Chemical Process Instrumentation
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Lecture - 47
Level Measurement (Contd.)

Welcome to lecture 47. We are talking about Level Measurement. In our previous class, we have talked about classification of various level measuring instruments. Then, we started talking about level measuring instruments that come under Direct Measurement of Liquid Level. So, we have talked about a Dipstick method, Optical Dipstick method. We have talked about Hook Type. We have talked about Float Type, various Float types including Float and Shaft Type.

So, today we will talk about Displacer Type Liquid level measuring instruments which is which comes under Direct Measurement of Liquid Level. And then, will start talking about Indirect Measurement of Liquid Level; where, we won't measure the liquid level directly. We will measure some property of the liquid related to the liquid level and then, infer the value of the level from that information.

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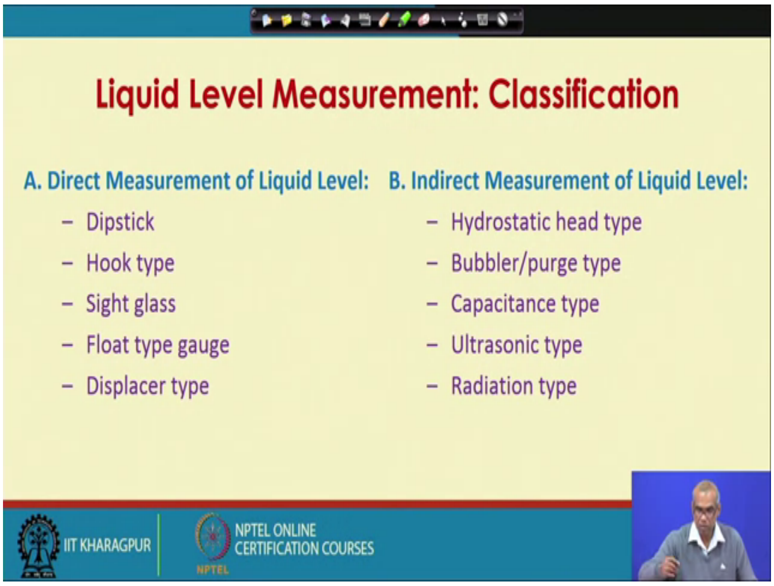

So, this was our classification. So, we talked about Dipstick, Hook type, Sight glass, various Float types including Float and Shaft. So, let us start with Displacer type after that we will talk about Hydrostatic head type and Bubbler or purge type which come under Indirect Measurement of Liquid Level.

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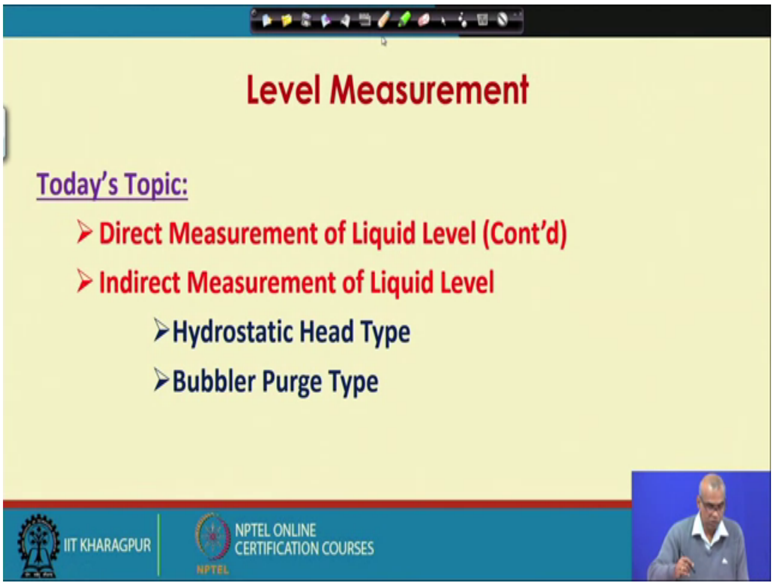

So, this is our today's topic. Displacer type will continue with Direct Measurement of Liquid Level to complete the Displacer type and then, under Indirect Measurement of Liquid Level, will talk about Hydrostatic Head Type and Bubbler or Purge Type.

