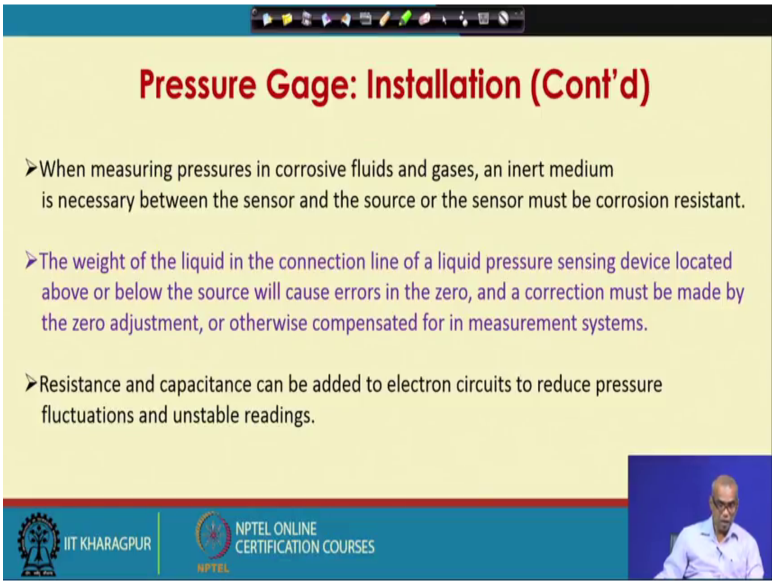


When measuring pressures in corrosive fluids and gases, an inert medium is necessary between the sensor and the source or the sensor must be corrosion resistant. You should isolate the pressure gage from the effect of corrosive fluids. So, normally we put an inner medium between these two or we have to suitably choose the material of construction so that the sensor is corrosion resistant. The weight of the liquid in the connection time in the connection line of a liquid pressure sensing device located above or below the source will cause errors in the zero and a correction must be made by the zero adjustment, or otherwise compensated for in measurement systems. Resistance and capacitance can be added to electron circuits to reduce pressure fluctuations and unstable readings.

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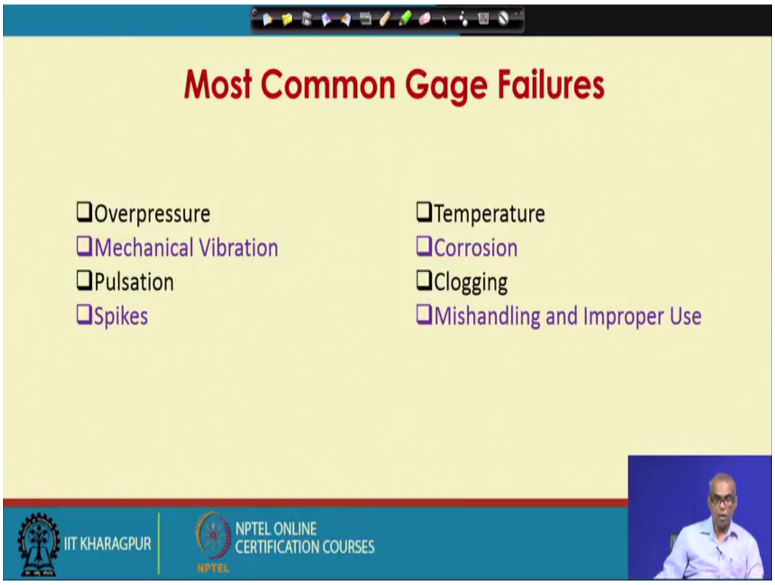


These are common gage failures; overpressure, mechanical, vibration, pulsation, spikes, temperature, corrosion, clogging, mishandling and improper use. So, these are certain most common gage failures.

