Chemical Process Instrumentation

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Lecture – 50
Level Measurement (Contd.)

Welcome to lecture 50. So, this is the last lecture of week 10 this week we have talked about Level Measurements. So, we started with classification of all level measuring instruments we categorized as direct level measurement and indirect level measurement and we have seen various instruments under both categories.

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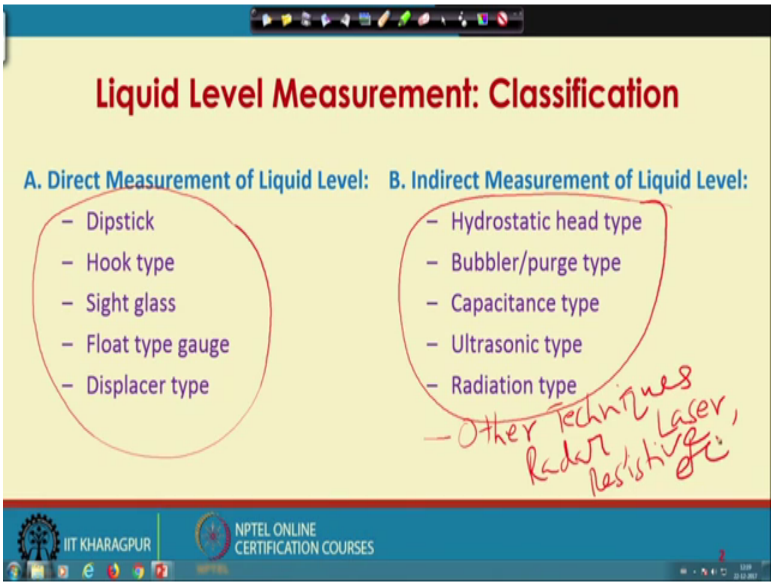

So, if you look at the classification more time these are the instruments that we have covered under direct measurement of liquid level and under indirect measurement of liquid level. We have covered these additionally we have also talked about other techniques of liquid level measurements such as radar, laser based, resistive type etcetera. So, what we plan to do today is we will take some numerical problems on level measuring instrument as well as flow measurements.

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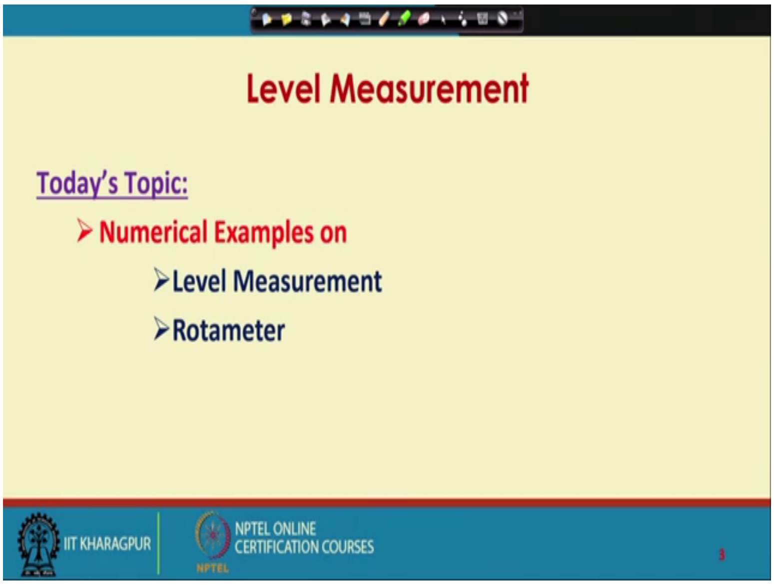

So, we will take specifically we will take one problem on level measurement and we will take two problems on flow measurements by Rotameter.

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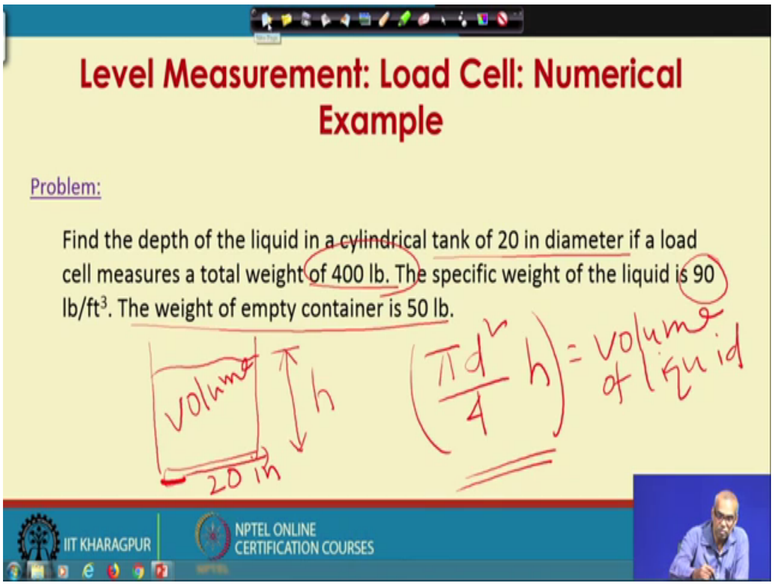

