Chemical Process Instrumentation
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Lecture- 49
Level Measurement (Contd.)

Welcome to lecture 49. This is week 10; we are talking about Level Measurement. So, in our previous lecture, you have talked about capacitive type level gauge and we are talking about level measurement that uses indirect principal for measurement of level. So, we do not measure level directly we measure some property related to level and then, infer the value of the level.

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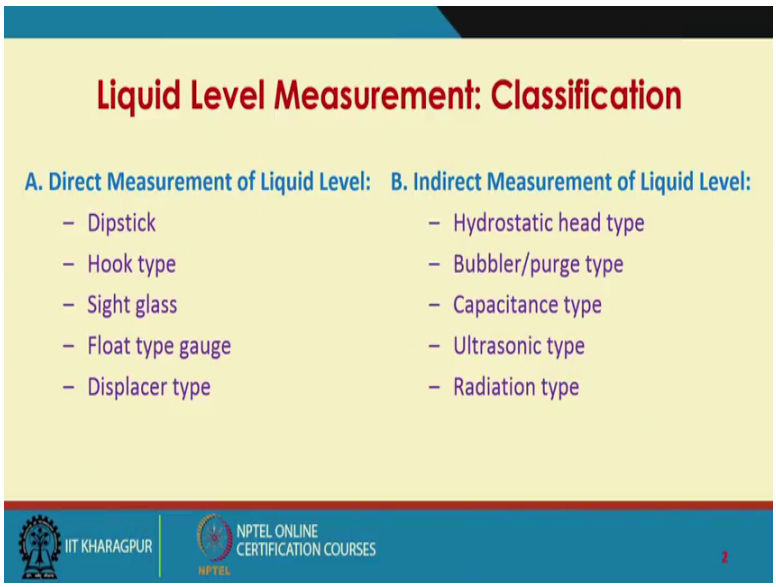

So, this was our classification, we have talked about Capacitance type in our previous lecture. Today, we will talk about Ultrasonic type and Radiation type level gauges.

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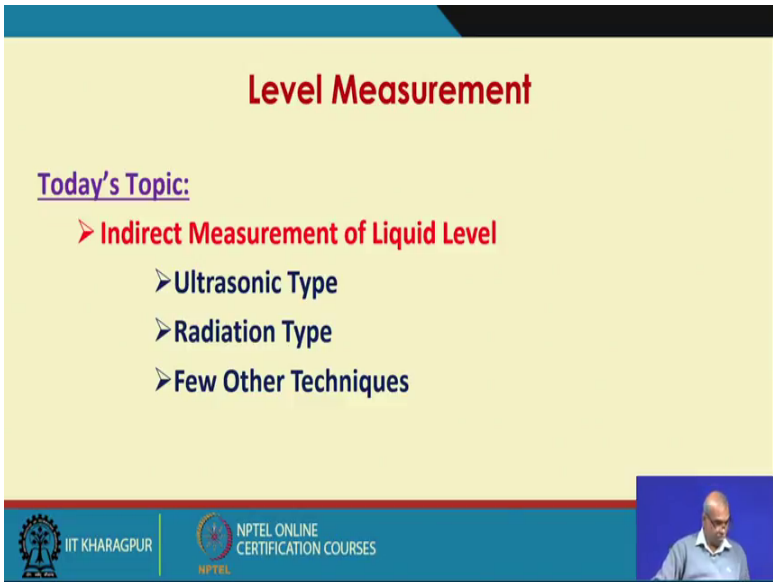

In addition to that we will also talk about few other techniques for measurement of level. So, today we will talk about Ultrasonic Type level gauge, Radiation Type level gauge and briefly we will talk about Few Other Techniques that are used for measurement of level.

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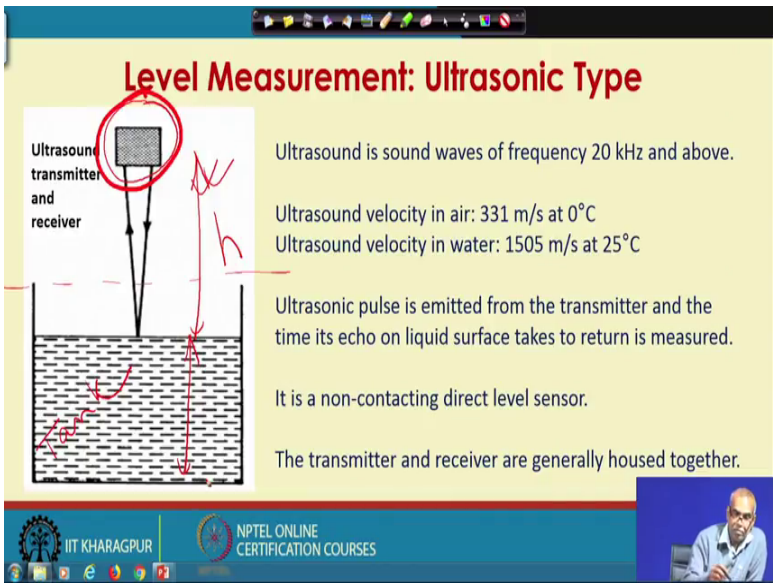

