Chemical Process Instrumentation
Prof. Debasis Sarkar
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture- 48
Level Measurement (Contd.)

Welcome to lecture 48. This is week 10 and we are talking about Level Measurement. In our previous lecture, we have talked about classifications of various level measuring instruments that are available. We are broadly categorized level measuring instruments as direct measurement of level and indirect measurement of level and the direct measurement of level, we have talked about instruments such as Hook type level gauge, Float type level gauge, Sight glass, Displacer type, as well as Dipsticks; ordinary dipsticks as well as ordinary dipsticks.

Then, we started talking about level measurement indirectly; that means, instead of measuring level directly, we measure some property of the fluid and from that we can infer the level of the liquid. Under this category we have talked about various Pressure head type level measuring instrument and also we have talked about Bubbler or Purge type level measuring instruments. Today, we will talk about Capacitance type level measuring instrument.

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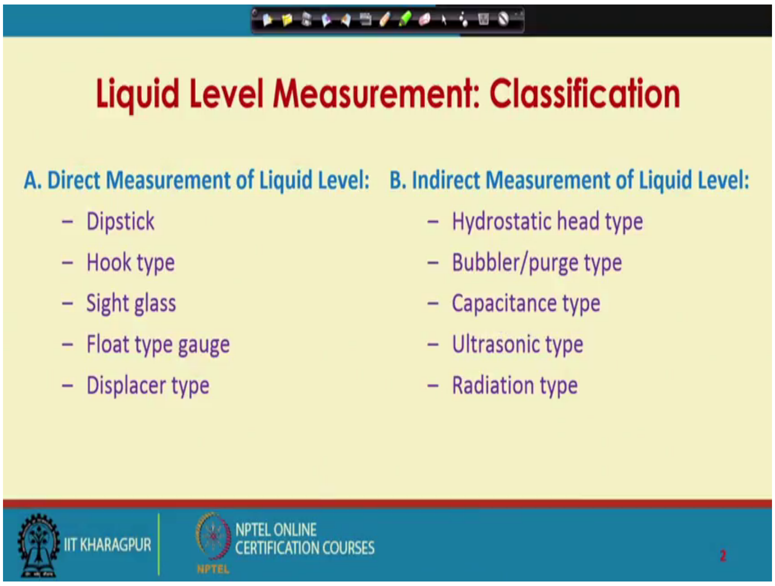

So, these are the various classification we have completed this part. So, we have completed this part and you have talked about this two in your previous class and today we will talk about Capacitance type level measuring instruments.

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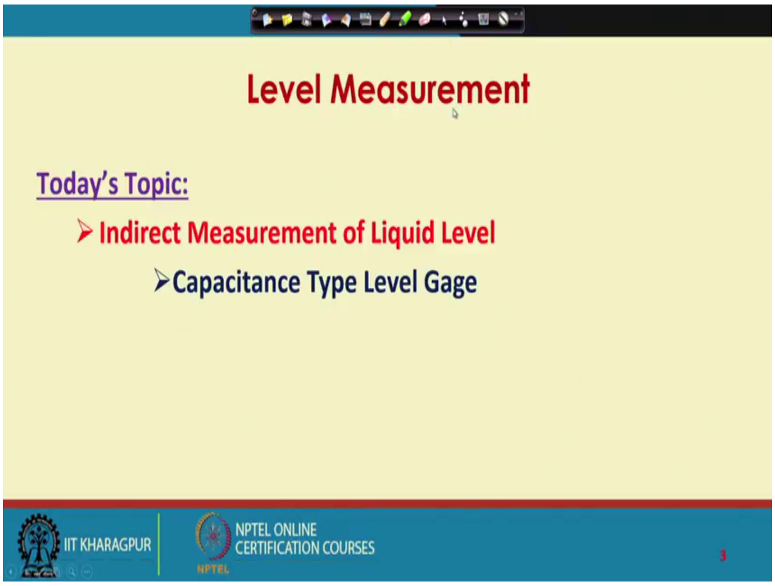

So, this is our today's topic Capacitance Type Level Gage.