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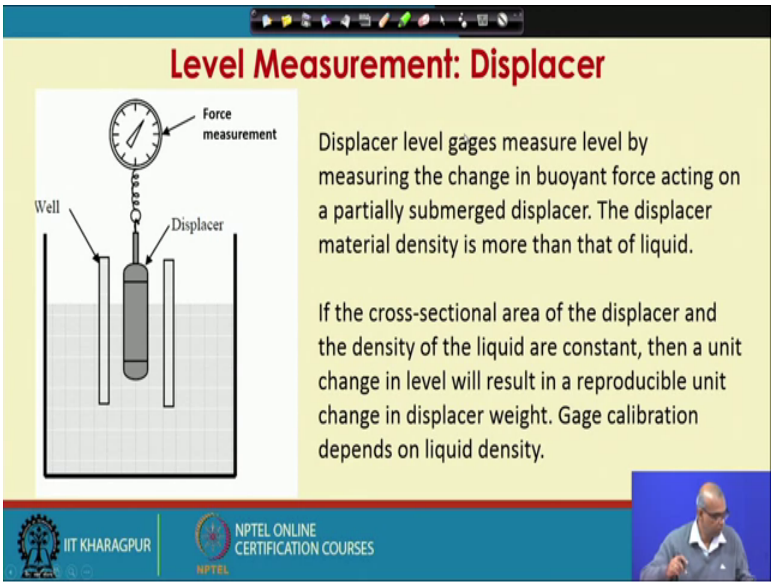

So, we will first start with Displacer type liquid level measurement which comes under direct measurement of liquid level. Displacer level gages measure level by measuring the change in buoyant force acting on a partially submerged Displacer. The displays the material density is more than that of liquid.

So, this is a Displacer which is partially submerged in this liquid. The density of the displacer material is more than the density of the liquid. Now, if the cross-sectional area of the Displacer and the density of the liquid are constant, then a unit change in the liquid level will result in a reproducible unit change in displacer weight; Because, when this displacer is partially submerged according to Archimedes principle. There will be apparent loss of weight in the displacer.

So, if the cross sectional area of the displacer and the density of the liquid are constant, then a unit change in the level will result in a reproducible unit change in displacer weight. So, if I can measure force or weight, I will be able to in measure the level of the liquid from the apparent loss of the weight of the displacer. Since, the measurement depends on the density of the liquid whose level you are measuring the gauge calibration depends on the liquid density.

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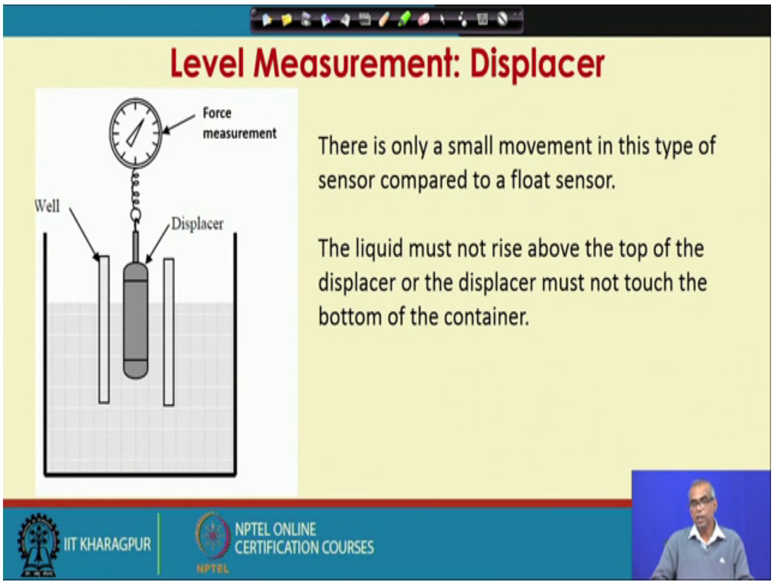

Note that, there is only a small movement in this type of sensor compared to float sensor. The liquid must not rise above the top of the displacer for the displacer must not touch the bottom of the container. So, the displacer will always be partially submerged.

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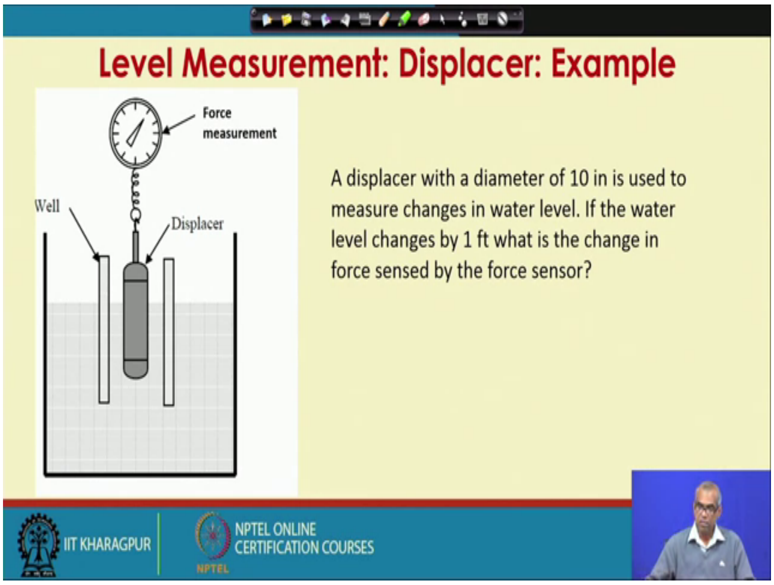

Let us take a very simple numerical example. A displacer with a diameter of 10 inch is used to measure changes in water level. If the water level changes by 1 feet, what is the change in force sensed by the force sensor? So, let us consider this displacer. It is diameter is given as 10 inch.