So, let us consider the first problem on level measurement by load cell, find the depth of the liquid in a cylindrical tank of 20 inch diameter if a load cell measures a total weight of 400 pound. The specific weight of the liquid is 90 pound per feet cube the weight of empty container is 50 pound. So, load cell can be used for measurement of level; so, what you do is we take help of the load cell to find out the weight of the cylindrical tank which contains some amount of liquid in it.

So, the load cell will give me the weight of the tank plus the weight of the liquid contained in the tank and that weight happens to be 400 pound. The diameter of the tank is given; so, if I consider this to be tank its diameter is 20 inch if I consider that liquid level is h, then since the dimension of the tank is now given I can find out the volume of the liquid in the tank by pi d square by 4 into h.

So, this becomes volume of liquid in tank where d is the diameter of the tank which is given as 20 inch. If I multiply these quantities by the specific weight of the liquid which is given as 90 pound per feet cube; what I will get is the weight of the liquid. Now I also can get weight of the liquid if I subtract the weight of the empty container from the load cell measurement. Because load cell measurement is weight of liquid plus weight of empty tank; so, I subtract 50 pound from 400 firm to get the weight of the liquid in the tank. So, that I equate with pi d square by 4 into h into specific weight of the liquid. So, then I solve for h; so, this is a straightforward simple problem.

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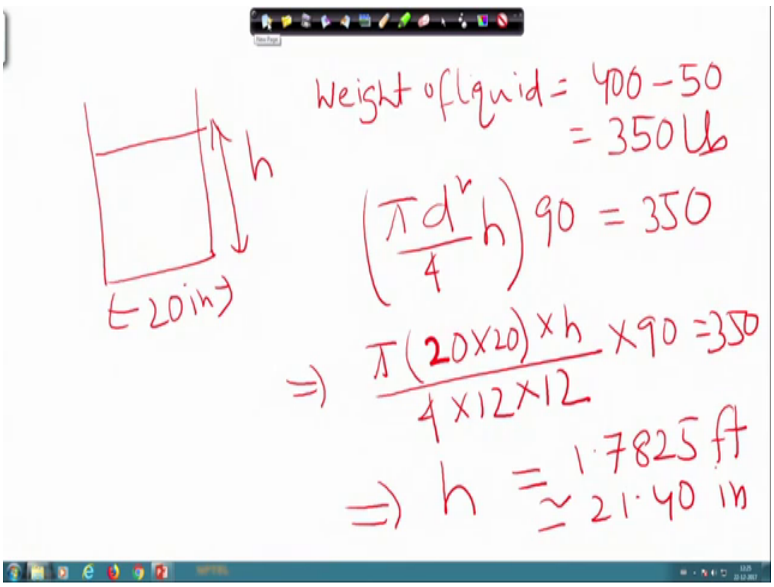

So, again if icon so I consider h as the liquid level the diameter is given as 20 inch, weight of liquid is 400 pound is the load cell reading which contains weight of liquid plus weight of container minus 50 pound which is given as weight of empty container. So, this will become 350 pound.

Now the volume of the liquid in the tank pi d square by 4 into h multiplied by specific weight will be equal to 350 pound. So, pi d square by 4 your d is 20 inch; so, 20 into 20 into h divided by 4 and it is expressed in inch. So, I have to divide by 12 square to convert it to 50. So, this times 90 is 350; so, now, you can easily solve for h and if you do it will be 1.7825 feet. So, if we multiply by 12 we will get as approximately 21.40 inch. So, that is the level of the liquid in the tank.