Ultrasound is sound waves of frequency 20 kilohertz and above. The velocity of ultrasound in air is 331 meter per second at 0 degree Celsius; ultrasound velocity in water is 1505 meter per seconds at 25 degree Celsius. So, please note two things; one is

the velocity of the ultrasound depends on the medium through which it is moving. It also depends on the temperature. So, the velocity of the ultrasound depends on the medium and it also depends on temperature. Now here, is a schematic of a typical ultrasonic type level gauge.

So, this is the tank which contains liquid and you want to measure the level of this liquid. This is an ultrasonic transmitter and receiver. So, this is the device which will produce ultrasound and it can also detect ultrasound. So, it will transmit the ultrasound and it will also receive the ultrasound. Now, ultra this device is located at a fixed position say certain h unit above from say a given reference height or say maybe even if maybe from the bottom of the tank as well.

So, the position of this device is known. Ultrasonic pulse is emitted from the transmitter. So, ultrasonic pulse is emitted by the ultrasonic transmitter. This gets reflected from the top surface of the liquid and the receiver receives the echo. So, the ultrasonic transmitter transmits ultrasound. It is directed to the top surface of the liquid. It gets reflected from the top surface of the liquid and the ultrasonic receiver detects it.

You now, find out the time difference between the production of ultrasound and the time at which the reflected ultrasound was received by the receiver. If I now know the velocity of the ultrasound in this medium, I can find out the distance, the ultrasound has travelled. Since I know the exact position of this device let us say from the bottom of the tank, I can find out this diff easily. So, this basically you produce an Ultrasonic pulse from a fixed location above the top surface of the liquid level. The ultrasound is directed to the top surface of the liquid level and as it gets reflected, the receiver receives it.

So, its finds out the time difference between these two events and if you know the velocity of the ultrasound in the medium, I can now find out the distance the ultrasound has travelled. From that I can find out the distance of the ultrasonic device from the top surface of the liquid. Since, I know the distance from the bottom of the tank to the location of the device, I can find out the level of the liquid in the tank. Note that this is a non-contacting direct level sensor. The transmitter and receiver are generally housed together.

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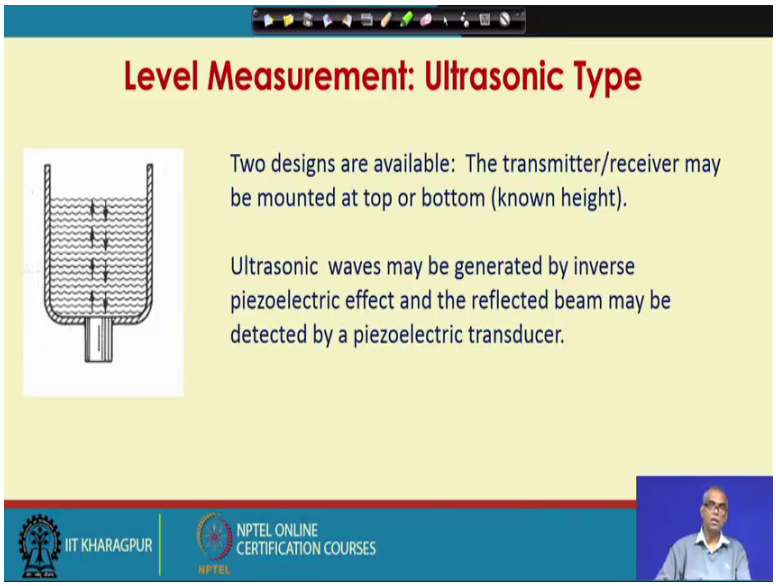

Two designs are available: The transmitter/receiver may be mounted at top or at bottom, but known height. So, here the ultrasound transmitter and receiver was mounted at the top, but here the ultrasound transmitter receiver is mounted at the bottom of the tank. So, both the designs are possible. Ultrasonic waves may be generated by inverse piezoelectric effect and the reflected beam may be detected by a piezoelectric transducer.