So, the diameter of this displacer is 10 inch. The water level changes by 1 feet. So, if you consider two situations before change in water level and after change in water level, there has been a difference in the length of displeasure that was submerged and that is 1 feet. So, what is the change in force sense by the force sensor?

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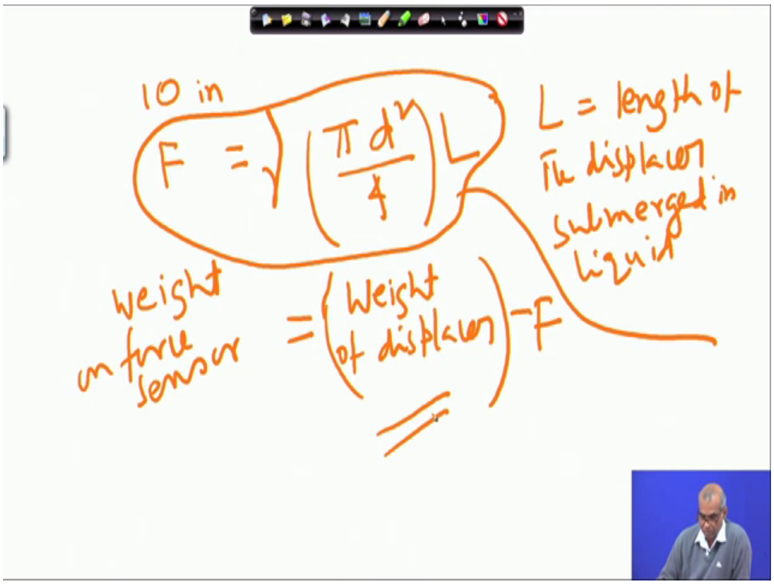

So, I have 10 inch dia displacer. What is the buoyancy force on the cylindrical displacer? Buoyancy force F is pi d square by 4. There is a cross sectional area times L which is the length of the displacer submerged in the liquid. So, L is length of the displacer submerged in liquid and d is the diameter of the float and this has to be multiplied with the specific weight gamma.

So, this is specific weight. So, what is the weight on force sensor? That will be the weight of displacer minus this F. So, this is the buoyancy force that will be subtracted from the weight of the displacer.

So, that is the weight which of the force who is the force sensor will sensed. So, now, let us consider what happens, when the diameter is 10 inch and when the level changes by 1 feet.

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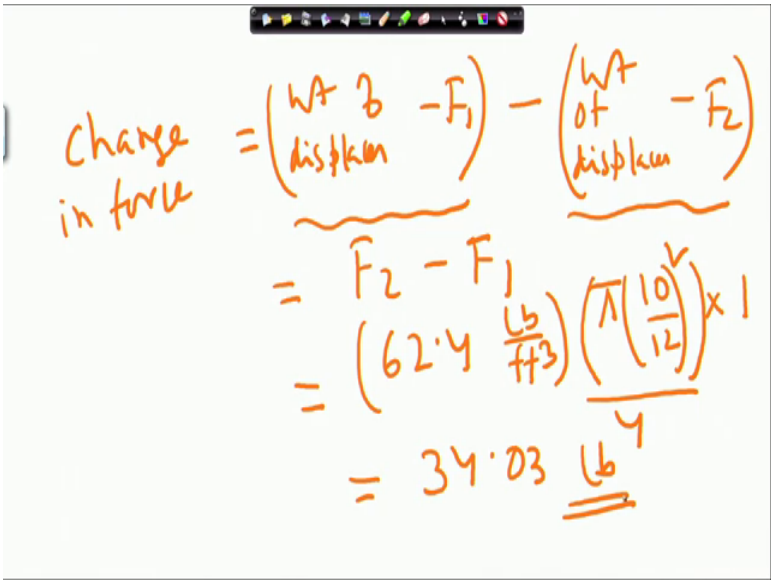

So, change in force will be weight of displacer minus F 1 that is a before, before the liquid level change the 1 feet and this is weight of displacer minus F 2. So, this is this is the force sense by the sensor before changing liquid level and this is the force sensed by the force sensor after the liquid level has changed by 1 feet.

So, their difference will be the change in force. So, this will be nothing but F 2 minus F 1 which will be nothing but 62.4 pound perfect cube. So, this is the gamma for the liquid specific weight for the liquid into pi d square by 4. So, pi d square, I have 10 inch. 10 by 12 whole square by 4 and 1 feet L 1. This will turn out to be 34.03 pound. So, you have to take care of the unit.

