Industrial Instrumentation
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Lecture - 13
Flowmeter - II

Welcome to the lesson 13 of Industrial Instrumentation. We will continue with the flowmeters. So, in the lesson 12 also we have seen the flowmeters, because as I told you earlier, that the flow, the, the variety of the flow, I mean the variety of the instruments for measuring the process parameters like flow is, are the huge in number. So, what we have to do? We have to cover lot of sensors; unlike the temperatures and pressure level, very few number of sensors are available. But, due to the varieties and the environment conditions, the number of flowmeters are quite large in number. So, this lesson 13 also is for the flowmeter. So, we have given the name Flowmeter II.

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You see here, the contents of this lesson is Pitot tube, which is extensively used for, not only for the flow measurement, also for the velocity measurements. If I can install and it is basically mostly used for the, not for the liquid, but for the gas. Even for high speed vehicles also I can use this for measurement of the speed of the vehicles by using the

Pitot tube. One of the common, I mean applications of the Pitot tube is the aircraft, the speed measurements, where in high altitude, so the, there is a differential pressure and another important thing this Pitot tube as well as, as well as the elbow meter which is next, you will find basically depends on the differential pressure measurements.

We have seen that differential pressure, differential pressure measurement technique is utilized in the case of orifice meter and Venturi meter. So, in Pitot tube and elbow meter also, you will see that we will use the same principle. That means there is a differential pressure and that pressure is calibrated in terms of flow, flow velocity or the volume flow rate. So, the contents are Pitot tube, elbow meter, then rotameter is another example, but rotameter as you know, it is a, it is not the differential, it is not the flowmeter. It depends on the, based on the differential pressure measurement, it is basically variable area meter. So, that we will discuss in detail how it works actually and also we will solve one problem on the Venturi meter. So, the differential pressure meters, so either Venturi or orifice, so in this particular lesson we will consider one problem on the Venturi meter, right?

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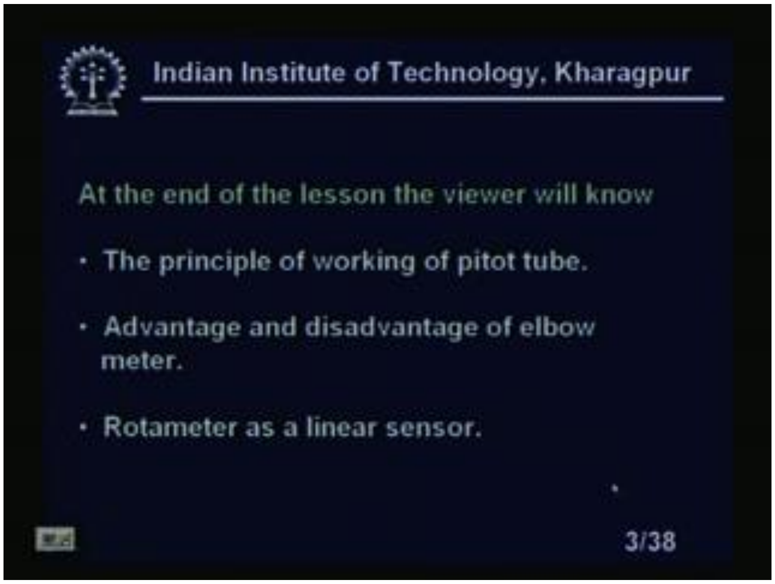

So, at the end of this lesson, the viewer will know the principle of working of Pitot tube, advantages and disadvantages of elbow meter, also its principles also we learn in this process. So, principle is common. Principle of working of Pitot tube, I mean elbow meter, your rotameters, everything will be, all will be discussed here. But also we will discuss advantage and disadvantage of the elbow meter. Also we, we will see that rotameter can be used as a linear sensor that is a great achievement, because in most of the differential pressure, in all differential pressure measurement based flowmeter, you will find its relation between the flow and the differential pressure is non linear, so which creates a problem. So, we need some other circuitry to linearize, which is not necessary in the case of rotameter. Though it is usually used for very short range of flow measurement, range is not much, right?

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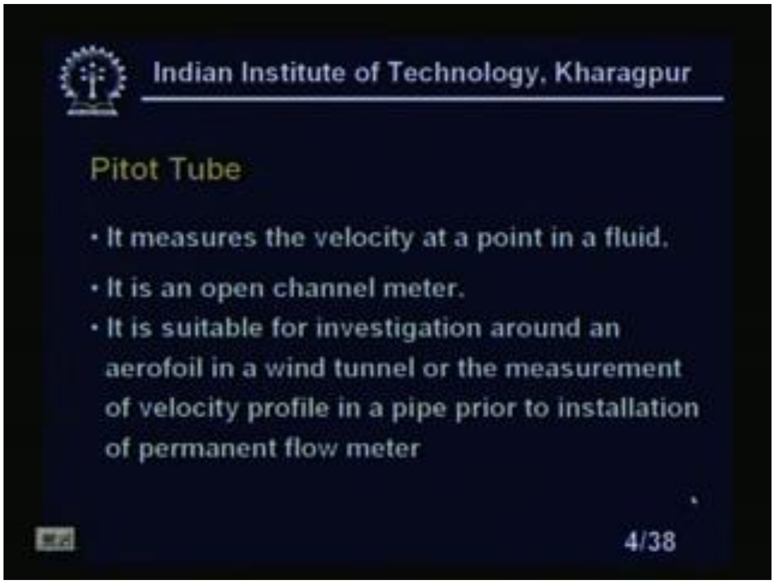

So, Pitot tube, you see, it is like this. It measures the velocity at a point in a fluid, right? That means, it will measure particularly velocity at a point. Unlike the, unlike the orifice meter and Venturi meter which measures a, over a area, I mean, if you look at the, along the pipe, if you go along the pipe, so but the Pitot tube basically measures the velocity at a point, particular point in a fluid, right?

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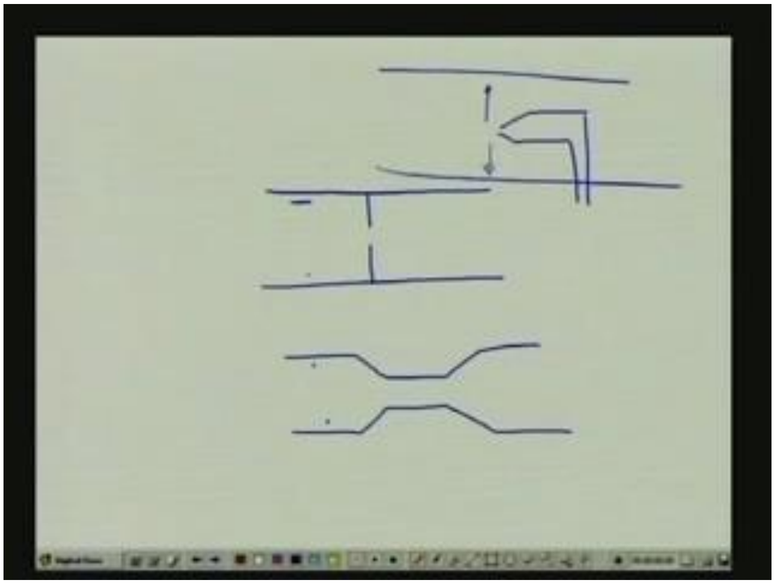

So, this is very important that means what I am saying, here you see if I have, if I take a white board, that means what I am saying that if I have a pipe, you have seen that in the case of orifice meter or if I have a, in the case of Venturi meter we have seen, so it is average the velocity at the whole point. So, it is like this only, it average the velocity. If I am interested by the Pitot tube, if I am interested to measure the velocity, suppose at this point of the fluid or at this point of the fluid or this point of the fluid or this of the fluid that is not possible by Venturi or orifice meter, right?

But, it is possible by the Pitot tube and another important thing is it is an open channel meter, it is not closed. So, you can use it as a closed channel meter, but you can use it as well as open channel meter. That means I have a tube what we actually do we will discuss in details. So, this tube is installed inside the pipe. Suppose this is a pipe, so depending on installation, I can move it little up here in this here or I can move it down. So, I can, at a particular point I can measure the velocity of the fluid, right, like where this is also an open channel meter, but we can use it as a closed channel meter also.