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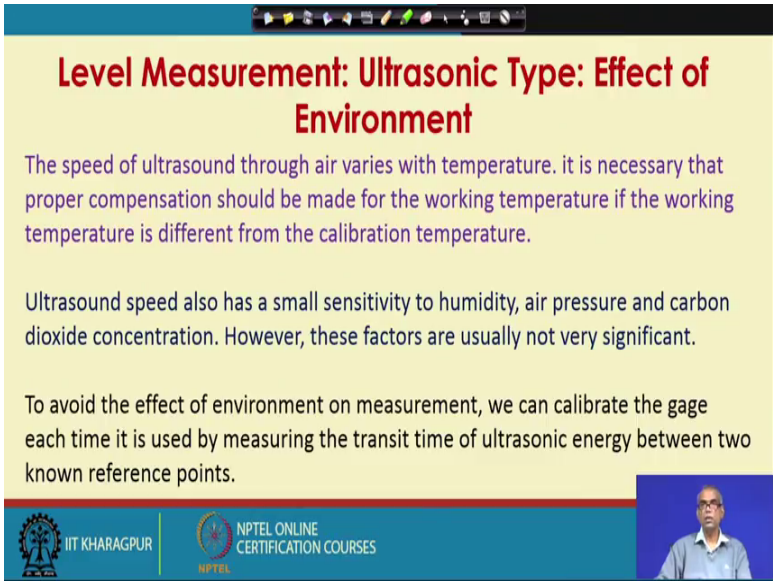

Now, let us talk about Effect of Environment on the measurement of level using ultrasonic type level gauge. As we discussed the speed of ultrasound through air varies

with temperature. It is necessary that proper compensation should be made for the working temperature, if the working temperature is different from the calibration temperature.

So, since the speed of ultrasound through air varies with temperature and if the working temperature is not same as the calibration temperature, we should compensate for the effect of change in temperature. Ultrasound speed also has a small sensitivity to humidity, air pressure and carbon dioxide concentration.

So, if you take the device to different places, the different environment will have different humidity, different air pressure, different carbon dioxide concentration. Even at the same location on different days, there may be changes in humidity, air pressure and carbon dioxide concentration. And velocity of ultrasound has a dependence on these. However, this dependence is very small.

So, these factors usually not very significant; So, they will they do not invite much error in the calculations or in the level measurement. But to avoid the effect of environment on measurement, we can always calibrate the gauge each time it is used by measuring the transit time of ultrasonic energy between two known reference points.

So, every time I use the ultrasonic device I can take two known difference points and find out the transit time of ultrasonic energy between these two points. That means, the time ultrasound takes to travel between these two known reference points; two reference points at that two points whose distance we know exactly.

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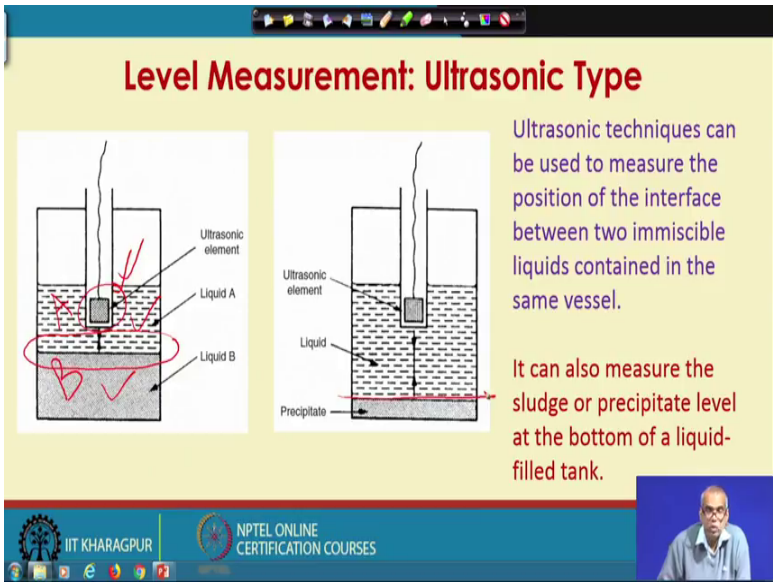

Ultrasonic techniques can be used to measure the position of the interface between two immiscible liquids contained in the same vessel. So, here I have liquid A, I have liquid B. So, liquid A and liquid B are immiscible. So, there is an interface between these two immiscible liquids. So, using ultrasonic device, it is possible to locate this interface between these two.

So, what we have done is these ultrasonic level gauge, I have dipped inside let us say the top liquid A. So, an ultrasound beam is directed towards the interface and it gets reflected back. So, using the same principle, I can find out the location of the interface. The location of this device is known. So, the location of the interface can be found out with respect to the location of the ultrasonic device.

Similarly, we can also measure the sludge or precipitate level at the bottom of a liquid filled tank. This becomes useful when you are storing a dirty liquid or a liquid containing sludge which can precipitate at the bottom of the tank. So, you can find out the precipitate level. So, if we do this measurement periodically, I will be able to find out how much of precipitate at the bottom of the tank is getting accumulated. Next, let us talk about Radiation Type level measuring device.