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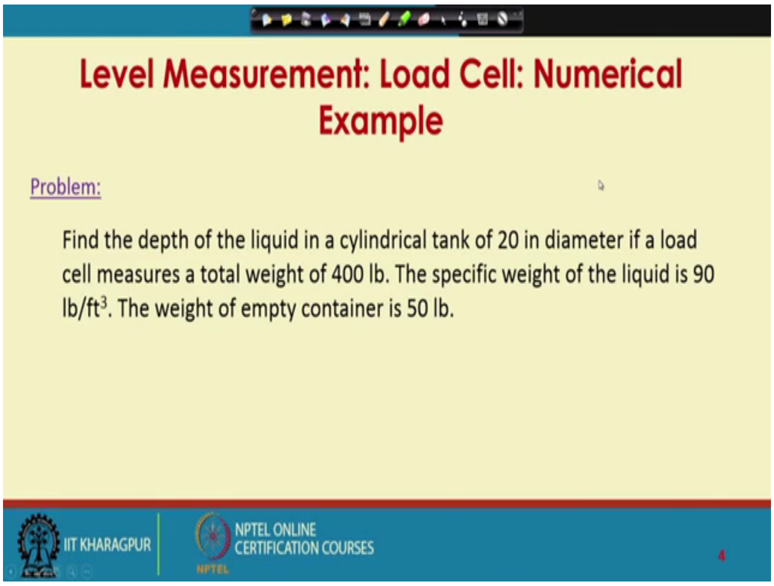

Now, let us move on to our next problem on flow measurement by rotameter. We have discussed about rotameter; rotameter measures volumetric flow rate if you multiply that by density of the fluid that is flowing through the rotameter you get the mass flow rate. So, we have discussed the rotameter is a variable area constant 8 meter. So, rotameter contains a float and the float changes its position with the flow rate from the position of the float we can measure the flow rate.

So, the problem is as follows a rotameter with an aluminum float is calibrated for metering a liquid of density 1200 kg per meter cube. And has a scale ranging from 1 to 100 liter per minute; the rotameter will now be used for meter metering the flow of another liquid of density 120 kg per meter cube with a flow range between 2 to 200 liter per minute. If the same calibration has to be used what will be the density of the new float? The density of aluminium is given as 2700 kg per meter cube, you can consider that the shape and volume of the new float and the old float are same.

So, basically there is an existing rotameter and which has a float made of aluminum the scale ranges from 1 to 100 liter per minute. Now I am going to use the same rotameter of course, is the different float I am using the same rotameter with the same scale to meter flow of another liquid with much less density; in fact, one tenth of the original density. So, the new fluids density or new liquids density is 120 kg per meter cube.

So, it is one tenth lighter than the previous one, but now I increase the scale range I in fact, double it the initial scale range was 1 to 100 liter per minute; the new scale range will be 2 to 200 liter per minute. If the same calibration has to be used what will be the density of the new float?

So, let us try to understand the problem we have a rotameter which is being used to measure the flow rate of a liquid whose density is 1200 kg per meter cube; the scale ranges is 1 to 100 liter per minute. Now I use some other process liquid whose density is one tenth of the previous one, but now I want scale range which is double the previous one. So, under this circumstance what will be the density of the new float, so that I can use the same scale that is attached to the rotameter.

So, the only change I will make is I will change the float. So, let us try to solve this problem what we will need to know is what will the information that we will need is the working expression for the rotameter.

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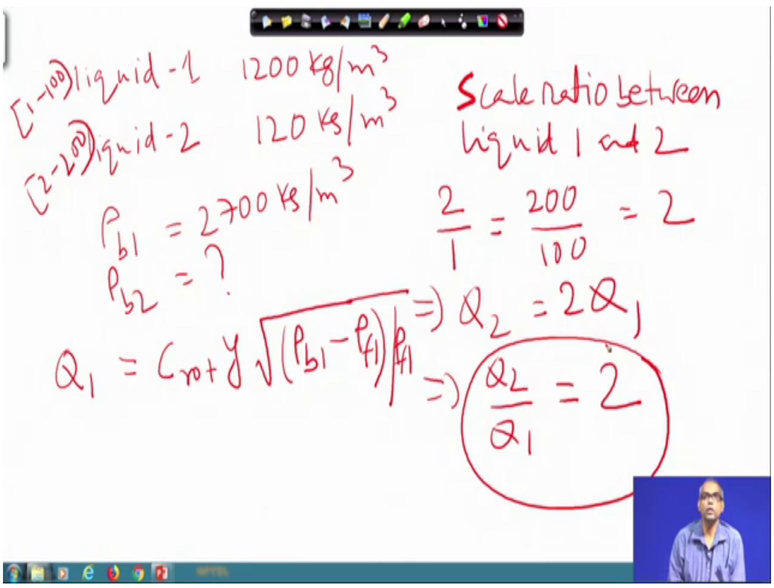

So, I have liquid 1 I have liquid 2; the density of the liquid 1 is given as 1200 kg per meter cube. The density of second liquid is given as 120 kg per meter cube, I have the density of the float 1 corresponding to liquid 1 as 2700 kg per meter cube; I have to find out the density of the new float b for bob or float right. So, now, the scale ratio between the liquid 1 and liquid 2 is what 2 by 1 is 200 by 100 equal to 2, this one for 1 to 100 and this one for 2 to 200.