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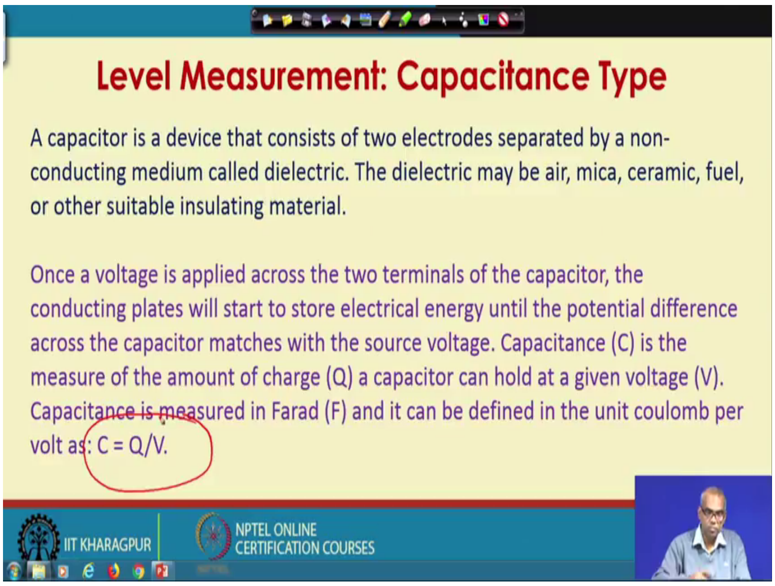

So, let us first learn, what is capacitor? A capacitor is a device that consists of two electrodes separated by a non-conducting medium called dielectric. The dielectric may be air, mica, ceramic, fuel or other suitable insulating material. Once a voltage is applied across the two terminals of the capacitor, the conducting plates will start the store electrical energy until the potential difference across the capacitor matches with the source voltage. Capacitance is the measure of the amount of charge a capacitor can hold at any given voltage.

So, if I indicate capacitance as C, amount of charge as Q and the voltages; the capacitance C can be expressed as C equal to Q by V. Capacitance is measured in Farad. So, its unit is Farad and it can be defined in the unit coulomb per volt. So, K is coulomb; K is the charge has unit coulomb and V is the voltage. So, capacitance equal to Q by V is coulomb per volt which is Farad. The capacitance depends on the geometry of the conductors.

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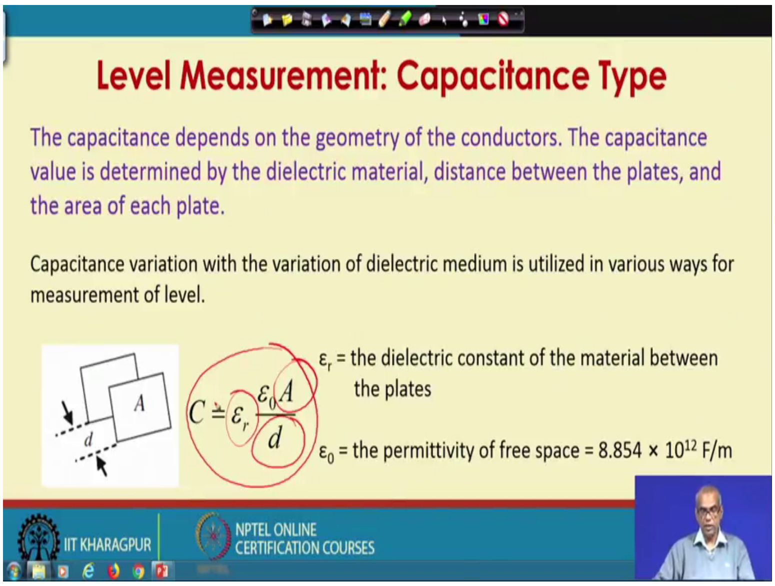

The capacitance value is determined by the dielectric material, the distance between the plates and the area of each plate. So, there are three factors. Imagine these two plates as capacitors plates. So, the area of the plates let us say A. The distance between the plates is d and let us say, the medium that exist between these two plates has a dielectric constant or relative permittivity as epsilon r. So, the capacitance C will depend on area; it will depend on dielectric constant of the medium and it is also depend on the distance by which these two plates are separated.