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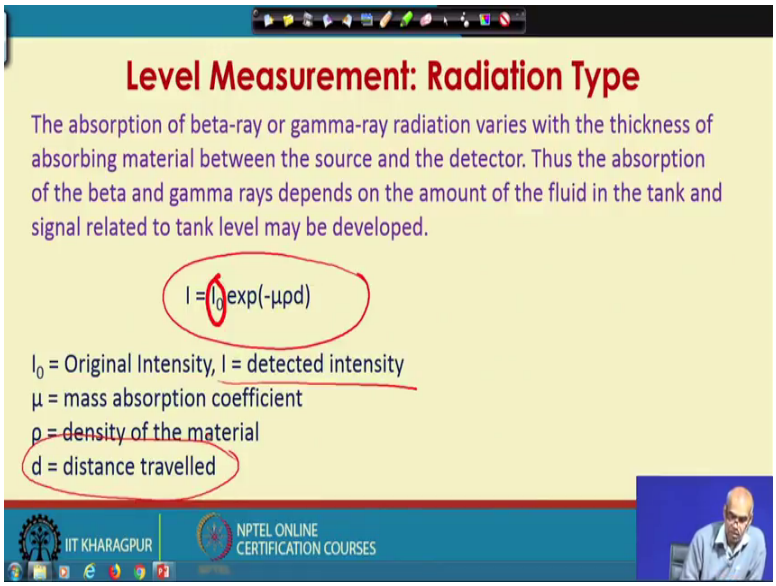

The absorption of beta-ray or gamma-ray radiation varies with the thickness of absorbing material between the source and the detector. Thus, the absorption of the beta and gamma rays depends on the amount of the fluid in the tank and signal related to tank level may be developed. So, the absorption of beta-ray or gamma-ray radiation varies with the thickness of absorbing material between the source and the detector.

Thus, the absorption of the beta and gamma rays depends on the amount of the fluid in the tank and a signal related to the tank level maybe thus developed. This is the expression that is used for designing Radiation type level gauge or working of the Radiation type level gauge can be explained with help of this equation.

So, as you said that the absorption of beta-ray and gamma-ray radiation varies with the thickness of the absorbing material. So, I have some material let us say and I am sending a radiation from a source the intensity of the radiation from the source let us say I 0 and I am measuring the intensity of the radiation when it is passing through the medium of say thickness d. So, the detected intensity is I and the distance travelled or the thickness of the material is d. The density of the material is rho and the mass absorption coefficient is mu.

So, then, then the detected density, the detected intensity of the radiation depends on the thickness of the material d; density of the material rho and mass absorption coefficient

mu and of course, on the original intensity by this expression. I equal to I 0 into e to the power minus mu rho into d.

So, d is the distance travelled. So, note that for a given gauge, I can find out d; if I know, I 0 I and of course, rho and mu. We can measure the intensity of radiations using appropriate sensors and then, can compute the distance travelled or the thickness of the material or the level as d.

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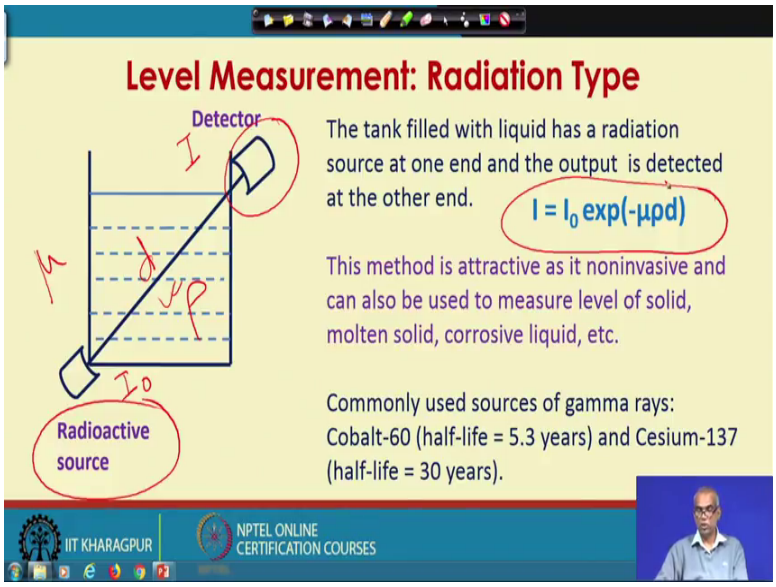

So, on typical design is on in the schematic, we have a Radioactive source. It has been attached at one corner and in the other corner, we have this radiation Detector. So, this Radioactive source emits a radiation with intensity I 0 and let us say the Detector detects the intensity as I. The mass absorption coefficient is mu and the density of this medium is rho.