So, what it means is Q 2 equal to 2 Q 1, where Q 1 is the flow rate of the liquid 1, Q 2 is the flow rate of the liquid 2 or Q 2 by Q 1 is equal to 2. Now let us remember that expression for the flow rate using rotameter what was the expression Q was equal to C rotameter constant, reading of the rotameter and density of the float minus density of the liquid divided by density of the liquid.

So, I will erase the screen so, that it becomes more clear let us remember that we have arrived at Q 2 by Q 1 equal to 2.

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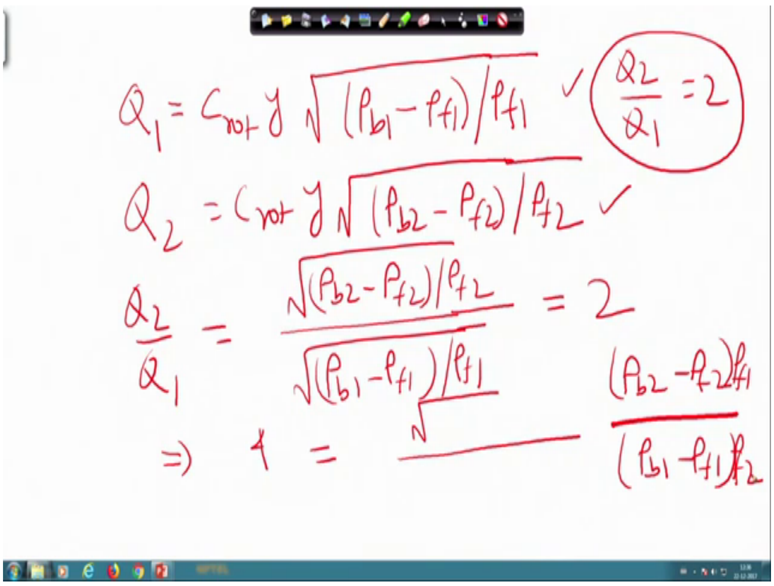

So, if you remember the flow rate expression for rotameter was Q equal to rotameter constant, y the rotameter reading density of the flow minus density of the liquid divided by density of the liquid. So, this was the expression for the flow through rotameter, Now I am using the I am using the rotameter for liquid 1 and liquid 2; so, let us apply this equation for the liquid 1 and liquid 2.

So, for liquid 1 I will use Q 1 I will use rho b 1, rho f 1, rho f 1. So, I want the same reading because the same calibration will be used. So, rotameter constant y I am not touching the remaining unchanged. So, the flow rate 2 will be C rotameter y rho b 2 minus rho f 2 divided by rho f 2.

Now if I take ratio I will get Q 2 by Q 1 and we will be able to equate it to 2; Q 2 by Q 1 we have found out on your previous slide as 2. If I do that you see that we know all other values rho f 1 we know, rho f 2 we know rho b 1 if we know. So, you have to find out rho b 2. So, if I do that Q 2 by Q 1 will be equal to this expression, this expression divided by this expression.

So, that will be rho b 2 minus rho f 2 by rho f 2, rho b 1 minus rho f 1 by rho f 1 this is equal to 2 because Q 2 by Q 1 equal to 2; so, if you square it both sides. So, what we will get is two square will be 4 equal to sorry this square root sign will go. So, what we will get is I will write here rho b 2 minus rho f 2 and here you will get rho b 1 minus rho f 1. And then rho f 1 will go and multi be multiplied with this and rho f 2 will come and get multiplied with this.