The capacitance variation with the variation of the dielectric medium is utilized in various ways for measurement of level. The expression that relates capacitance with area and diameter is as follows. Capacitance C equal to epsilon 0 into A divided by d. Where, A is the area of the plates; d is the distance by which they are separated; epsilon r is the dielectric constant of the material between the plates and epsilon 0 is the permittivity of free space and its value is 8.854 into 10 divided by 12 Farad per meter.

So, you see that the capacitance increases as the area of the plates increases; the capacitance decreases as the distance by which they are separated increases. It also increases directly with the numerical value of the dielectric constant of the medium. So, the variation of the capacitance with variations in dielectric medium may be utilized in various ways for measurement of level.

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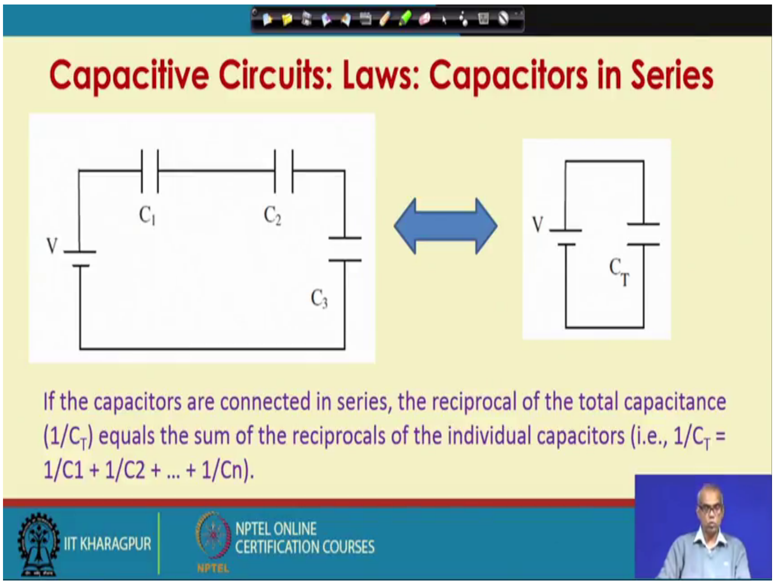

Before you go further, let us remember these 2 laws of capacitive circuits. What you see is capacitors C1 C2 C3 C4 are all connected in parallel. The capacitance of 2 or more capacitors connected in parallel is equal to the sum of the individual capacitances; that means, the capacitance of this circuit is represented by C T, total capacitance that will be equal to C1 plus C2 plus C3 plus C4. So, if there in capacitors connected in parallel; the total capacitance will be sum of all this individual capacitances. Similarly, if the capacitors are connected in series here C1 C2 C3 are connected in series.

So, the equivalent total capacitance will be 1 by C T equal to 1 by C1 plus 1 by C2 plus 1 by C3. So, the reciprocal of the total capacitance will be equal to sum of the reciprocals of the individual capacitors. So, if there are n capacitors connected in series and the total capacitance is C T, 1 by C T will be equal to 1 by C1 plus 1 by C2 plus up to 1 by Cn.

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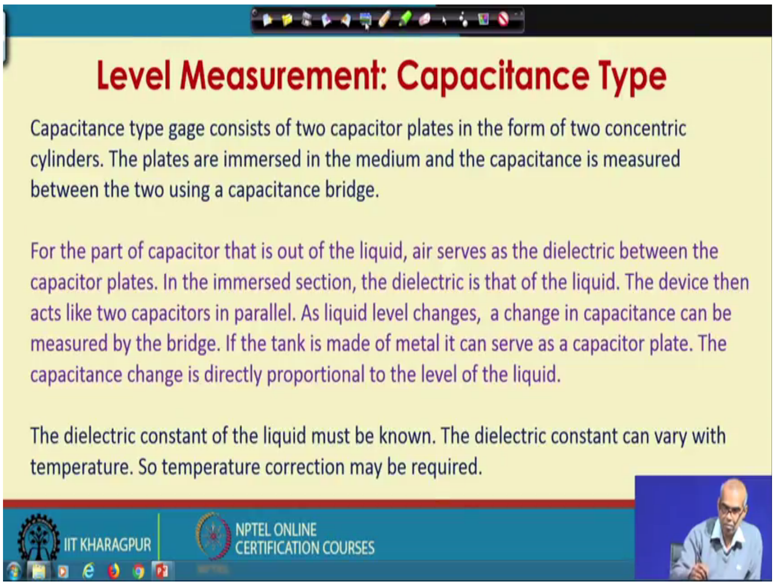