So, the distance travelled is this d can be found out from this equation provided we have measured I I 0 and of course, you should know mu one rho. The method is attractive as it is noninvasive and can also be used to measure level of solid, molten solid, highly corrosive liquid etcetera. Commonly used sources of gamma rays are Cobalt-60 which has half life of 5.3 years and Cesium-137 which has half life of 30 years. There are other designs also possible.

So, you can have sources various radioactive sources and various levels and by detecting the sources the detecting the intensity from a particular source you can find out the level in increments.

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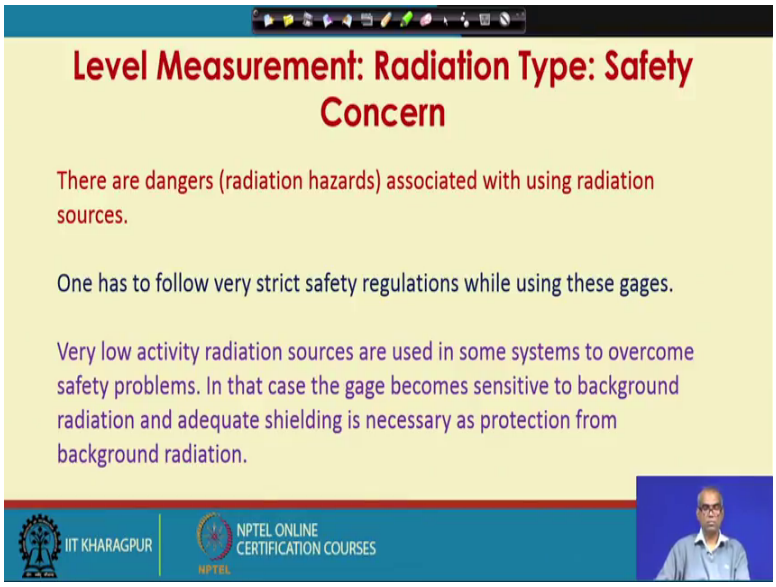

When you are using radiation type level gauge, there are some safety concerns. There are dangers or radiation hazards associated with using radiation sources. One has to follow very strict safety regulations while using these gauges. Very low activity radiation sources are sometimes used in some systems to overcome safety problems. In that case the gauge becomes sensitive to background radiation and adequate shielding is therefore, necessary to protect the device from the effect of background radiation.

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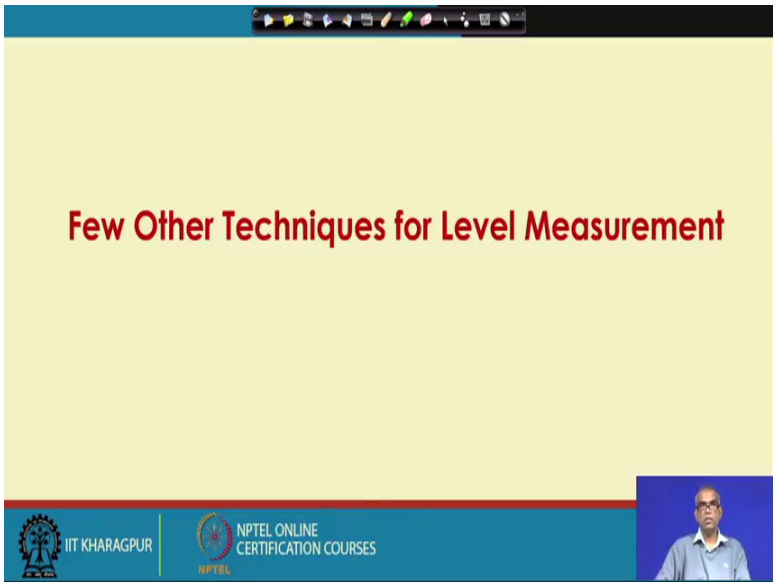

Now, we will talk about Few Other Techniques for measurement of level.

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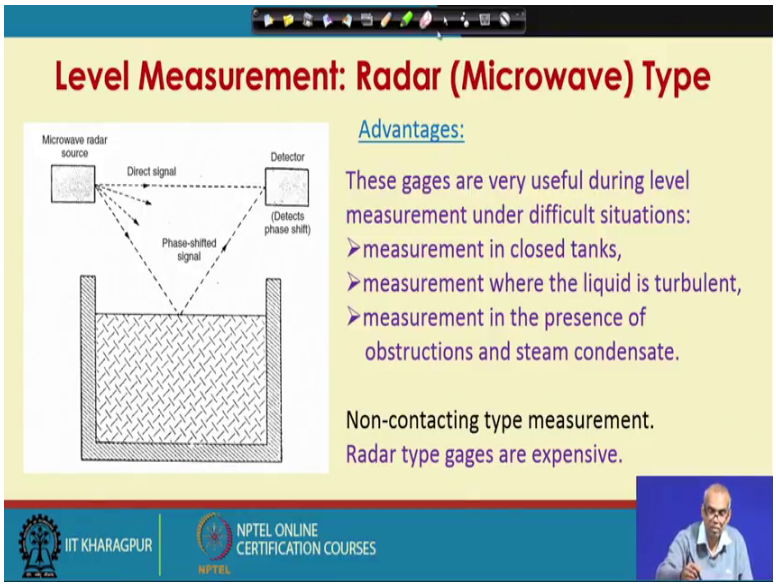