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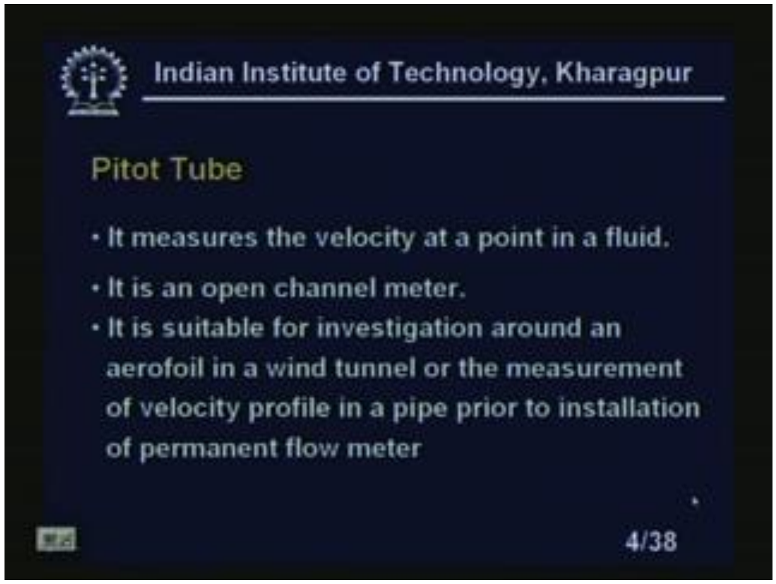

It measures the velocity at a point in a fluid. It is an open channel meter that I told you. It is suitable for investigation around an aerofoil in a wind tunnel or the measurement of velocity profile in a pipe, prior to the installation of the permanent flowmeter. Sometimes, some estimation is necessary. That means how much is the flow, I mean before I mean installing your flowmeters like Venturi meters or orifice meter or … tube and flow nozzles, so we need some estimation. So, in that type of situation, Pitot tubes can be easily inserted and take the measurement, because you know that in the case of orifice meter, Venturi meter, it is a very cumbersome device, it needs a lot of time for estimation. This is not, you cannot spend that much amount of time, neither what will allow to disturb the, the installation.

But, by using the Pitot tube you can overcome that type of difficulties; that I can estimate. As well as I can measure quite accurately the flow, flow velocity or flow measurement. You can see, there in the case of Venturi meter and orifice meter also we are actually measuring the velocity, then we are multiplying the area of cross section, finding the, finding the total volume flow rate. Here, we will find the velocity, then with the area, if you, of the cross session of the pipe if I multiply, obviously you will also get the volume flow rate.

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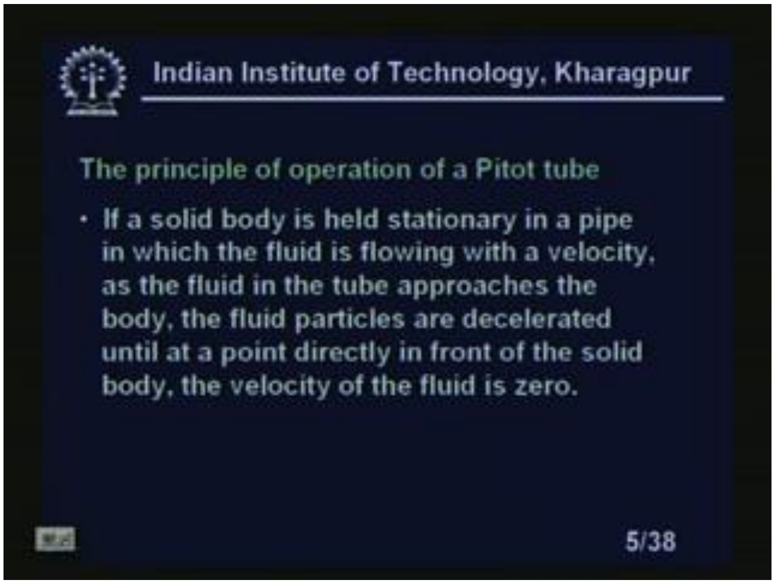

The principle of operation of a Pitot tube is like this. If a solid body is held stationary in a pipe in which the fluid is flowing with a velocity, as the fluid in the tube approaches the body, the fluid particles are decelerated and until at a point directly in front of the solid body, the velocity of the fluid is zero, right? What does it mean? Let us take a blank page, then it will be more clear.

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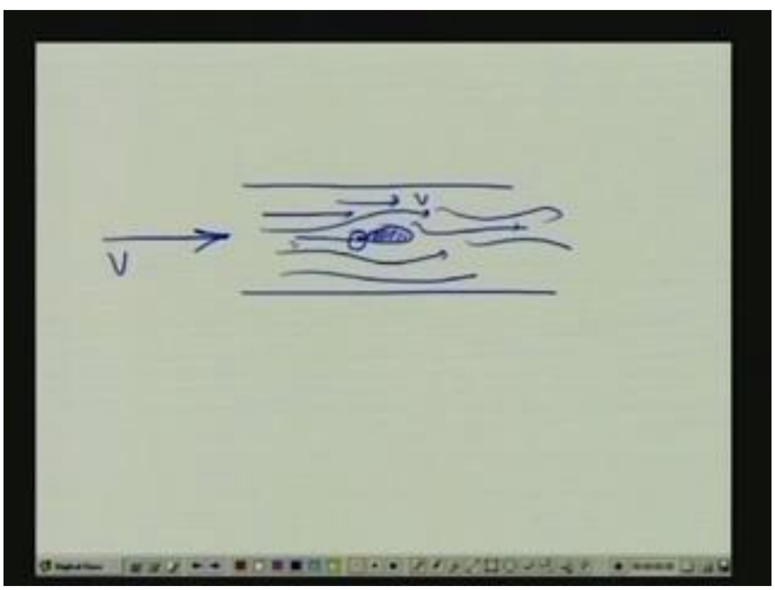

See here, so what I am saying, suppose a fluid, I have a pipe and liquid is flowing through this, right? Now, I put an object, suppose like this one, a solid object, then what will happen? See, here the liquid will flow; flow in this direction, flow in this direction, all this direction? What will happen to the flow which is coming to this, hitting this portion? It is coming to rest at that position. Supposed to be the, if it is raised the pressure will be very high compared to the pressure of the fluid here, right? So, that means the liquid which is coming to the rest in contact, so liquid, so what will happen? The fluid will be decelerated.

When it is approaching this solid body, suppose if I take, this is the solid body, fluid, the fluid will be decelerated. So, at this point, it will be total stop, totally stopped. So, the velocity of the liquid at this point will be zero exactly, identically zero and the velocity of the fluid, suppose this is V, so this liquid is also flowing with the velocity V, then it is flowing out. Again it is flowing out, right? But, whenever the fluid is flowing here, so obviously the, just in front of this one, if we look at here, at this position the fluid will come to rest. Using this principle actually people developed the Pitot tube, right?

Just take the, so again I will repeat.

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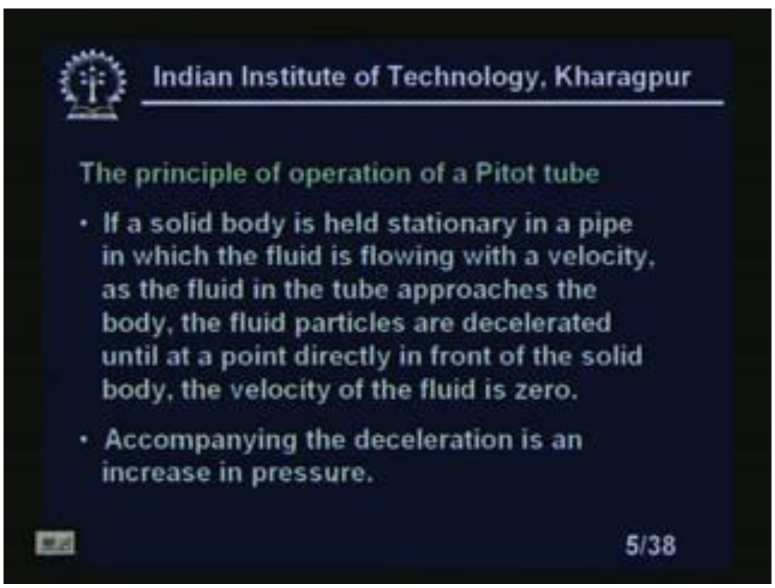

If a solid body is held stationary in a pipe in which the fluid is flowing with a velocity, as the velocity in the tube approaches body, the fluid, that solid body, obviously this is the pipe and the solid body, the fluid particles are decelerated until at a point directly in front of the solid body, the velocity of the fluid is zero, velocity of the fluid is zero, right? So, accompanying the deceleration is an increase in pressure, right? That means whenever I told you earlier also that means what will happen?