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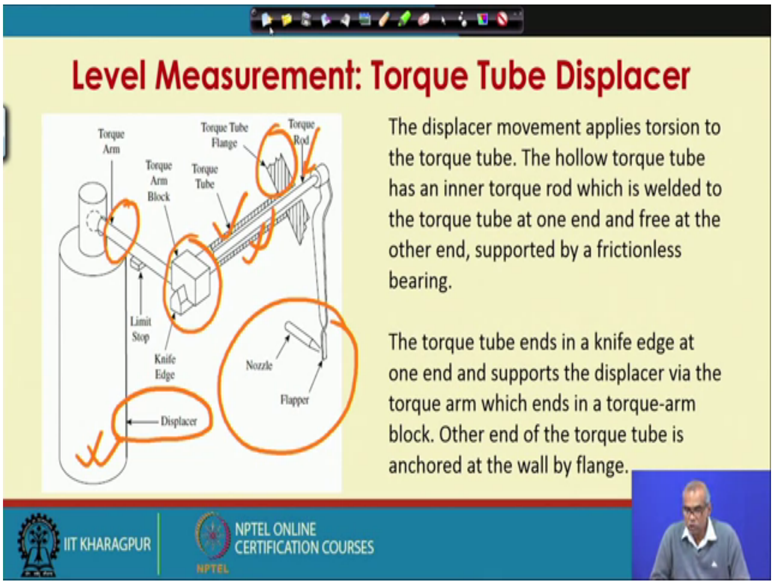

Next to talk about a variation Torque Tube Displacer; In the schematic, this is the Displacer. This is a Torque tube. This is Torque Arm Block. This is Torque Arm and here, I have a Flapper nozzle system connected to one end of the Torque Rod and this part comes out of the wall of the tank and you have this Flange which rigidly connects the Torque Tube with the wall of the tank.

So, the displacer movement applies torsion to the torque tube. The hollow torque tube has an inner torque rod which is welded to the top tube at one end and free at the other end, supported by frictionless bearing. The displacer movement applies torsion to the torque tube. This is the displacer and this is the torque tube. As the liquid level changes its position, the displacer changes its position and this displacer movement will apply a torsion to the torque tube. The hollow torque tube has an inner torque rod look at here, this is the inner Torque Rod.

The hollow torque tube has an inner torque rod which is welded to the torque tube at one end and free at the other end, supported by frictionless bearing. The torque tube ends in a knife edge at one end and supports the displacer via the torque arm. So, the torque tube supports the displacer via this torque arm which ends in a torque-arm block. This is a torque-arm block. The other end of the torque tube is anchored at the wall by flange.

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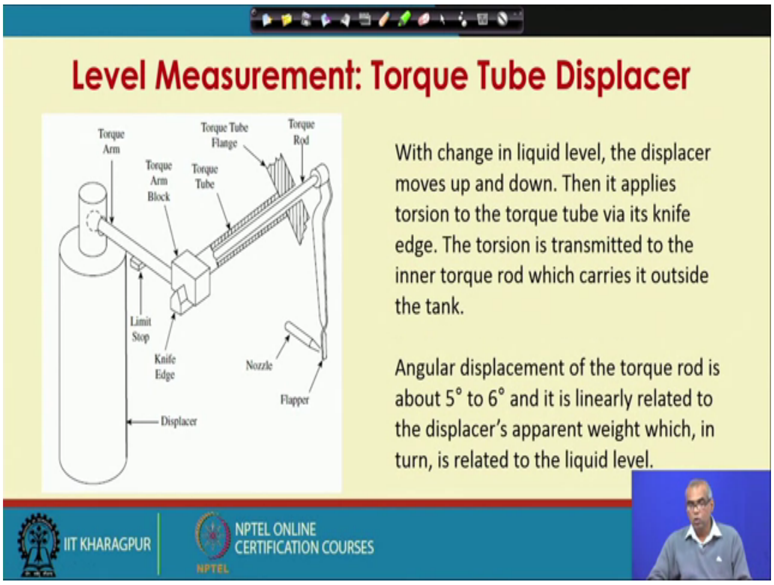

With change in liquid level, the displacer moves up and down. Then, it applies torsion to the torque tube via its knife edge. The torsion is transmitted to the inner torque rod which carries it outside the tank. So, it change in liquid level, the displacer moves up and down. Does it applies torsion to the torque tube via its knife edge?

The torsion is transmitted to the inner torque rod which carries it outside the tank. Angular displacement of the torque rod is about 5 degree to 6 degree and it is linearly related to the displacer's apparent weight which, in turn, is related to the liquid level. So, the displaces apparent weight is related to the liquid level. We have seen this when we talked about displacer type liquid level measurement.

According to Archimedes principle, there will be apparent loss of weight for the partially submerged displacer. So, the displacer's apparent weight is related to the liquid level and the angular displacement of the torque tube is linearly related to the displacer's apparent weight. So, angular displacement of the torque rod is then, a measure of the liquid level. This angular displacement of the torque rod is only 5 to 6 degree.