Capacitance type level gage consists of two capacitor plates in the form of two concentric cylinders. So, this is the most common design, the capacitor level gage will consist of two capacitor plates in the form of two concentric cylinders. The plates are immersed in the medium and the capacitance is measured between the two using a capacitance bridge circuit. For the part of the capacitor that is out of the liquid air serves as the dielectric between the capacitor plates. In the immersed section the dielectric is that of the liquid.

The device that acts like two capacitors in parallel as liquid level changes a change in capacitance can be measured by the bridge. If the tank is made of metal it can serve as a capacitor plate. The capacitance change is directly proportional to the level of the liquid. The dielectric constant of the liquid must be known. The dielectric constant can vary with temperature. So, temperature correction may be required in case of level measurement using capacitive type level gage.

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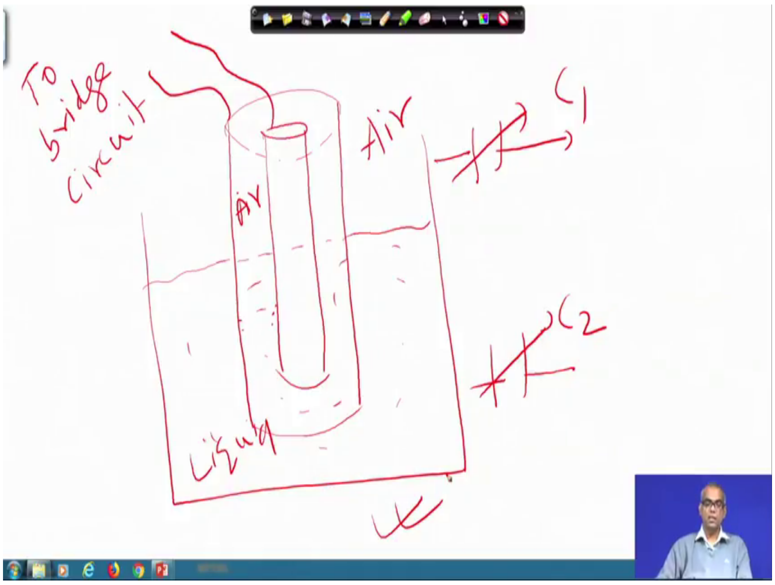

So, you have two concentric cylinders; you have concentric cylinder which will work as capacities. So, these are connected to the bridge circuit. Now, this is immersed in the tank which contains liquid and you want to measure the level of the liquid. Now, the part which is immersed the liquid will work as dielectric between these two capacitor plates, but here there is no liquid here there is air.

So, you have here air as dielectric medium between the two concentric cylinder or between the two capacitors plates. So, you have a capacitor here, you have a capacitor here. So, these two capacitors on of parallel in; so, these two concentric cylinder capacitors will work as two capacitors connected in parallel to each other.