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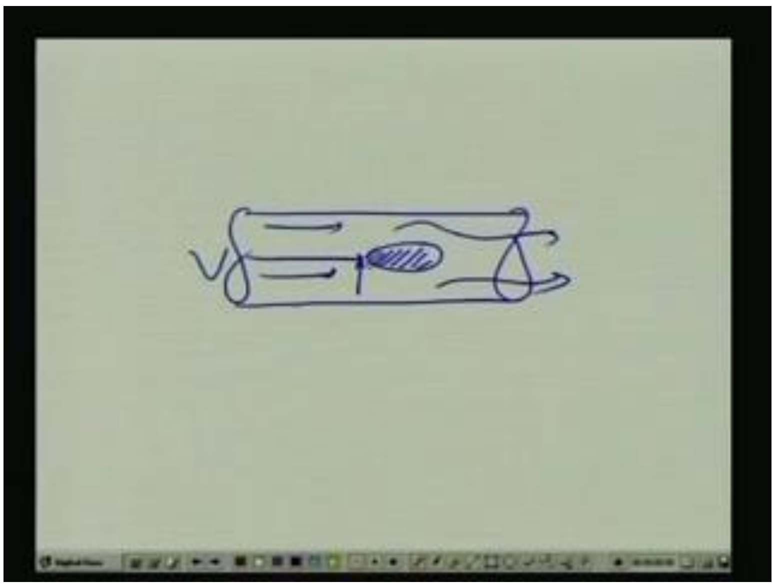

That means I have a solid body here. Again, I am telling, so liquid is coming and hitting here, so velocity at this point is zero, right, velocity V, it is flowing, right? This is a pipe, pipe is flowing, so what will happen here? I will take a new page.

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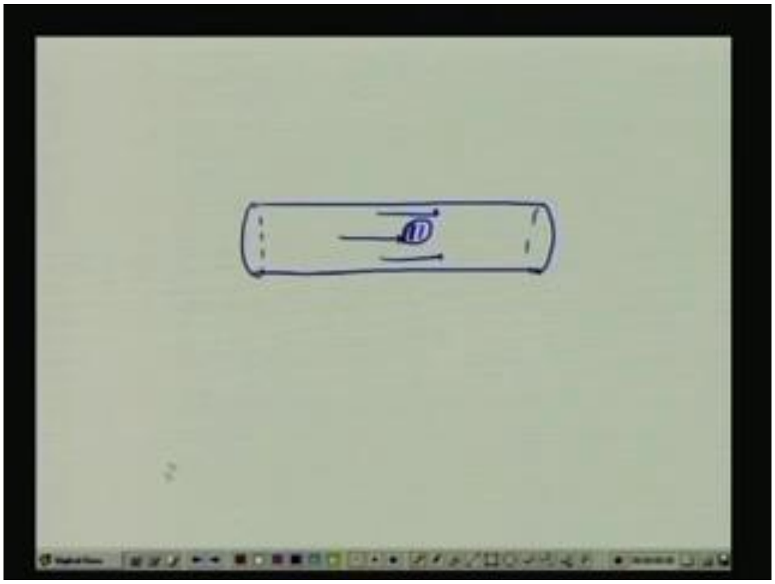

So, like this one, it is flowing like this, right? So, what will happen, you see here. So, I have a solid body, so which is coming and coming to …. So, the pressure at that point will be high compared to the or highest I should say, compared to the fluid, I mean static pressure here, right? So, accompanying the deceleration is an increase in pressure.

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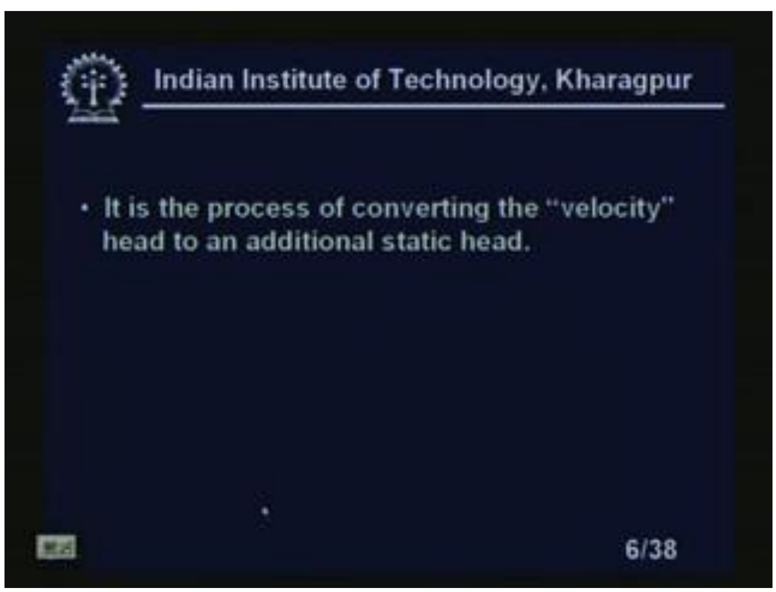

So, it is the process of converting the velocity head to an additional static head, right? We are calling it head, because it is a, basically if we look at, it is basically we are, we are writing the equations in terms of the liquid head, right? That is the reason we have to, because I mean if the pressure is, as you know, hdg if you divide by density and the acceleration due to gravity, so obviously it can be expressed in terms of only the height. That means assume the liquid, the pressure is usually defined by this one, is not it?

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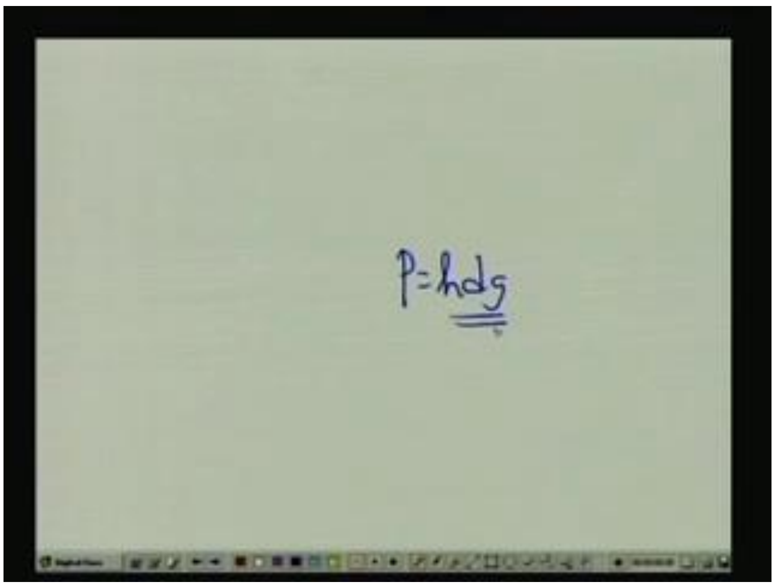

P equal to height into d into g. So if you express it, if you multiply it, I mean divide by d and g, obviously I will get a, if I write the Bernoulli's equation only in the, sorry, only in the case of, in the terms of height, so it will be all in, I mean head. So, that is the reason sometimes we call it head.

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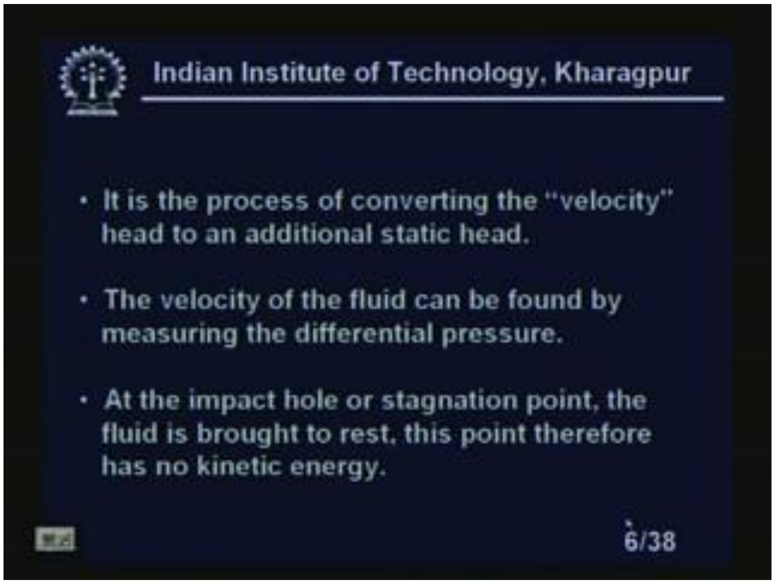

It is a process of converting the velocity head to an additional static head, right, because additional static head is coming, velocity is becoming zero, the pressure is increasing, so that head is also increasing. The velocity of the fluid can be found by measuring the differential pressure. Again, the same principle, because this also depends on the, basically the principle of work depends on the measurement of differential pressure. At the impact hole or stagnation point, the fluid is brought to rest and this point therefore has no kinetic energy, right? If the velocity is zero, obviously that what is the kinetic energy? Half MB square; if the velocity is zero, the kinetic energy also will be zero, right?