This can be amplified by this flapper and nozzle system. Note that, this angular displacement will cause this flapper to move against this nozzle. So, accordingly an amplifier pneumatic signal can be generated using the flapper nozzle system. So, that is the purpose of the flapper nozzle system. It can amplify the angular displacement of the torque rod which is a measure of the liquid level.

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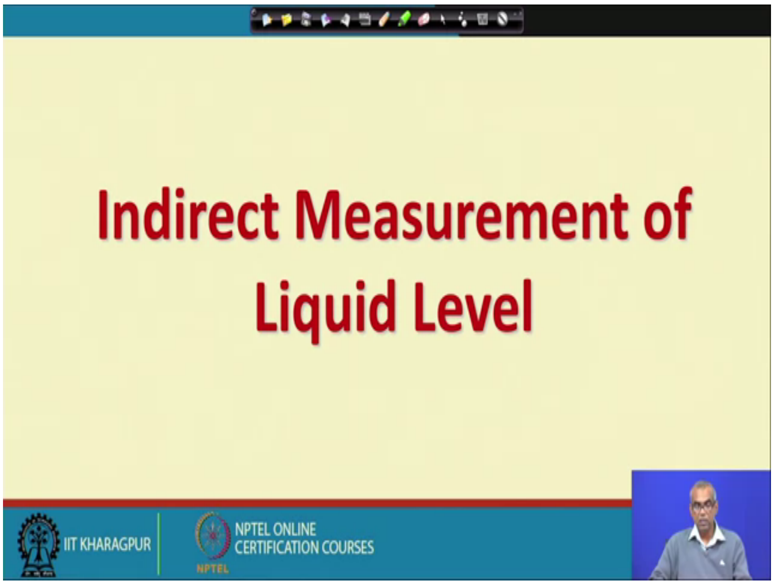

Now, we will talk about Indirect Measurement of Liquid Level.

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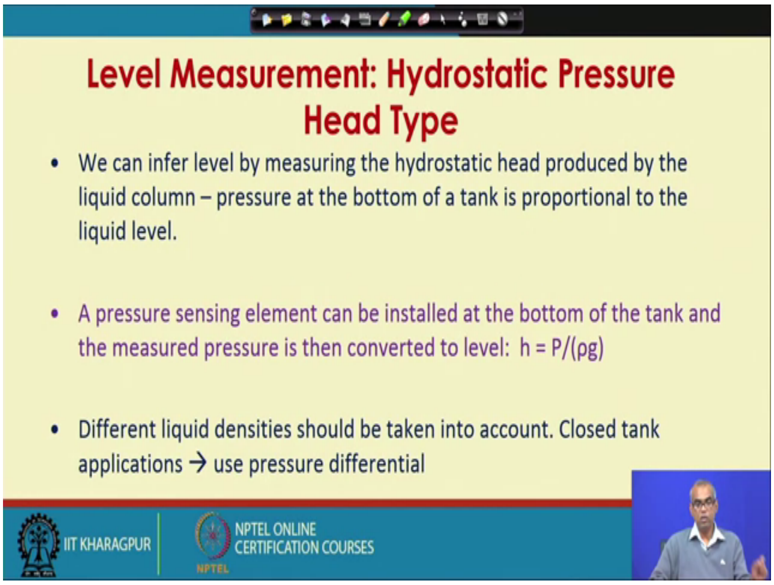

And will start with Hydrostatic Pressure Head Type. We can infer liquid level by measuring the hydrostatic heat produced by the liquid column - pressure at the bottom of a tank is proportional to the liquid level.

A pressure sensing element can be installed at the bottom of the tank and the major pressure is then converted to level: using the familiar equation p equal to row g h; where, p equal to pressure. Rho is the density; g is acceleration due to gravity and h is the level of the liquid. Rho is the density of the liquid whose level where measuring.

So, p equal to rho g h; if you rearrange it, h equal to p by rho g. You can also write it as p by gamma; where, gamma is the specific weight which is rho times g. Different liquid densities should be taken into account. This equation h equal to p by rho g or h equal to p by gamma depends on the density of the liquid or the specific weight of the liquid.

So, this different liquid density should be taken into account, also when you are talking about pressure level measurement in a closed tank. Then, we need to measure differential pressure. It is an open tank the liquid surface is free is open to atmosphere, but when it is closed tank, I have to measure the pressure difference; The pressure difference between the liquid at the bottom of the surface, bottom of the tank and at the top of the tank, liquid top liquid surface.