Let us talk about a technique which is similar to Ultrasonic type level measurement. This is Radar Type or Microwave Type. Look at the schematic you have a microwave radar as a source which sense a microwave signal directed towards the top surface of the liquid level and there is a detector which receives the reflected radar signal.

A constant amplitude frequency modulated microwave signal is directed to the liquid surface. A receiver measures the phase difference between the reflected signal and the

original signal transmitted directly through air to it. So, you have a micro radiate radar source, a signal can go directly to this detector. A signal can also be directed towards the surface and then it gets reflected and reaches detector.

So, this receiver or this detector measures the phase difference between the reflected signal and the original signal transmitted directly through air to the detector. The measured phase difference is linearly proportional to the liquid level. So, a constant amplitude frequency modulated microwave signal is directed to the liquid surface. It gets reflected and reaches detector. The signal from the micro radar source also reaches directly to the detector.

Now, the phase difference between these two is found out and this phase difference is linearly proportional to the liquid level. There are advantages of using radar type or micro type level gauge. This gauges are very useful during level measurement and a difficult situations where, it will be difficult for you to use other types of level measuring instruments such as situations under measurement in closed tank, measurement when the liquid is turbulent, measurement in the presence of abstractions and steam condensate.

So, during measurement in closed tank, during measurement for the liquid is turbulent and during measurement in the presence of abstractions or steam condensate the radar type of microwave type are very useful. Note that this is non-contacting type measurement. However, related gauges are expensive.

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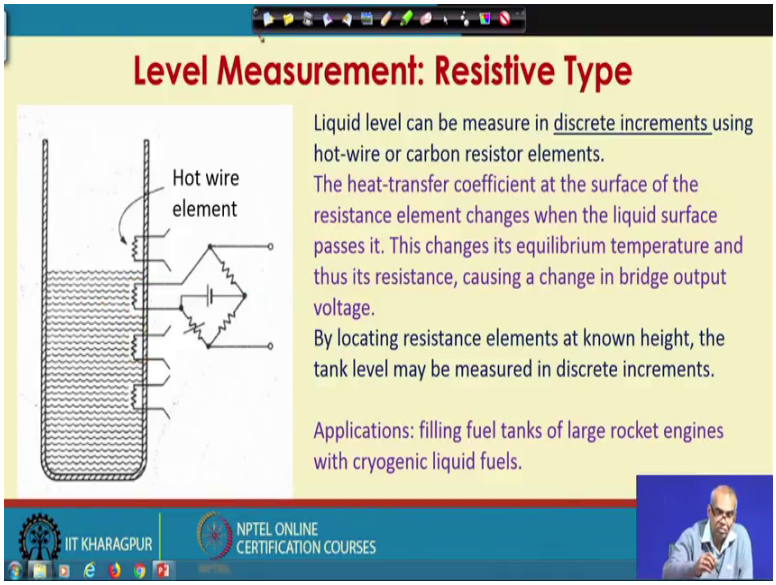

Next to talk about Resistive Type level measuring instrument. What you see is there a series of hot-wire element of carbon resistor connected to the wall of the tank and these hot-wire elements are connected to this bridge. Liquid level can be measured in discrete increments using hardware or carbon resistor elements. The heat transfer coefficient at the surface of the resistance element changes when the liquid surface passes it.

These changes is equilibrium temperature and that is its resistance causing a change in the bridge output voltage. By locating resistance elements at known height, the tank level may be measured in discrete increments. So, if you talk about any particular how to add element. When the liquid circle with the liquid surface passes this hot wire element, this particular hot wire element? The heat transfer elements at the surface of the resistance element changes.

So, this will change its equilibrium temperature and if its equilibrium temperature changes, it is resistance will change. So, thus a change in the bridge output voltage will be there. So, I now know that the level of the liquid in the tank will correspond to this hot-wire element. Similarly, here when I come here and this particular hot wire element in use, I know that the level corresponds to the location of these hot-wire element.

So, this way the level can be measured in discrete increments. It has an interesting applications filling of fuel tanks of large rocket engines with cryogenic liquid fuels.