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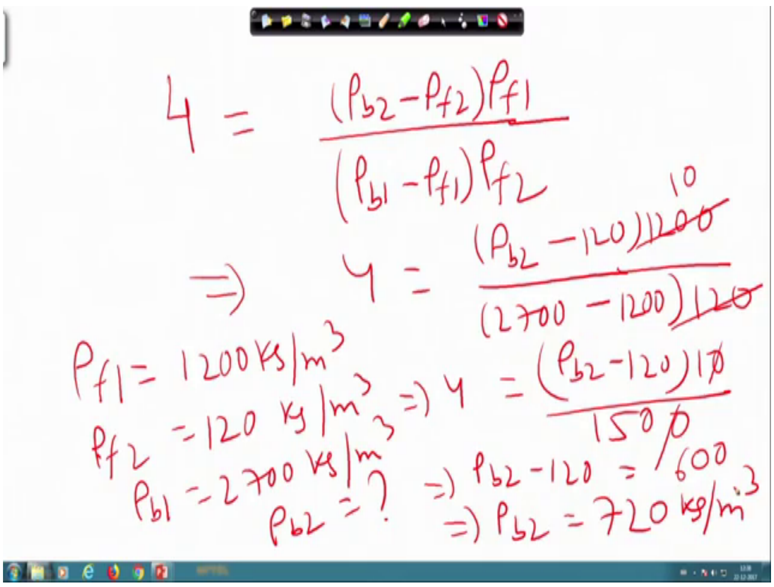

So, if I write again fresh what I am getting is 4 equal to rho b 2 minus rho f 2 multiplied by rho f 1 divided by rho b 1 minus rho f 1 multiplied by rho f 2. Now in this expression rho f 1; rho f 1 is given as 1200 kg per meter cube, rho f 2 is given as 120 kg per meter cube, rho b 1 is given as 2700 kg per meter cube I have to find out rho b 2.

So, everything is known here 4 equal to except rho b 2 everything is known rho f 2 is 120 rho f 1 is 1200 rho b 1 minus rho f 1 rho b 1 is 2700 minus 1200 into rho f 2 is 120. So, this will become 10; so, 4 equal to rho b 2 minus 120 into 10 by 1500; so, this also goes.

So, rho b 2 minus 120 equal to 4 into 150 which is 600 or rho b 2 equal to 600 plus 120 is 720 kg per meter cube; so, that is the answer. So, the density of the new float has to be 720 kg per meter cube. So, then you see that we have kept y unchanged that is rotameter reading unchanged. So, the same rotameter with the new flow, but the same existing calibration scale can be used.

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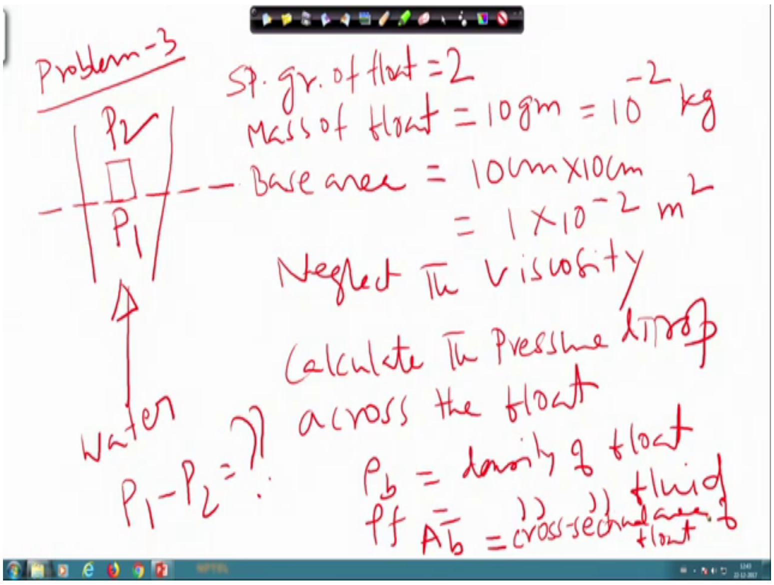

Now we will see another problem on rotameter; now let us consider again a rotameter another problem number; now 3 we have a rotameter let us say this is my flow a square specific gravity of the float is given as two mass of float is given as let us say 10 gram. So, which is 10 by 1000 kilogram; so, 10 to per minus 2 kilogram. Base area of the float is also given as let us say its 10 centimeter by 10 centimeter which is 1 into 10 to the power minus 2 meter square.

Neglect the effect of viscosity there; calculate the pressure drop across the float. So, consider this line let us say the water is flowing through the rotameter the pressure here is P1 the pressure here is P2 and I need to find out P1 minus P2 is how much ? So, that is the problem; you have a float with a square base 10 centimeter by 10 centimeter.