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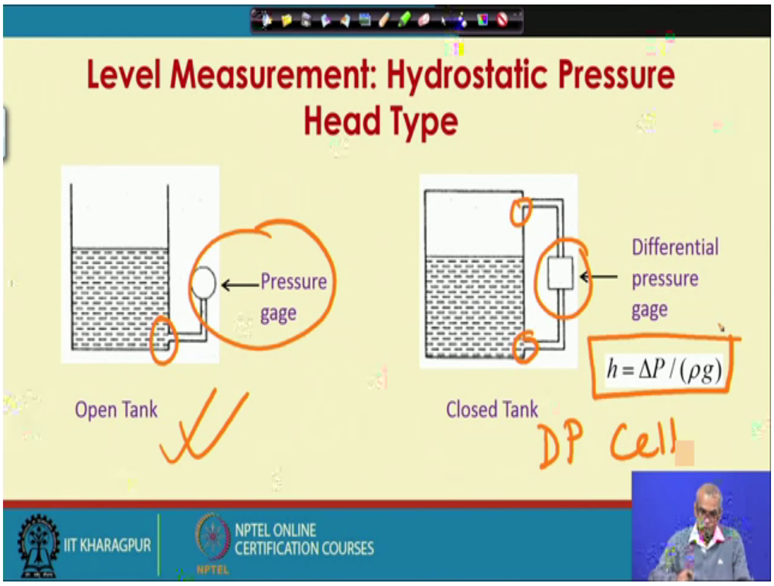

So, hydrated Hydrostatic Pressure Head Type can be used for measuring liquid level in open tank using this pressure gauge attached at the bottom of the tank. I can also measure differential pressure using a differential pressure gauge such as DP Cell by taking a pressure point here and pressure point there and using h equal to delta p by rho g.

So, this possible to measure liquid level using Hydrostatic Pressure Head Types for both Open Tank as well as Close Tank.

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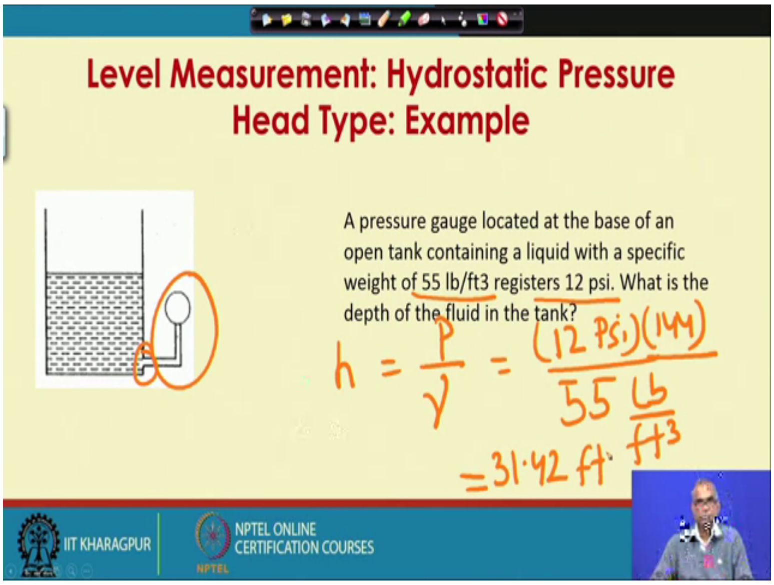

Again, let us take a very simple numerical example. A pressure gauge located at the base of an open tank containing a liquid with a specific weight of 55 pound per feet cube registers; A pressure of 12 psi, 12 pounds per square inch. What is the depth of the liquid in the tank?

So, I am going to measure level of the liquid using a pressure gauge. So, I measure the pressure at the bottom of the tank and that happens to be 20 by 12 psi. I know the specific weight of the liquid is 55 pound per feet tube. What will be the level of the liquid in the tank?

So, this is the state forward application of h equal to p by gamma; h equal to p by gamma. Where, gamma is the specific weight. So, p is 12 psi and gamma is 55 pound per feet cube. So, you need to take care of unit. So, this will be 12 psi. So, this has to be multiplied by 144 and this will become then, and so, will come in feet 31.42 feet.

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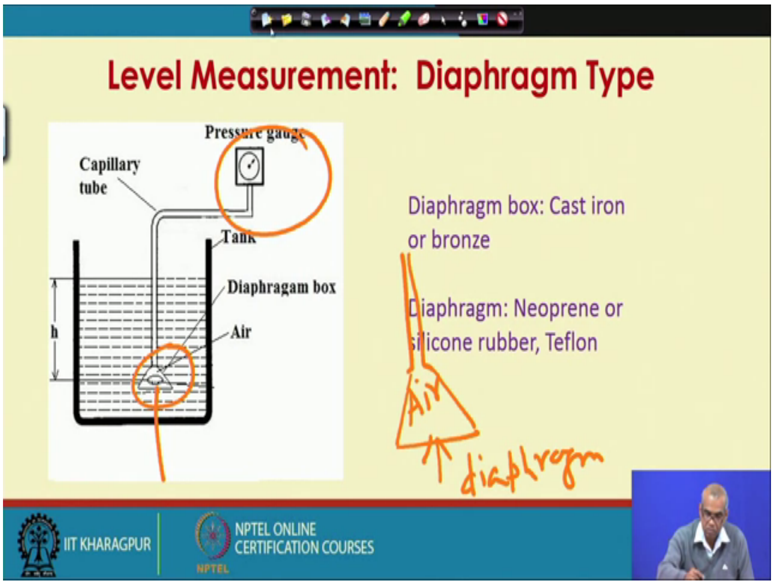

Now, let us talk about Diaphragm type level measurement. What you see in this schematic is a diaphragm in the Diaphragm Box. So, you have this diaphragm you have this gap. So, this is the diaphragm box. So, this is how it looks like here. You have this is diaphragm, this is the diaphragm.