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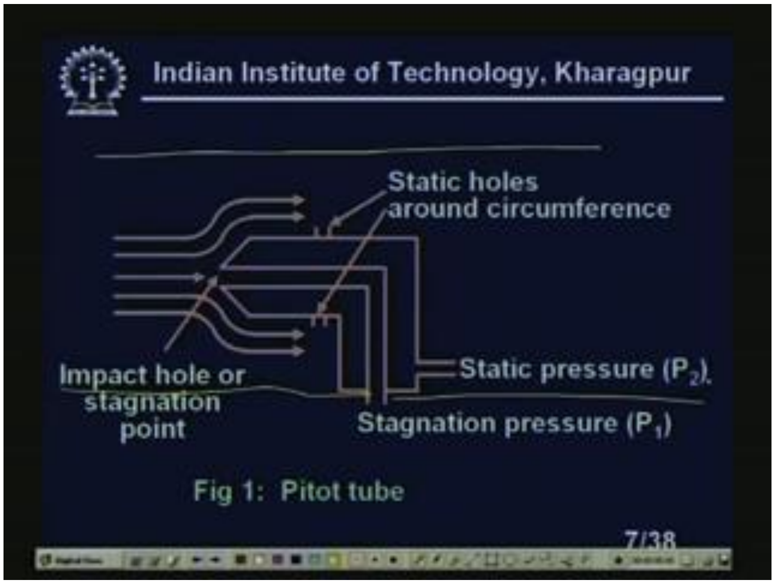

So, here you see the, a Pitot tube. Look at very carefully. Right? So you see, this is the Pitot tube, our liquid is flowing. It is installed in a pipe; I am not showing the pipe, so pipe will be there, right, pipe will be there, so and inside, the pipe it is going. If I take a different colour pen, so it is installed in a pipe. Please note, always installed in a pipe, right? So, this impact hole should be always in a direction opposite to the flow. Flow is, flow in this direction, so directly it is impacting here. So, it is to be installed in a direction where this that means I am saying like this one. If I can see the camera here like this one, you see the, this is Pitot tube suppose, right? So, this is our static hole, right, impact hole or stagnation point I should say, so what will happen here? See, the liquid is flowing here and hitting this position, right and liquid is flowing over this one. So, there is a hole on this, on this side. This side there is a hole. The fluid is flowing in this direction and it is going out. So, liquid is, I mean this, it is impacting here, so there is a point where the velocity of the fluid will be zero. If we consider this as solid body, so velocity of the fluid at this point will be zero, kinetic energy will be also zero. But, there is a pressure ….. inside the pipe also. That pressure we are calling it static pressure, right?

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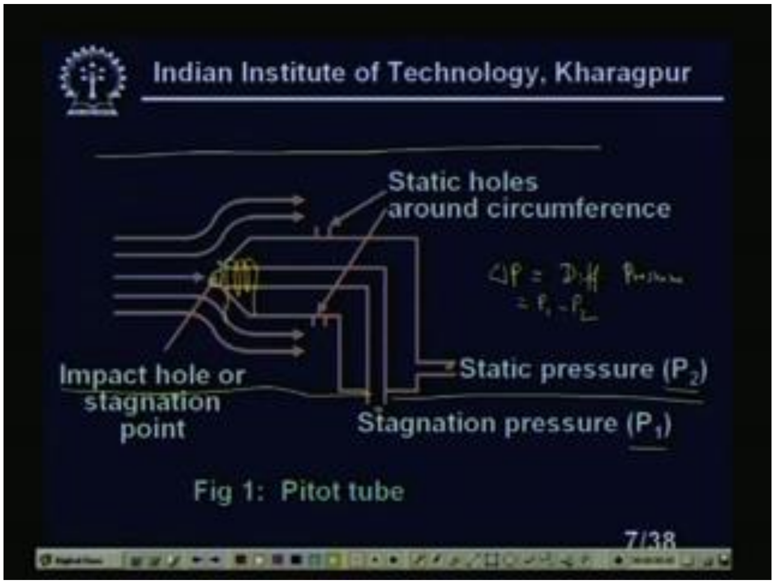

Fig 1: Pitot tube

And this pressure, the pressure at this one will be the stagnation pressure so obviously the stagnation pressure see the velocity is zero will be much higher than the static pressure right

so this static holes usually can be collected as it happens in the case of Venturi meters this static holes can be this static pressure can be sense by physio meter rinse that means it is averaging the ah pressures and this impact hole stagnation pressure we can be measured by if i just take out one hole here and take it out

so these two will give you differential pressures right this minus this this pressure P one minus P two will give you the differential pressure as a flow velocity increases P one will increase obviously delta P will increase what you have to see the delta P differential pressure [Noise]

so this is equal to P one minus P two right [Noise] so this P one minus P two so this is {stag} (00:16:17) this pressure differential pressure so this is our stagnation pressure so the {vel} (00:16:21) of velocity increases P one will be also increase

so delta P also will increase right so this way so this by measuring this differential pressure so i can calibrate this in terms of flow velocity right and if i know the area of cross sections of the tube where it is installed that Pitot tube i can measure the volume flow rate or if i installed on a some moving body this entire Pitot tube is install and a moving body is like an aircraft obviously what will happen you know that um having measure the aircraft velocity

(( )) (00:16:57) velocity of any vehicles also only thing the problems we need a (( )) (00:17:01) flits because if the there is a if there is a this hole is the this is small hole you can see here if this hole is clot by some particles or dust

so that will give us error in reading right that is happened actually in the case of aircraft as you know when it goes to {lar} (00:17:17) i mean huge height

so as you know the goings and all this things they are going very height and around thirty three thousand feet three thirty five thousand feet at the situation there is a ah ice formations and the stagnation point then what they do they put a heater coil around this one right

so continuously is melting that ice so there is no question of entiting erroneous reading so the flow can be calibrated in terms of actually measuring the differential pressures i can measure the flow velocity or the velocity of the {vehi} (00:17:48) vehicles and aircraft on which it is installed lets go back theory again [Noise] right

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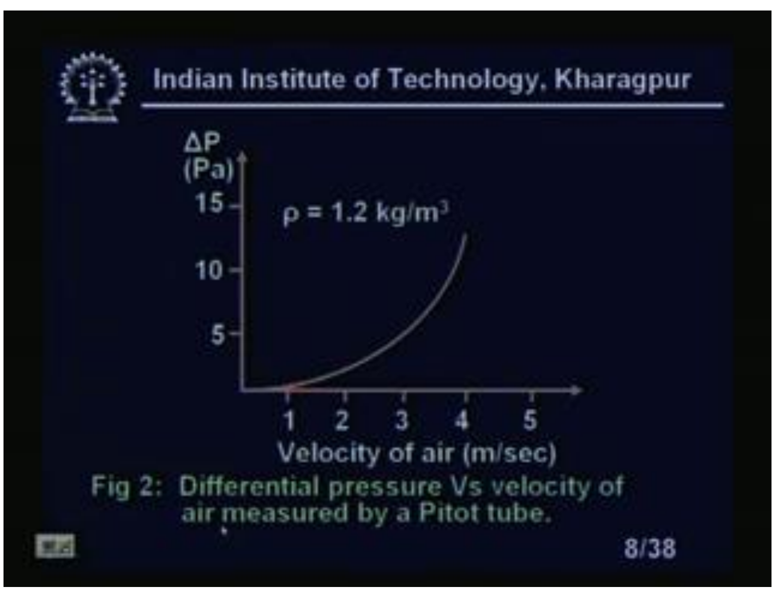

now this is the you see the this relation between the velocity of a air passes the differential pressure right x axis we have plotted the velocity of air and y axis we have plotted the differential pressure delta P which is in Pascal and velocity air is in meter per second and density of one point two kg per meter cube and differential pressure versus velocity of air measured by Pitot tube right

so this is the figure as you can see we will give some calculation is non linear in nature you can see okay