The mass of the float is given as 10 gram or 10 to the minus 2 kg, the specific gravity of the float is given as 2, water is flowing through the rotameter; I want to find out the pressure drop across the float. So, let us consider rho b as density of float and rho f as density of fluid. Also let us consider A b as the cross sectional area of the float. So, cross sectional area of float. So, rho b is the density of the float, rho f is the density of the fluid that is water and A b is the frontal area or cross sectional area of the float.

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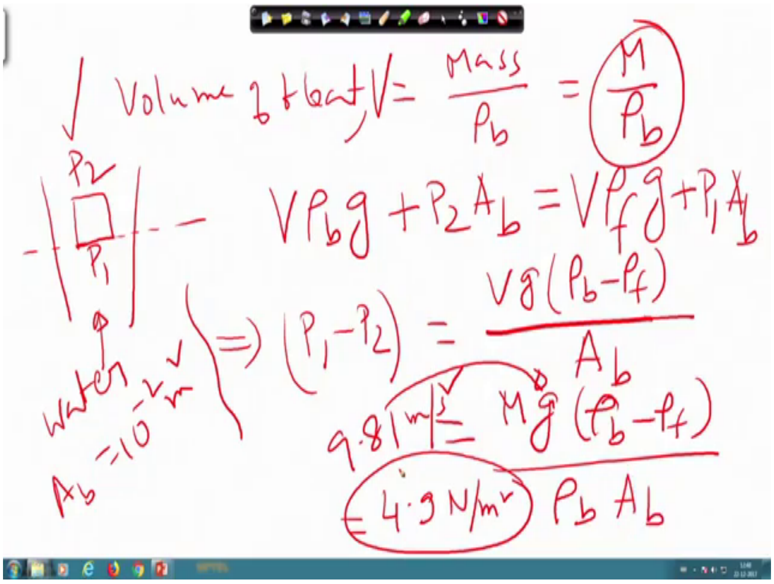

So, volume of the float I can find out because mass is given. So, mass divided by density of the float material let us consider mass as M density is rho b. So, volume of the float is this now what I will do is we will write down the balance equation, the force balance equation upward forces equal to downward forces.

V which is the volume of the float rho b into g; so, this is the mass of the weight of the float acting downward plus P2 into A b; force acting downward is equal to buoyancy force acting upward volume of the float that much of volume of water will be displaced rho f is the density of the fluid or water into g plus P1 into A b upward force.

So, from here we can rearrange this as P1 minus P2 is equal to V rho b g minus V rho f g divided by A b. So, V g common rho b minus rho f divided by A b. V; I can replace using this. So, this will become M into g rho b minus rho f to rho b A b. Now look at this expression we know all the informations; g is 9.81 meters per second square, density of the float specific gravity is given rho f density of the fluid or water it is known quantity.

A b is the area base area given 10 centimeter by 10 centimeter or 10 to the power minus 2 meter square. So, everything is given; do, if you put all these numerical values this will become 4.9 Newton per meter square. So, the pressure drop across the float is 4.9 meter square.

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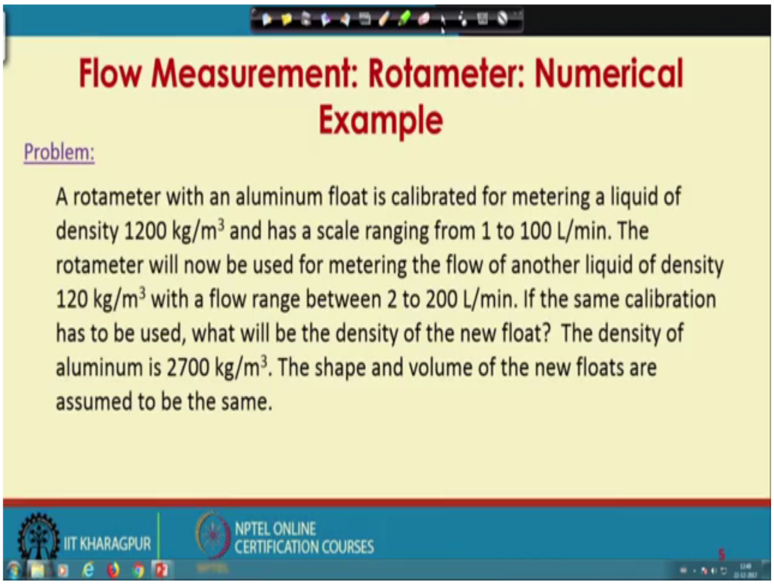

So, today we have seen three different problems one on; one on rotameter; two on meter and one on load cell.

So, we will stop our discussion on level measurement here.