Now, this diaphragm is connected by a capillary tube to this pressure gauge. So, I have a Diaphragm Box and then, the Diaphragm Box is connected to the pressure gauge using a capillary tube. This Diaphragm Box contains air. So, there is captive air within this Diaphragm Box. Now, this Diaphragm Box is located at a fixed position within the time. So, the position of the Diaphragm Box is let us say fixed; which is this.

Now as the liquid level changes this height changes. As this height changes, the pressure here changes ; that means, with change in liquid level, I am applying different amount of pressure on the diaphragm. So, as I apply pressure in the diaphragm that pressure gets transmitted through the air to the pressure gauge. So, as the liquid level changes, the pressure gauge will also show different reading. So, as the liquid level increases, the pressure here increases. So, increased pressure will be shown by the meter.

As the liquid level decreases, the pressure on the diaphragm decreases or decreased reading will be shown by the pressure gauge. So, it should be possible for me to calibrate this pressure gauge in terms of liquid level units. The Diaphragm Box is generally made of Cast Iron or bronze and the diaphragm is made of Neoprene or silicone rubber or Teflon.

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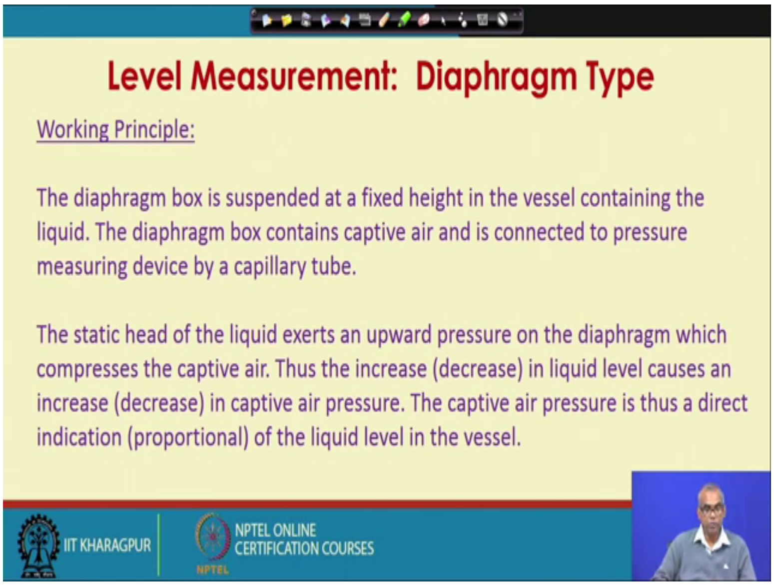

So, to summarize the working principle, the Diaphragm Box is suspended at a fixed height in the vessel containing the liquid. The Diaphragm Box contains captive air and is connected to pressure measuring device by a capillary tube. The static head of the liquid exerts and upward pressure on the diaphragm which compresses the captive air.

Thus, the increase in liquid level causes an increase in captive air pressure. Similarly, a decrease in liquid level will cause a decrease in captive air pressure. The captive air pressure is does a direct indication of the liquid level in the vessel.

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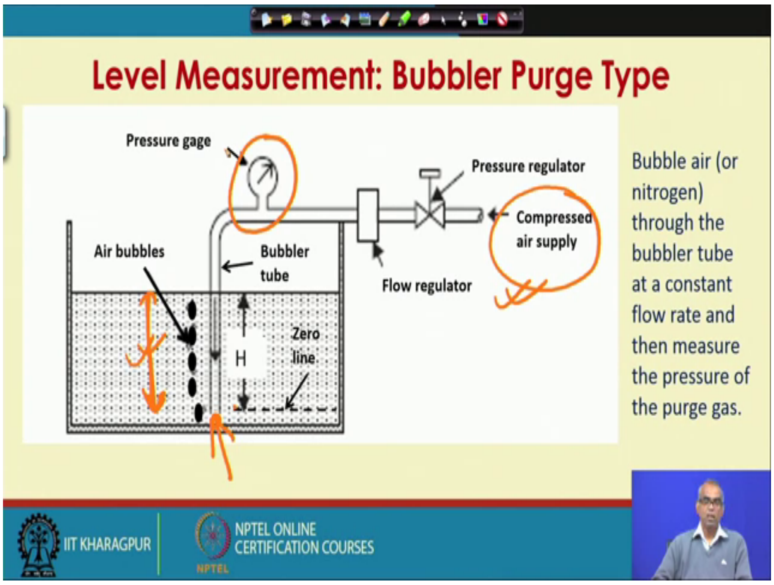

Next, we will talk about a Bubbler or Purge Type liquid level measurement. What you see is a Bubbler or Purge Type level gauge. So, this consists of a Bubbler tube. We have a Bubbler tube. This Bubbler tube has been put to the tank whose liquid level, I want to measure and this is dipped to a certain height. So, let us consider this is dipped up to this.