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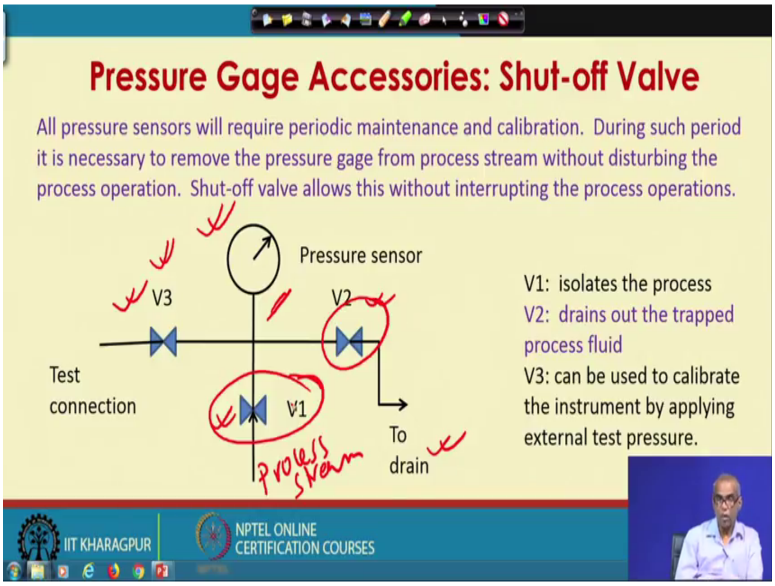


So, let us take a quick look at some pressure gage accessories. Shut-off valve; all pressure sensors will periodic maintenance and calibration. During such period it is necessary to remove the pressure gage from process stream without disturbing the process operations, process operation must go on and we need to isolate the pressure gage for maintenance or recalibration. Shut-off valve allows these operations without interrupting the process operations.

So, this is how the pressure gage is mounted. So, you have 1 valve, valve 2 and valve 3. So, this valve 1, this is the process stream. So, by using the valve 1, I can isolate this part. By using the valve 1, I can isolate the process from the pressure sensor. The V2 valve will drain out the trapped process fluid and the valve V3 can be used to calibrate the instrument by applying external test pressures. So, this is how a shut-off valve can be used for regular or periodic maintenance and recalibration of the pressure gage without disturbing the normal process operation we can make use of this valve V1, 2 seperate or isolate the pressure gage from the process stream.

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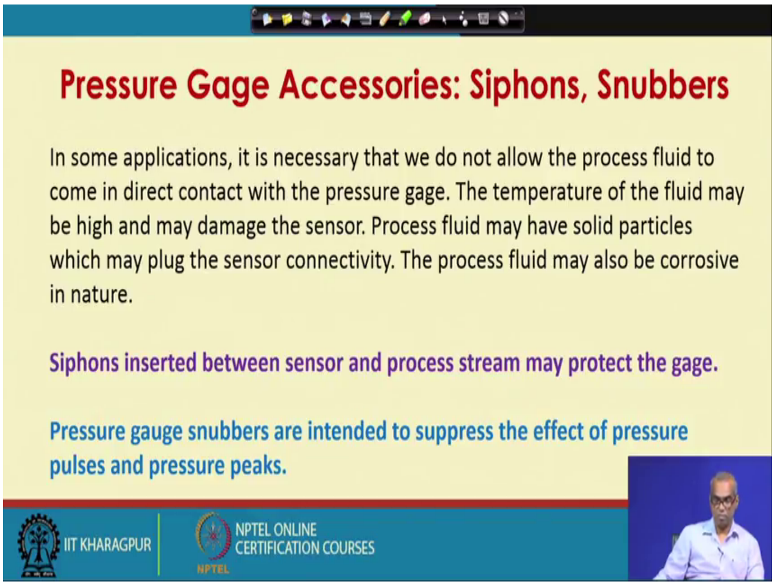


Let us talk about two more pressure gage accessories: siphons and snubbers. In some application, it is necessary that I do not allow the process fluid to come in direct contact with the pressure gage. The temperature of the fluid may be high and may damage the sensor. Process fluid may have solid particles which may plug the sensor connectivity. The process fluid may also be corrosive in nature. Siphons inserted between sensor and process stream may protect the gage. Pressure gauge snubbers are intended to suppress the effect of pressure pulses and pressure peaks.