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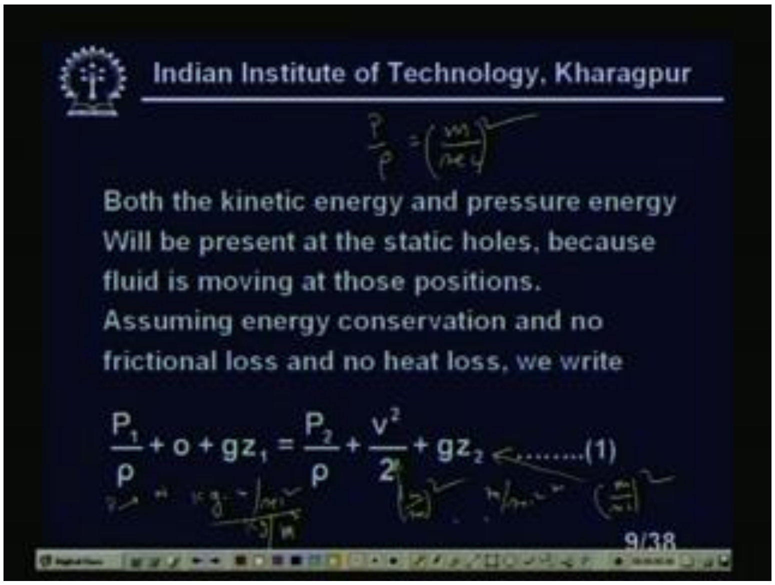

so this creates a problem both the kinetic energy and the pressure energy we will present at the static holes because fluid is moving at those positions right [Noise]

assuming energy conservation and no frictional loss and no heat loss obviously we can write P one by rho zero gz one P two by rho plus V two square by two into gz two

you can look at very carefully all the units of this one will be in you see here that reducing if i take meters or seconds square right so g will be ah z will be in meter

so it will be meter per second whole square this one this also will be meter per second square right P two it can be as a pressure so Newton per meter square right so if you ah if you simplify this one suppose this Newton's in kg P is in Newton right

so it means ah it means that ah P is in Newton means signifying that is a kg meter per second square so if you divide by rho that is kg per meter cube again it will be so this P by rho will find will be in meter per second square right

so it will be like this right so all the units are same units of which item will be same because this is the there is no velocity of the ah velocity at the stagnation this is a stagnation part the Bernoulli's equation is applied at the stagnation point this is the Bernoulli's equations apply at any other point of fluid right

here P one is a stagnation pressure P two is the static pressures (( )) (00:20:57) the z one is the elevation of the static i mean stagnation point and z two is the elevation of the your static point right if we have this slide we can go to the next slide [Noise]

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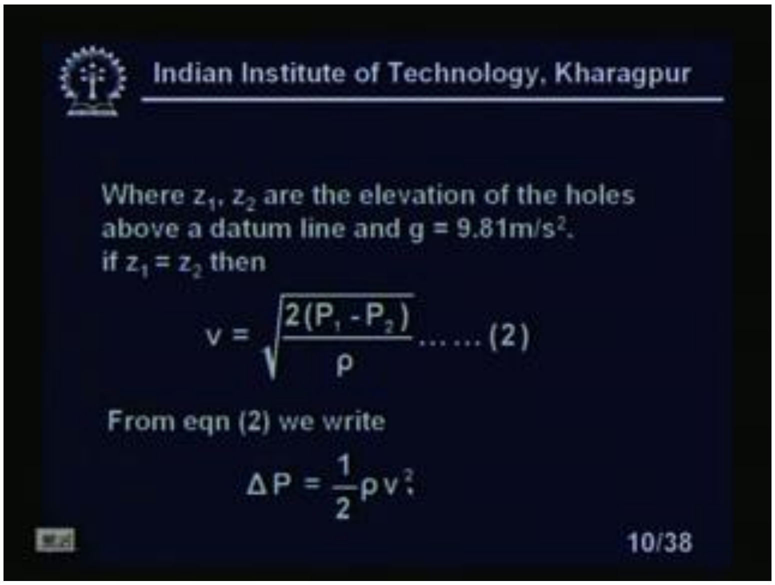

so where z one z two are the elevations of the holes above the datum line and g is the acceleration due to gravity which is nine nine point eight one meter per second square and if z one equal to z two then we can simply write v equal to two P one minus P two rho so this equation number two

now whether the rho varies let us look at that now from equation two we can write delta P equal to so this is delta P delta P equal to ah v square into rho divided by two isn't it differential pressure equaled half of rho v square

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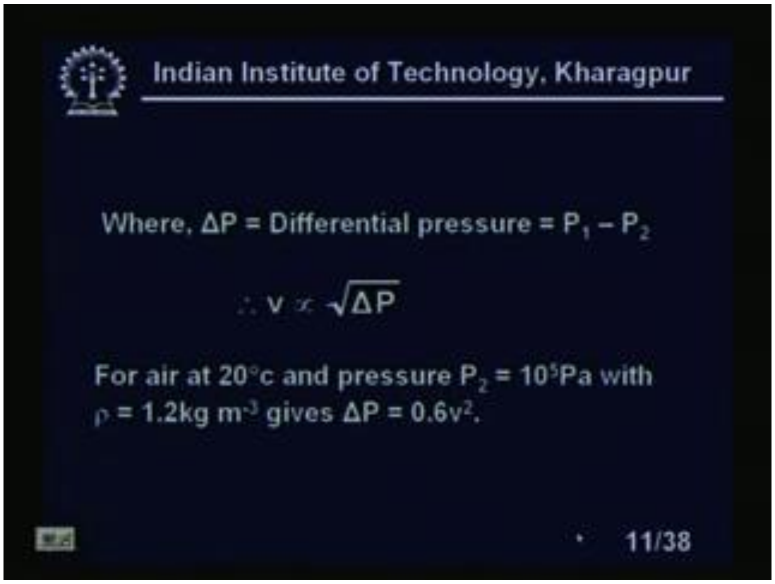

where delta is a differential pressure P one minus P two so v obviously i can see here you can see this most important equation count for all differential pressure from it you can see this is v equal to v proportional to [Noise] root over delta P right

so delta P if you calibrates in terms of v obviously there is non linear relationship right [Noise] so for air at twenty degree centigrade and pressure P two of ten to the power of five Pascal that is static pressures and i am talking about with rho equal to one point two kg per meter cubed gives delta P equal to point six v square

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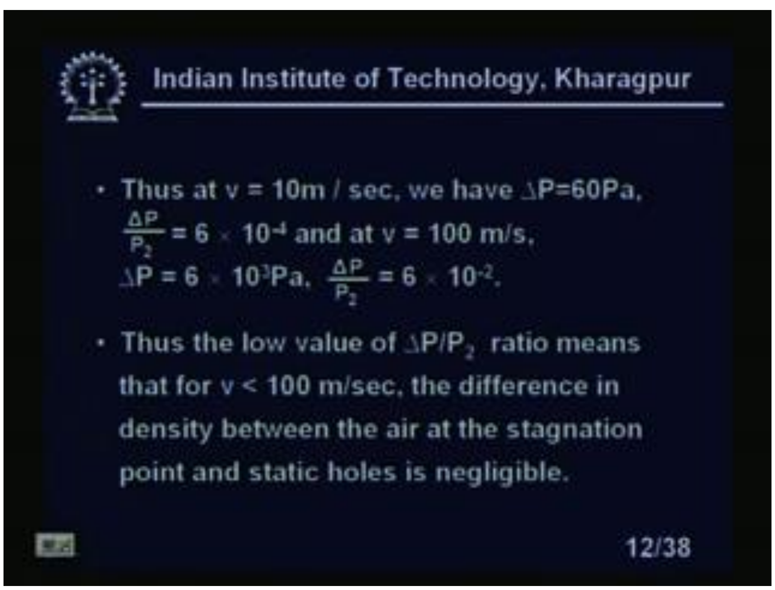

thus at v equal to [Noise] ten meter per second we have delta P equal to {sixteen} (00:22:38) sixty Pascal and delta P by P two equal to six into ten to power minus four and at v equal to hundred meter per second delta P equal to six into ten to the power three Pascal's and delta P by P two into six into ten to the power minus two

what does it mean it means the when the flow velocity ah the this the low value of delta P by P two ratio means that for the velocity less than hundred meter per second hundred meter per second is quite fast and quite high speed right

that mean the difference it's a extremely high speed hundred meter per second right the difference in density between the air at the stagnation point and static holes is negligible right