So, this is my 0 line. Now from the other end of the dip tube, the other end of the dip tube is connected to this connection through which I can supply compressed air. So, I can send compressed air through this tube to this Bubbler tube. I have attached a Pressure Regulator, a Flow Regulator to know how much flow it is going is passing through this tube; you can even put a rot meter here and I have a pressure gauge to measure the supply air pressure.

Now, when it is saying compressed air through this pipe, this air will travel through this pipe and through this bubbler tube and will try to escape from here. But this air will face opposition from the liquid from the pressure that the liquid level exhausts here.

So, the amount of pressure that is being exerted here at this point at the free end of the bubbler tube, the amount of pressure that is exerted, the amount of pressure that is exerted at the free end of the bubbler tube depends on this column of the liquid. Note that, this is 0 line this is fixed. So, this basic any changes with change in the liquid level. So, the amount of pressure that is being applied on the free end of this bubbler tube varies with the liquid level.

So, if the pressure of this air is less than the pressure of the liquid level, pressure due to liquid level at the free end of the bubbler tube, when the air will not escape from the bubbler tube. If the pressure of this air just exceeds the pressure at the end of the bubbler tube exerted by the column of the liquid or the level of the liquid the bubble will just escaped.

So, to measure the liquid level, what I will do is I will slowly regulate the supply of this compressed air and note at what pressure the air bubble just escapes from the free end of the bubbler tube. At that point of time, the pressure shown by this special gauge is saying that the pressure at the end of the bubble tube exerted by the level of the liquid in the tank.

So, from the pressure measured by the pressure gauge, I can infer the liquid level in the tank. Advantage of this bubbler type pressure gauge is this that it can be used to measure pressures of liquid containing slurries or dirty liquid. So, bubble air or nitrogen through the bubbler tube at constant flow rate and then, measure the pressure of this purge gas; purge gas is the compressed air and nitrogen that I am passing through this bubbler tube.

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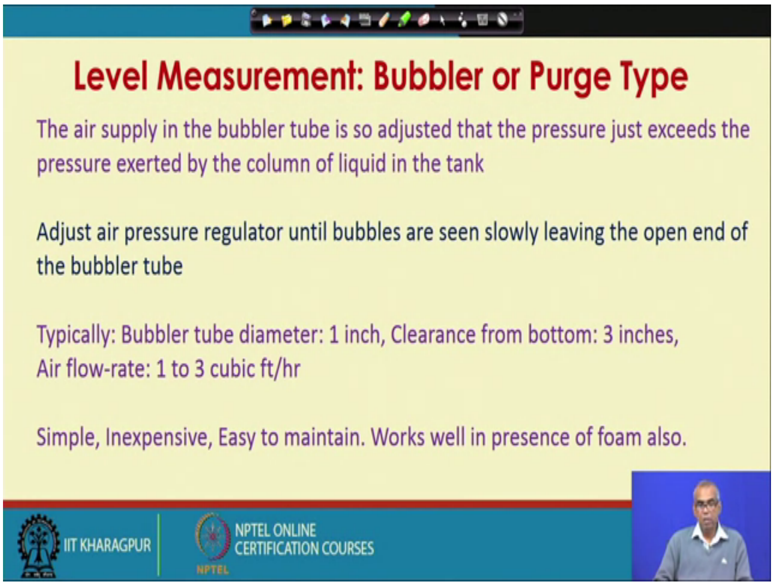

So, the air supply in the bubbler tube is so adjusted that the pressure just exceeds the pressure exerted by the column of the liquid in the tank because when the pressure exerted by the column of the liquid in the tank at the free end of the bubbler tube is equal to the pressure of the purge gas. Then, only the air bubble or nitrogen bubble will escape.

So, to for the nitrogen bubble or the air bubble to escape, the pressure of the nitrogen bubble or the air bubble must just will height us to just exceed the pressure of the liquid level exerted by the column of the liquid in the tank.

So, adjust air pressure regulator until bubbles are seen slowly leaving the open end of the bubbler tube. Typically: Bubbler tube diameter is about 1 inch, clearance from bottom is around 3 inches and air flow rate is maintained between 1 to 3 feet cube per hour. Bubbler or purge type liquid level measurement is Simple, Inexpensive, Easy to maintain. It also works well in presence of foam. It also works well for liquids containing slide.

So, we will stop our discussion on Indirect Measurement of Liquid Level here. And other type of liquid level measuring instruments that come under Indirect Measurement of Liquid Level will continue in the next class.