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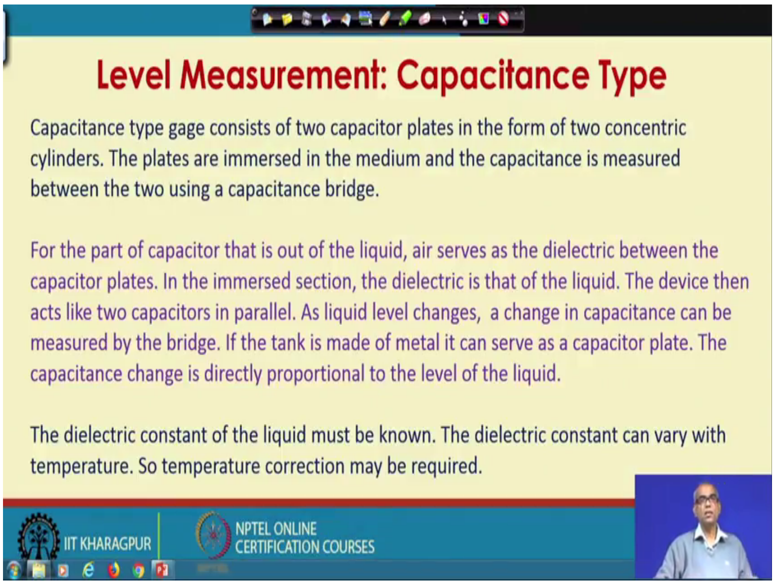

As the liquid level changes, the portion that is out of the liquid changes; So, the capacitance, individual capacitance changes. So, the total capacitance of the system will also change. So, change in capacitance will allow us to measure the liquid level.

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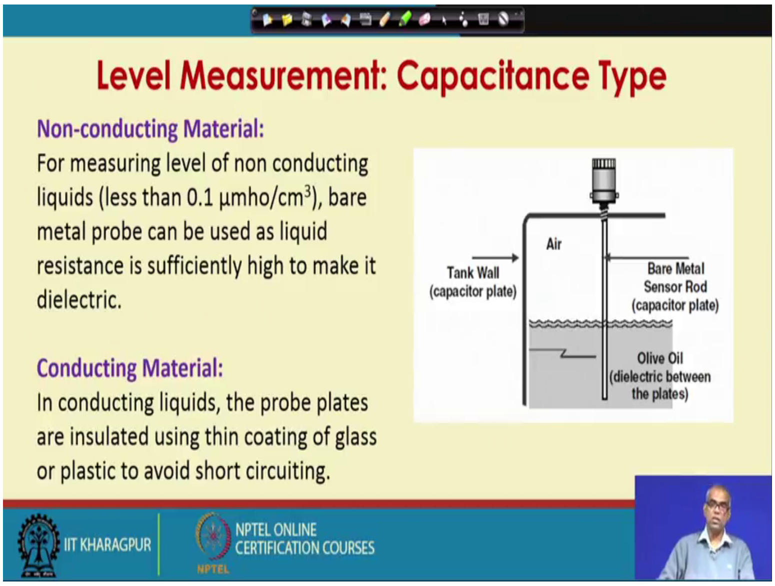

Now, when you are measuring the level of liquid in a tank or in a container, my liquid may be conducting type; it may also be non-conducting type. For measuring level of non conducting liquids by non-conducting liquid we mean a conductivity less than 0.1 micro mole per centimeter cube. If the liquid is non-conducting; then, a bare metal probe can be used as liquid resistance is sufficiently high to make it dielectric.

So, in the figure you see this is a case of non-conducting material. So, the liquid is non-conducting material. Here, I am measuring the level of olive oil which is the dielectric medium between the two capacitor plates. So, here a bare metal sensor rod has been used as capacitor plate. So, it is bare metal. So, there is no insulation around it; because they will medium is level measuring is non-conducting. If the tank is made of metal; then, the tank wall itself can act as another capacitors.

So, I left two walls; one is from this bare metal which works as one capacitor and that tank which works as another capacitor plate. So, this two will go and get connected to the capacitor bridge circuit; But, if you have conducting material in the tank. In other words, the liquid future they will level you are measuring is conducting material, the probe plates must be insulated using thin coating of glass or plastic to avoid short circuiting.