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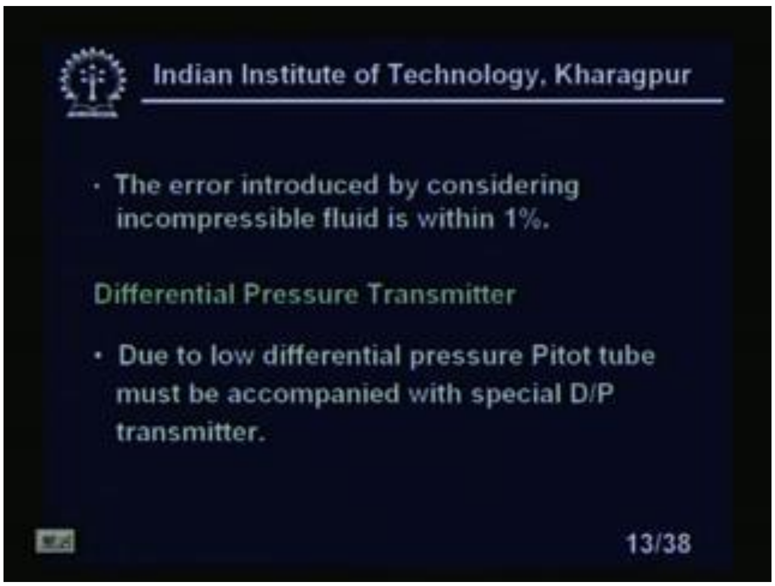

the error introduced by considering the incompressible fluid is within one percent right now differential pressure transmitter is a special type of {difren} (00:23:32) differential pressure transmitters is necessary for ah particularly in this case due to low differential pressure because if the ah if the fluid {velo} (00:23:45) fluid is actually air gas

so the differential pressure also will be less because ah as you know the differential pressure also depends on the density of the fluid right so the air as a lesser density so due to low differential pressure so the your differential pressure also will be low

so we need some more sensitive differential pressure sensing element because this differential pressure first you will sense and before converting to the electrical domain that is four to twenty milli ampere of current domain i need some ah i need some high ah i {nee} (00:24:18) i need some higher pressure higher differential pressures right so i need some more sensitive ah i mean this type of system which will convert this ah your differential pressure to some other change like capacity change or any other change displacement change that can be converted in the electrical current domain of four to twenty milli ampere

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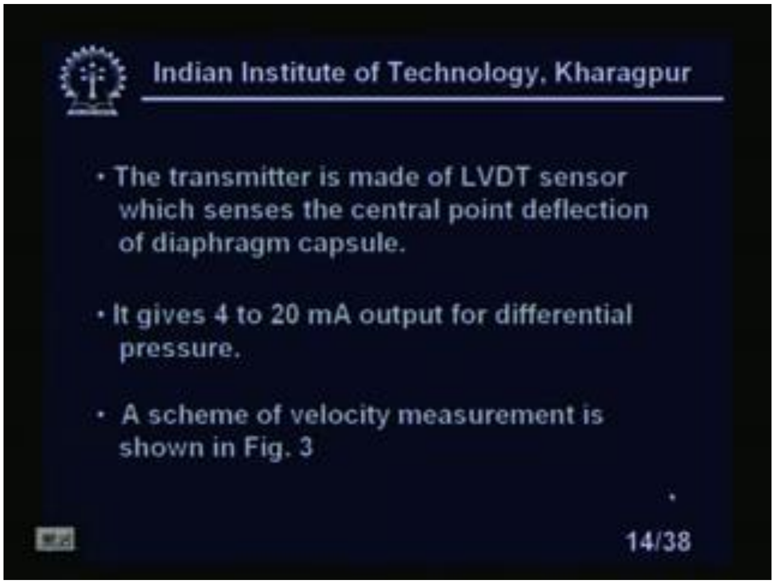

so it gives a four to twenty that voltage LVDT unbalanced voltage that means the secondary voltage which is in positions can converted easily to the current domain of four to twenty milli ampere output for differential pressure

a scheme of velocity you see everywhere its likes this one you have seen that in the case of this LVDT having the case of this flow measurement also what is a minimum flow that must be described right what is maximum flow that also in the process it is fixed

so what will do will accordingly we will fix of four to twenty milli amperes so the calibration is most important all the calibers so for the minimum flow velocity we must get four milli ampere of current for maximum flow velocity we must get it twenty milli ampere of current

accordingly our electronic circuit that converter which will convert because always you know that ah there are many simple circuits are available for to convert this type of signals voltage to current signals right

so depending on the whether you suppose have a zero ten volt accordingly for zero volt i want four milli ampere for ten volt i want twenty milli ampere so that type of things can easily made right so similarly here also instead of suppose zero volt i have a input voltage (( )) (00:25:50) output sign getting suppose ah ah zero two five volt no problem

see if it is zero to five volt accordingly i can set my circuit some reference voltage raised terms by which i can make four to twenty milli ampere of current right now scheme of velocity measurement is shown in figure three

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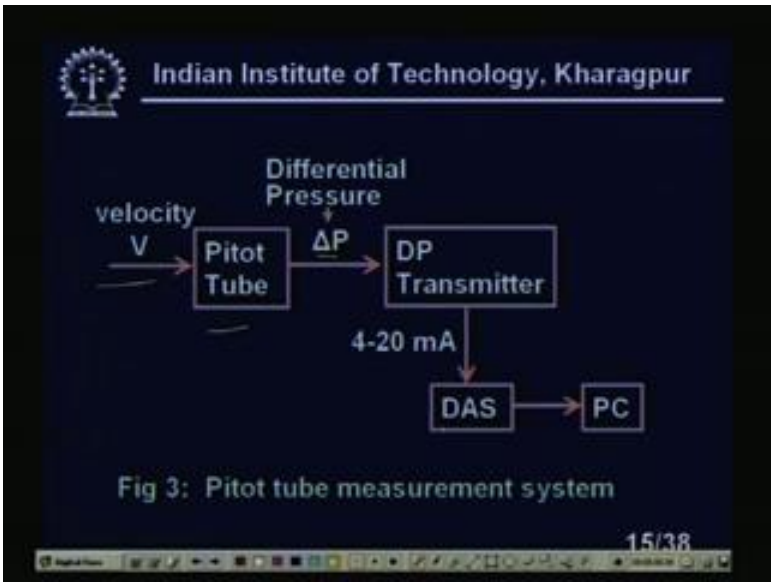

you see here that you can see here the input is velocity v right i have a Pitot tube i am getting into differential pressure of delta P so i have DP transmitter so DP transmitter is basically here not capacitive it is a heavy duty based in four to twenty milli ampere of current is coming we have data acquisition system

and we have PC data acquisition system is obviously it will convert this current to the voltage domain then it is digitizing it before we giving feeding to the {p} (00:26:42) PC where i can record the the flow velocity and if i have to take some action that means i have to feed back suppose this PC output through that data acquisition card again can go back to the control one to reduce the flow

ultimately the what is a use of this Pitot tube and all this things i have to set some already the pre prescribed the this much of oxygen will flow this much of hydrogen will flow in the pipe so to set that so i have to measure this i mean velocity then if feed it back to the some control valve so that by which it will either open or close to keep to being flow velocity to the prescribed level right

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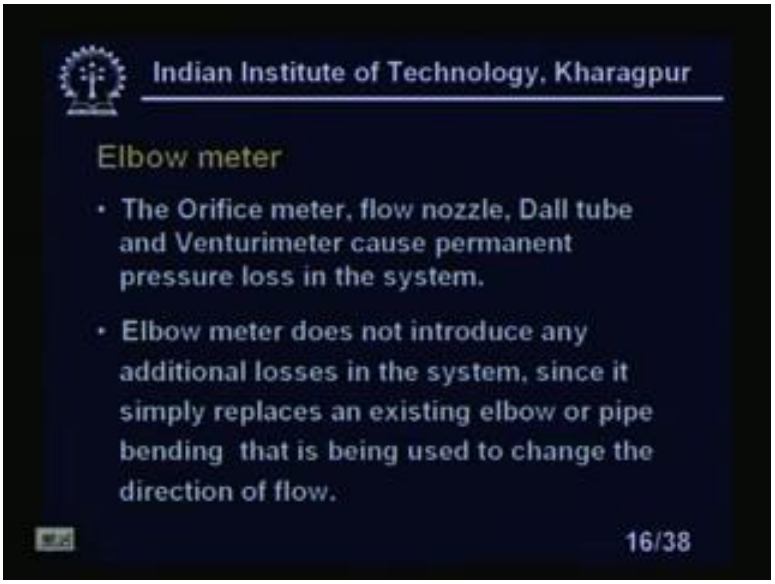

now elbow meter ah with this ah elbow meter is a different kinds of system it is actually usually used in a huge installation of the pipe is not is not suitable for the small bending of pipe so for the large bending of the pipe

now in all the cases except Pitot tube Pitot tube usually used for the gas you find that ah you will find that the there is a large differential pressure and and and there is a loss permanent loss have the permanent loss in the both in the case {or} (00:27:55) orifice meter or Venturi meter

in the case of orifice meter we have seen that this loss is more in the case of Venturi meter permanent loss is more in the case of Venturi meter we have seen the permanent loss is less

now aerometer is an instrument its also based on the differential pressure measurement but that permanent pressure loss is not there

but in fact it is there in fact not in that way because whenever there is a pipe bending there is a pressure loss as you now head loss is their so utilizing that principles without having any addition loss for the installation of the installation of the ah meter we can have a elbow meter let us look at what is that the orifice meter flow nozzle dall tube and Venturi meter we have seen cause permanent pressure loss in the system this will create permanent pressure loss in the system right all this flow nozzle dall tube less or more so obviously it will make some permanent pressure loss

we have seen that in the case of Venturi meter there is a i mean there are different types Venturi but long short in the long we are much {be} (00:29:05) better pressure recovery the short we have less pressure recovery in the case of orifice meter pressure recovery is watts right aerometer does not introduce any additional losses in the system send it

simply replaces and existing elbow or pipe bending that is being used to change the direction of flow right in a process we will find the always you need this type of things i am need some pipe bending somewhere okay

because pipe cannot all pipe cannot be straight in the process so you find a some there is pipe bending so in that bending will install that meter

so that no additional loss will be there [Noise] so aerometer does not introduce the any additional losses in the system since its simply replaces and existing elbow or pipe bending that is being used to change the direction of flow right