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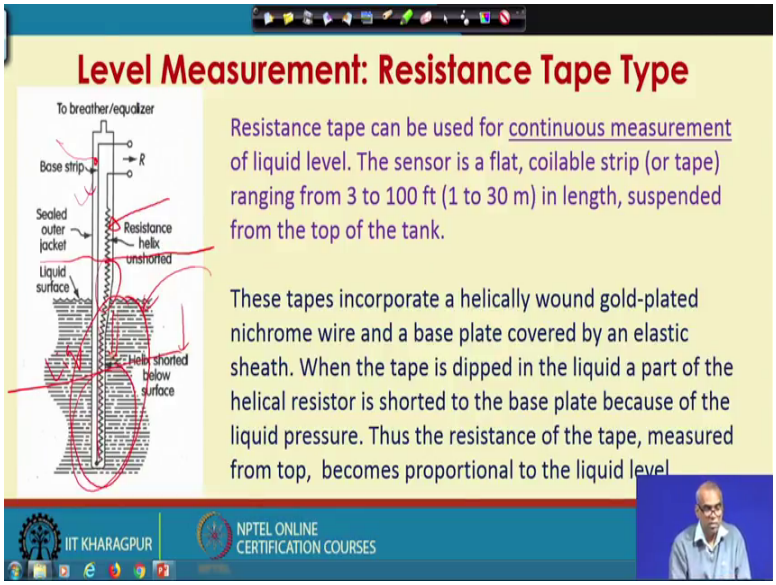

In the previous slide, we have seen the measurement of liquid level in discrete steps in increments. Here, we will see resistance tape type level measuring instrument which can measure liquid level continuously. Resistance Tape can be used for continuous measurement of liquid level. The sensor is a flat, coilable strip or tape ranging from 3 to 100 feet. That is about 1 to 30 meter in length. It is suspended from the top of the tank..

These tapes incorporate helically wound gold-plated nichrome wire and a base plate covered by an elastic sheath. When the tape is dipped in the liquid a part of the helical resistor is shorted to the base plate because of the liquid pressure. Thus the resistance of the tape, measured from top, becomes proportional to the liquid level. So, you consider this a Resistance helix. This is a gold plated nichrome wire and you have this base strip.

Now, this is immersed in the liquid whose level you are measuring; if you look at this part, due to pressure of the liquid. This resistance helix has touched this best strip. So, when the tape is dipped in the liquid, a part of the helical resistor is shorted to the base plate. Now, if this liquid if this device is dipped in a medium whose level is more; that means, if the liquid level now increases, the liquid level come here even this part will also be shorted; when the liquid level goes down say up to here maybe only this part will be shorted.

So, again this part will not be shorted them. So, the part that is shorted to the base plate will depend on the pressure that is the liquid is applying on this resistance helix and the pressure will depend on the level of the liquid. So, it is now possible to find out the level of the liquid by measuring the change in resistance of this device.

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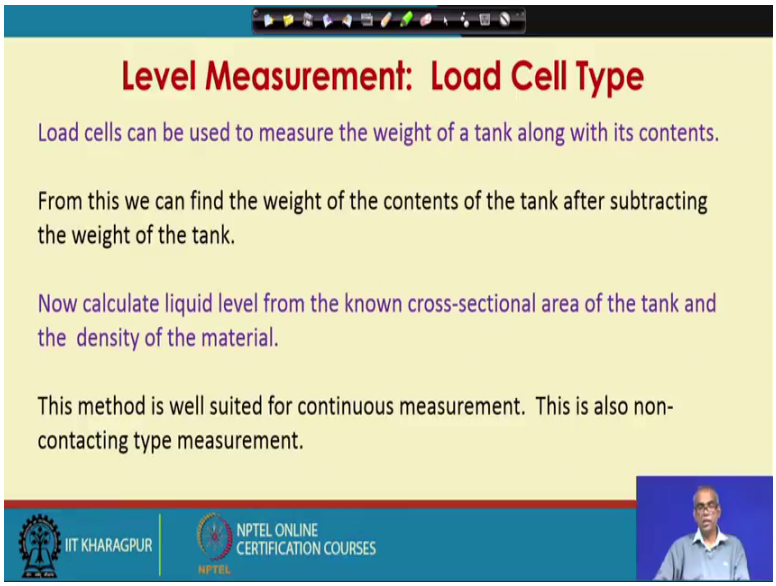

Level measurement, by Load Cell Type; Load cells can be used to measure the weight of a tank along with its container, along with its contents. From this, we can find the weight of the contents of the tank after subtracting the weight of the time. So, basically you are using load cell to measure the weight of the tank along with whatever it contains. Let us say we have liquid in the tank. So, you are using a load cell to measure the weight of the tank plus the weight of the liquid contained in it. From this, we will find the weight of the contents of the tank after subtracting the weight of the tank.