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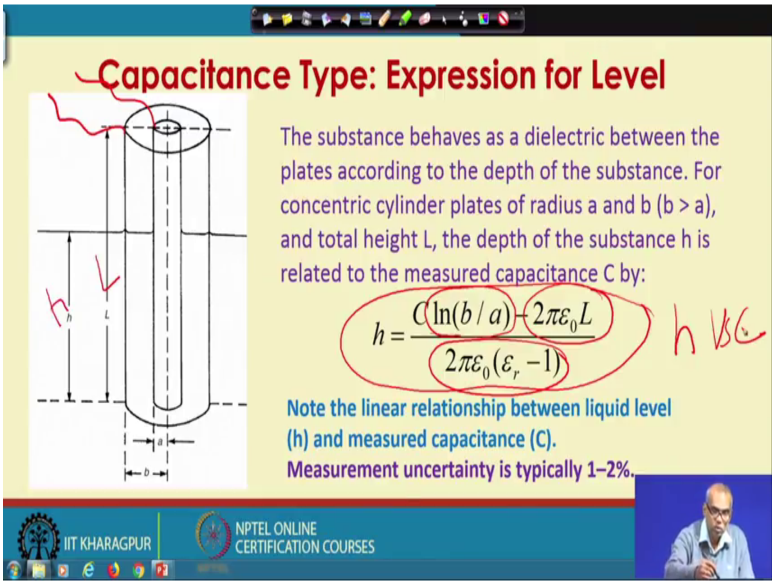

So, let us look at the mathematical expression that relates the level of the liquid in the tank with the capacitance that is produced in the capacitive level gage. As we discussed the substance whose level, we are going to measure; in other words, the medium waves has a dielectric between the plates according to the depth of the material in the tank.

So, what you see here is two cylinders; two concentric cylinders which works as capacitive type or capacitance type level gage. So, this will be connected. These two are still be connected to the bridge circuit for measurement of change in capacitance. The total length is L and let us say the level of the liquid is h.

So, up to h unit the capacitive gauge is immersed. If the radius of the inner cylinder is a and the radius of outer cylinder is b. Then of course, b is greater than a and then, the capacitance and the level of the liquid is related by these expression; h equal to C ln b by a minus 2 pi epsilon 0 L divided by 2 pi epsilon 0 into epsilon r minus 1. Where, epsilon r is the relative permittivity of dielectric constant of the medium, they will level measuring; epsilon 0 is that of free space and we have seen its value; a is the radius of the inner diameter inners inner cylinder and b is the radius of the outer cylinder. L is the total length.

So, if you look at this expression all this part are constant for a given capacitive gage and given a liquid. So, that dielectric constant is also dielectric constant is also constant. So, you can note that there existed linear relationship between level of the liquid h vs C. The measurement uncertainty of capacitive type level gage is typically 1 to 2 percent. Now, this expression we can easily derive from the knowledge of capacitance that is produced between 2 concentric cylinders.

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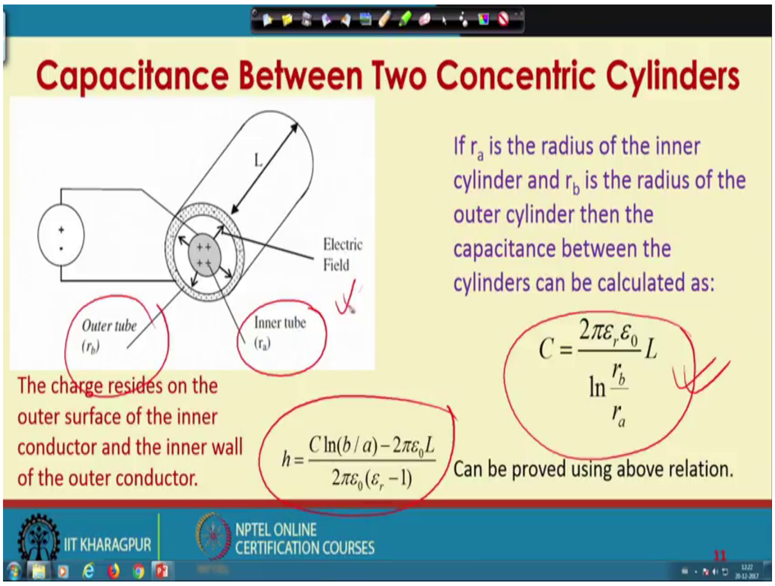

So, if say ra is the diameter of the inner tube or inner cylinder and rb is the diameter of the outer one, then the capacitance between these 2 is given by this expression: C equal to 2 pi epsilon r epsilon 0 divided by ln rb by ra whole times L. So, if you look at any text book on electrical engineering or electrical technology, you will see this expression.