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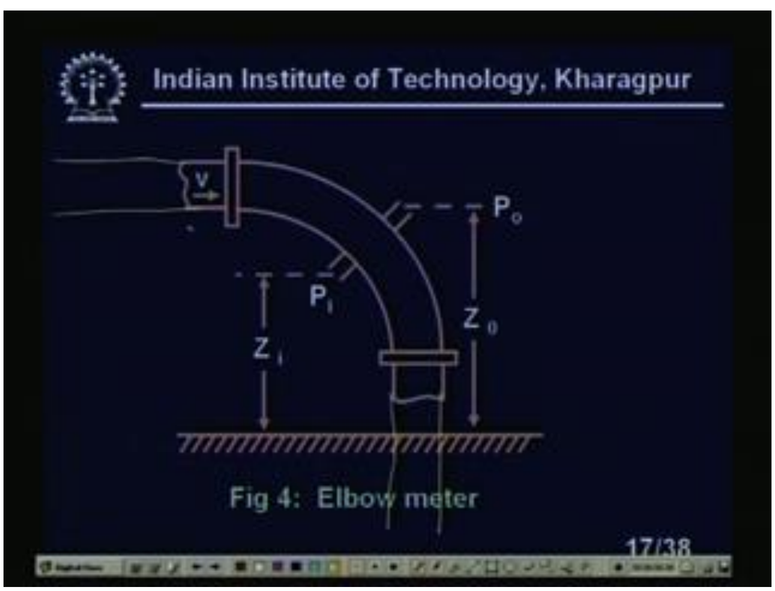

you see here the elbow meters we have it looks like you see that i have this is a this a ah section of pipe bending i have shown here you see this is a section of pipe bending you can see here this is a section of pipe bending right that means there is a pipe here there is a pipe here the continuous pipe and there is pipe going also here in this direction right

so just that pipe bending at the {a} (00:30:27) at the pipe bending i have installed this elbow meter fluid is flowing through a velocity v and it is coming out going out through this velocity and there is a two only two pressure tapings there one will be inside the pipe another will be {ins} (00:30:41) outside the pipe

you see what will happen the liquid which is flowing through this {pi} (00:30:46) outer side of the pipe it will must faster velocity than the pipe which is the liquid is flowing through the inside this one right it is usually increases in this direction

it is maximum here and by {min} (00:30:59) velocity is maximum here in this direction and minimum in this {dire} (00:31:01) here every where the flow velocity if you take any point to flow velocity suppose to be same right but here what will happen the liquid which is flowing very near to the pipe bending it has much higher lower flow velocity

and here we have a higher flow velocity according to the {bondis} (00:31:19) Bernoulli’s theorem obviously what will happen the pressure to this one will be [Noise] on the liquid side excuse me liquid i mean [Noise] will be much higher compare to the pressure

because here the flow velocity will be flow velocity will be higher right so we have ah datum point Zi and Zo from the datum level we have taken the height of the pressure tap this is the ah i mean inside the {paperpe} (00:31:42) pressure tap this is outside pressure tap

this is our basic principal in the elbow meter so what the advantage that means you see that i am not putting any restrictions inside the pipe like orifice or Venturi clear

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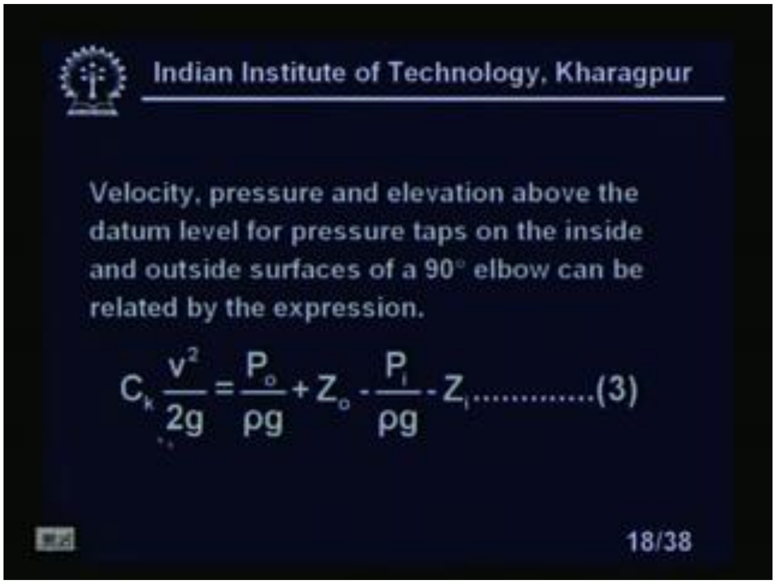

so velocity pressure and elevation above the datum level for pressure taps on the inside and outside surfaces of a ninety degree elbow can be related by the expression is that shape is ninety any bending in a industrial process is ninety degree

that is the reason we call it ninety degree elbow can be related by the reexpression Ck equal to Ck multiplied by v square by two g P naught by rho g plus Z naught minus Pi by rho g minus Zi equal to this equation number three right

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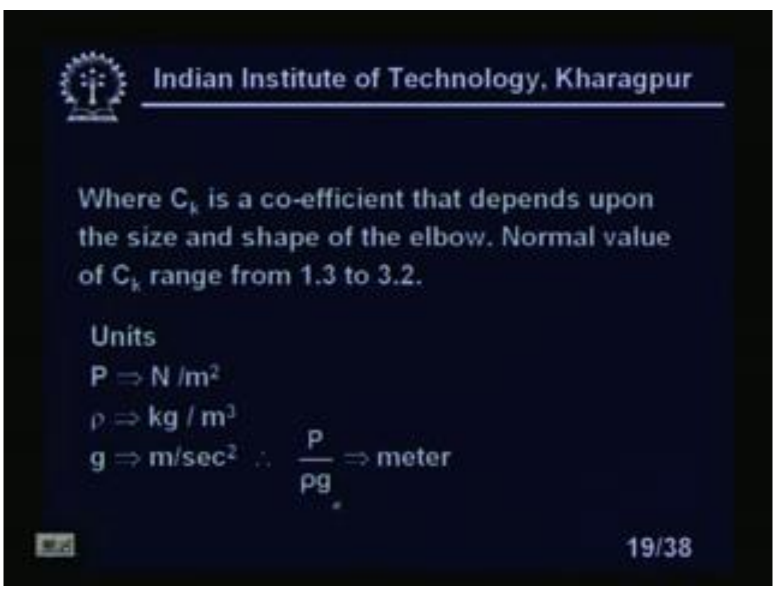

where Ck is the co efficient that depends on the (( )) (00:32:36) of the elbow that means shape and size of the elbow a normal of Ck range from one point three to three point two units you see here if i go back so Ck v square by two g Ck v square by two g P naught by rho g Zo Pi rho g so all this units let us look at P is a Newton per meter square rho is kg per meter cube and g is meter per second square

so all the units all the heads are in meter you can look at so P by rho g is in meter and Z is meter so all are in coming in meter right