We must know the weight of the empty tank. Now, calculate the liquid level from the known cross sectional area of the tank and the density of the material. So, if I know the cross sectional area of the tank, I can find out the volume of the tank. So, I will be able to find out the depth of the liquid that is correspond to the weight of the liquid contained in the tank that you have found out by subtracting the weight of the tank from the load cell measurement. This method is well suited for continuous measurement. This is also non contacting type measurement.

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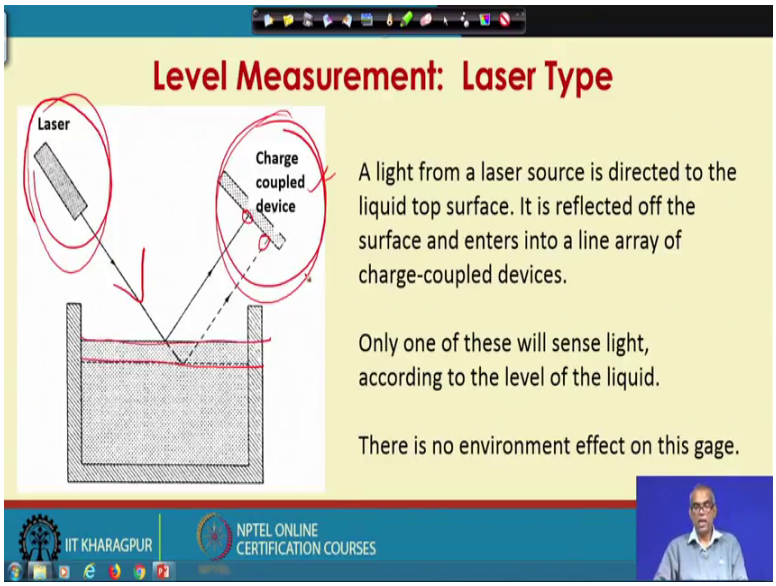

Finally, will talk about level measurement by Laser Type level gauge; A light from a laser source is directed to the liquid top surface. It is reflected off the surface and enters into a line array of charge-coupled devices. So, you have a laser source, you have a charge coupled device which receives the reflected laser beam. Only one of these will sense light. So, there is a line array of charge coupled devices and only one of these will sense light according to the level of the liquid.

So, when the level of the liquid is this; so, this will sense light. When the level of the liquid is this, this will sense the light. So, there is an array of charge coupled devices. So, light from a laser source is directed to the liquid top surface; it is reflected of the surface and interest into a line array of charge coupled devices. Only one of these will sense light according to the level of the liquid. There is no environment effect on this gauge.

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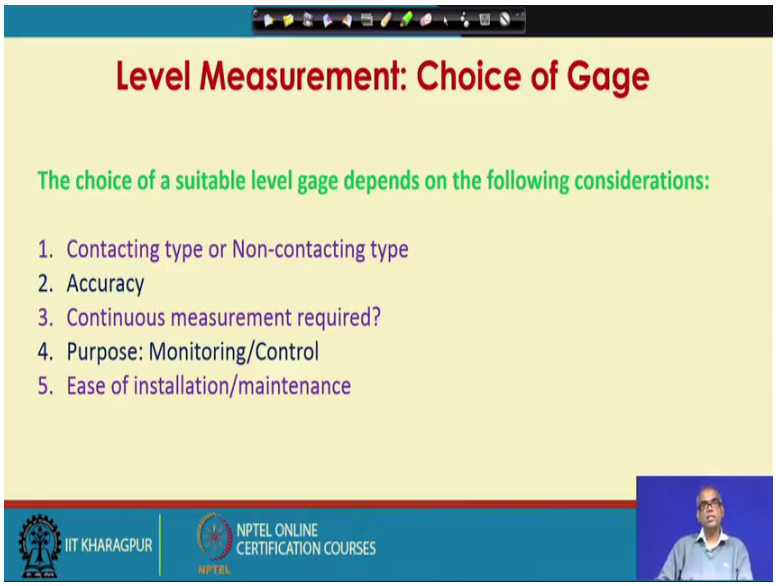

So, finally, we have talked about various level measuring instruments. Now, how do I select a suitable gauge for my application? The choice of a suitable level gauge depends on the following considerations. We must ask whether we need a Contacting type level gauge or Non-contacting type level gauge. What is the accuracy required? Is Continuous measurement required?

Because all level gauges are not suitable for continuous measurement. What is the purpose of the liquid level measurement? Is it only an indication of the level is required for monitoring purpose or it is required for the purpose of control? If it is required for the purpose of process control that transmitters, level transmitters which is gives me the information about the level as an electrical signal for pneumatic signal will be more useful. You also should take into account, ease of installation and ease of maintenance.

So, these various considerations are there for choice of a suitable level gauge for your application. So, we will stop our discussion on level measuring instrument here.