In fact, there are several physics textbook also which will tell you the capacitors produce for various geometries, you look under geometries which is 2 cylinders or 2 cylinders 2 concentric cylinders and will get this equation. Now, I have to apply this equation for our case. Then, I will get this relationship which relates the level of the liquid with the capacitance in our case. Here, the charge resides on the outer surface of the inner conductor and the inner wall of the outer conductor. So, let us look at how I get this equation.

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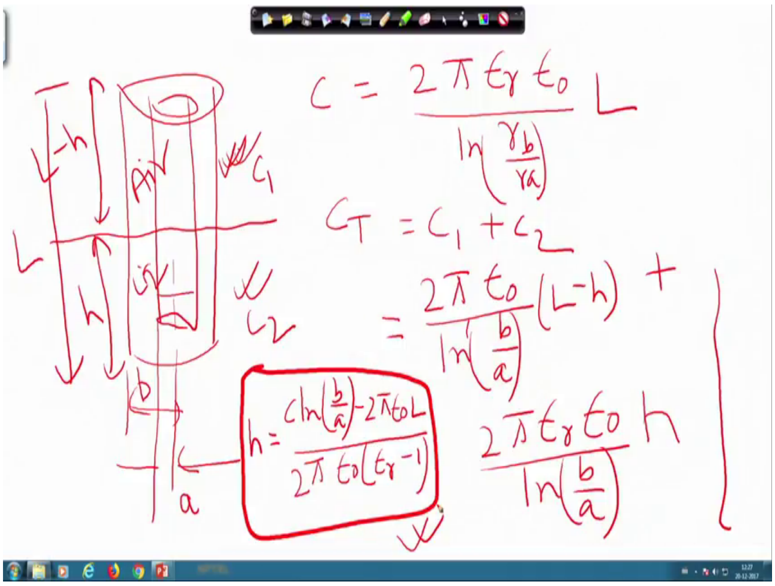

So, I know is I have 2 concentric inner cylinders. My radius here is a for the inner one and for the outer one my radius is b. So, I know that capacitance is two pi epsilon r epsilon 0 by ln rb by ra L. For the previous slides explanation; where, r b is base r a is inside ok. So, here as we discussed that this device will act as 2 capacitors connected in parallel.

So, I know the total capacitance will be the C1 plus C2 because it is see marks up to this. So, here it is the liquid whose level you are measuring and here this is air. So, one capacitance here, another capacitance; one dielectric constant here, another dielectric constant here; 2 different capacitors connected in parallel. So, what will be C1? Let us say C1 is here and C2 is here. So, if this is L and this is h this much is L minus h.

So, C1 will be 2 pi epsilon r is 1 for air. So, epsilon 0 for free space divided by ln b by a outer dia by inner dia into; L is basically here L minus h plus corresponding expression for C2. So, C2 will be 2 pi epsilon r which is the dielectric constant for the liquid whose level we are measuring epsilon 0 dielectric constant for free space divided by ln b by a and this multiplied by h, here length is h.

So, if you now simplify this you will get the equation that you wrote for the h versus C; that means, the question that you wrote is h equal to C ln b by a minus 2 pi epsilon 0 L divided by 2 pi epsilon 0 epsilon r minus 1. So, just simplify this, you will get this. This equation also tells you that h versus C relationship is linear.