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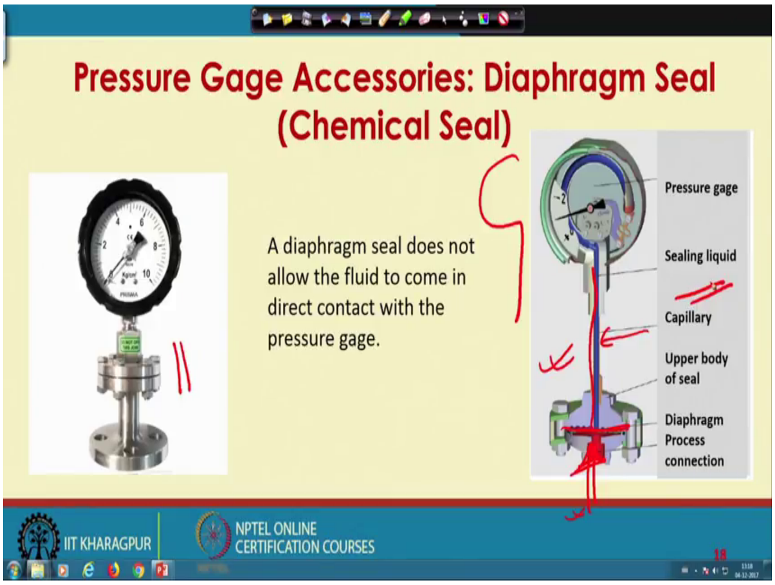


A diaphragm seal does not allow the fluid to come in direct contact with the pressure gage. So, here I have the diaphragm seal also known as chemical seal. So, look at here now, we have a diaphragm; this is the process fluid this is the pressure gage. Let us say this is the bourdon tube pressure gauge and this is the capillary. So, this capillary and the entire bourdon tube is completely filled with the sealing liquid pressure silicon oil.

Now, this diaphragm receives the pressure from the fluid. The fluid is corrosive I use suitable material of construction for the diaphragm. So, the diaphragm is corrosion resistance. Diaphragm receives the fluid pressure and then it is transmitted to the bourdon tube or the pressure gage through this capillary tube, which is also filled with the sealing liquid. So, now, the pressure gage is being isolated from the effect of process fluid by putting a diaphragm in between. So, diaphragm receives the pressure and it transmits the pressure to the pressure gage maybe a bourdon type, C type or spiral type or it maybe a diaphragm, another diaphragm. So, this way you can isolate the process fluid from being from coming in direct contact with the pressure gage.

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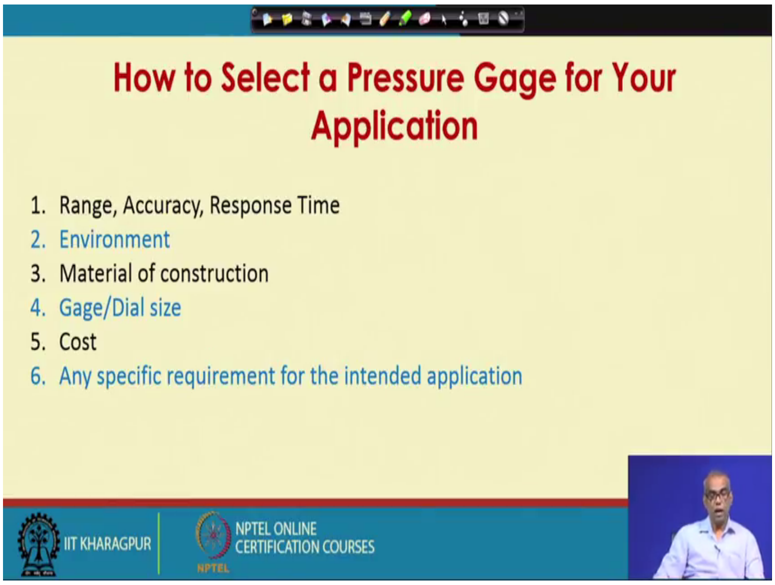


Now, finally, how do I select a pressure gage for my application. There is no a single point answer for this question. You have to consider various aspects. The first thing that should be considered or that comes in our mind is the range or pressure the accuracy desired required and the response time required. So, what is the range of the pressures, what should be the accuracy and what should be the speed of response, accordingly we must select a pressure gage. We also have to take care of environment, is it corrosive, is the corrosive fluid is being measured, what should be the material of construction then, what is the size of the gage or dial, cost is also another important factor, you may also have any specific requirement for the intended applications.

So, there are various factors which will govern the choice of a pressure gage, but most important one is will be the range of pressure gage or accuracy required and the response time and of course, whether corrosive liquid or dirty liquid is being used and the cost. So, these factors will govern the choice of pressure gage for our application.

So, that ends our discussion on pressure measuring instruments. From the next week, we will start talking about temperature measuring instruments.