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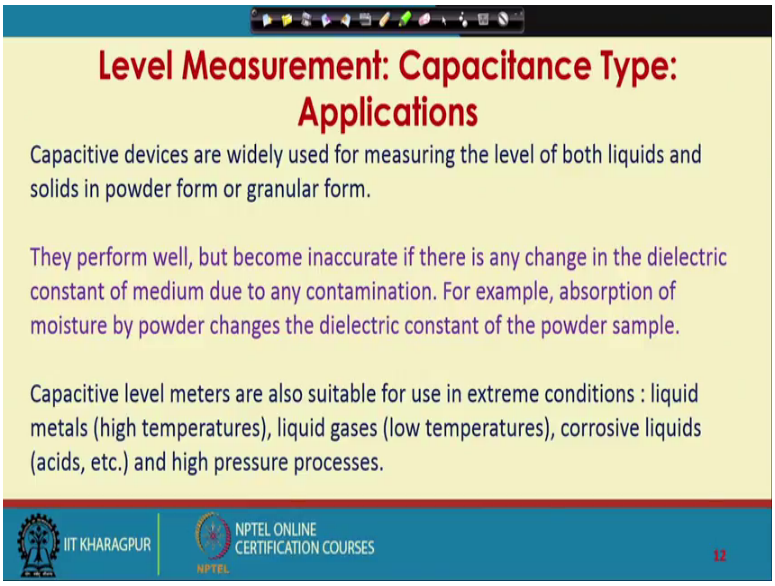

There are various applications of Capacitance type level gages. Capacitive devices are widely used for measuring the level of both liquids and solids in powder form or granular form. They perform very well, but become inaccurate, if there is any change in the dielectric constant of medium due to any contamination or some other reasons. So, they will ordinary perform very well, but will become inaccurate, if the dielectric constant of the medium changes due to factors such as contamination. For example, absorption of moisture by powder changes the dielectric constant of the powder sample.

So, if there is moisture in the absorber, the dielectric constant of the powder will change and that will bring in some in accuracy in the result. Capacitive level meters are also suitable for use in extreme conditions such as liquid metals or molten liquids, liquids with very high temperature; liquid gases is low temperatures, liquefied gases, corrosive liquids such as acids. May be hydrofluoric acid very corrosive and high pressure processes.

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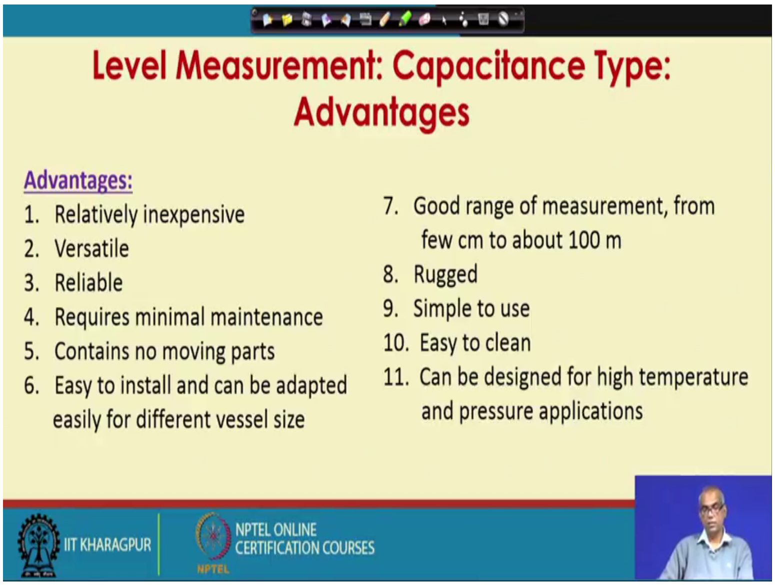

Here, are a list of advantages for capacitance type level gages.

Relatively inexpensive; Is Versatile; Reliable; Requires minimum maintenance; Contains no moving parts; Easy to install and can be adapted easily for different vessel size; Good range of measurement. You can measure from 2 centimeter to about 100 meter. The construction is Rugged type. Is simple to use; Easy to clean.

Can be designed form for measurement of high temperature and high pressure applications. The disadvantages are not much; one thing is that if the dielectric constant of the medium changes due to contaminations, there will be error in the measurement and we have mentioned one example that of moisture absorption by the powder.

Also there has to be variation since, variation of dielectric constant is being used as a principle for measurement of level, there should be changes in the dielectric constant which were using for the purpose of measurement. But in case of see powder absorbs moisture and changes is dielectric constant; then, you will be using the same old value of the dielectric constant of powder and that will bring in error.

So, we stop our discussion on Capacitive Type Level Gage here.