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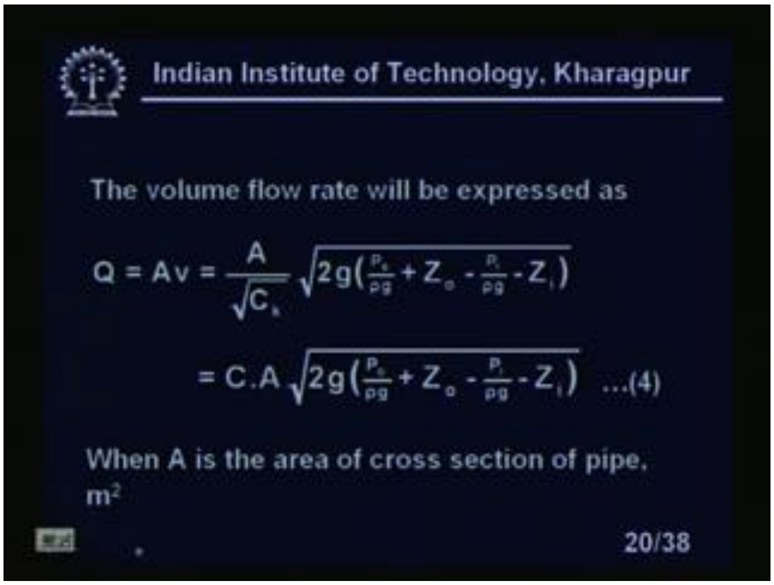

so volume flow rate will be expressed as Q equal to Av A (( )) (00:33:30) root over Ck two g P naught by rho g plus Z naught minus Pi by rho g minus Zi C into A we have combined ah instead of writing A and root over Ck we write C into A two g P naught by rho g plus Z naught minus P naught up and rho g minus Zi equation number four right

where A is the this should be where please note where A is the area of cross section of pipe in meter square

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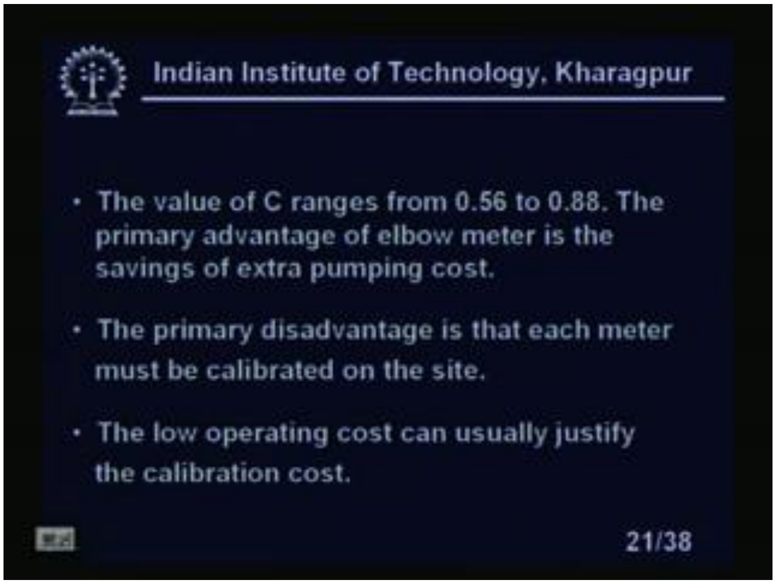

the value of C ranges from point five six to point eight eight and the primary advantage of the elbow meter is the savings of {ex} (00:34:18) extra pumping cost for the range installation that is a ah good amount of saving right

so the primary disadvantage is that of each meter must be calibrated on the site its very difficult to i mean find the flow coefficients as we know there is value of this C ranges from here all has given the range

so we have to install it depends on the slight pipe bending is not exactly ninety degree something else may happen suppose it is {exa} (00:34:43) internal cross section exactly not in circular in shape

so obviously everything will ah change the installation change the calibration constants or the your the {da} (00:34:54) discharge co efficient C right a flow co efficient C so that creates the problem

so each and every installation that is um true for even for {al} (00:35:02) almost all the installations right though we can suppose ah we have a thermo (( )) (00:35:06)

we can calibrated we can calibrate in the laboratory but it’s better to install {inst} (00:35:11) calibrate at the site itself

the primary disadvantage is that each meter must be calibrated on the site right so the low operating cost can usually justify the calibration cost the low operating cost and usually justify the calibration cost

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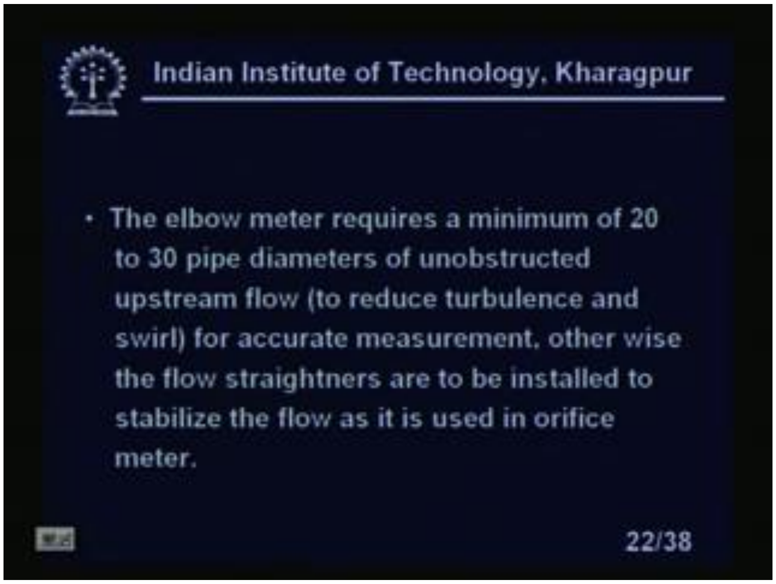

the elbow meter again the that restrictions the upstream flow restrictions and the downstream flow restrictions that means obstructions that means any pipe bending this that ah will be there so that is rather restriction is there which we had previously in the case of orifice and Venturi

the elbow meter requires a minimum of twenty to thirty pipe diameters of unobstructed upstream flow to reduce the turbulence and swirl for accurate measurement otherwise the flow straightners ah are to be installed in to stabilize the flow as it is used in the case of orifice meter

it's a bundle of tubes all held by insert and put inside the pipe so the liquid will be i mean so it will eliminate on the turbulence or reduce the turbulence and where swirl right

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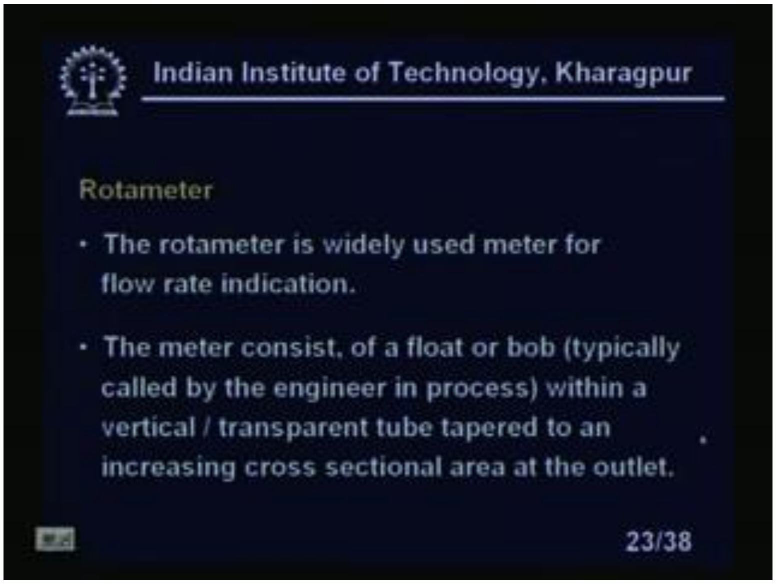

now rotameter is ah slightly different ah um it's a ah meter it basically depends on the ah ah is a variable area flow meter first of all so with this we are finishing this differential pressure meters we are starting now rotameters

rotameter you see the basic principle is widely used for meter for flow rate indications it is not used for transmitting instruments or rather so i mean {monite} (00:36:47) it's basically monitoring instrument

but you will find this meter is extensively used for many ah crucial applications or vital applications like biomedical applications also and also in the process we will find these are in plenty right

but basically it is a so far if the ah if the indicating instrument is concerned i think rotameter as the only choice if we look at the flow meters we have a several flow meters transmitting facilities and all these things

but if i want to make a simple ah i mean indicating type of instrument or monitoring type of instrument rotameter is the only choice please note that

the meter consists of a float or bob bob is typically called in the industry people call it bob i don't know why anyway ah with in a vertical or transparent tube tapered to an increasing cross sectional area at the outlet it must be tapered okay

if its ah if does not tapered that is not a rotameter so the meter consists i will repeat the meter consist of a float or bob typically called by the engineer in process within a vertical transparent tube tapered to an increasing cross sectional area at the outlet right

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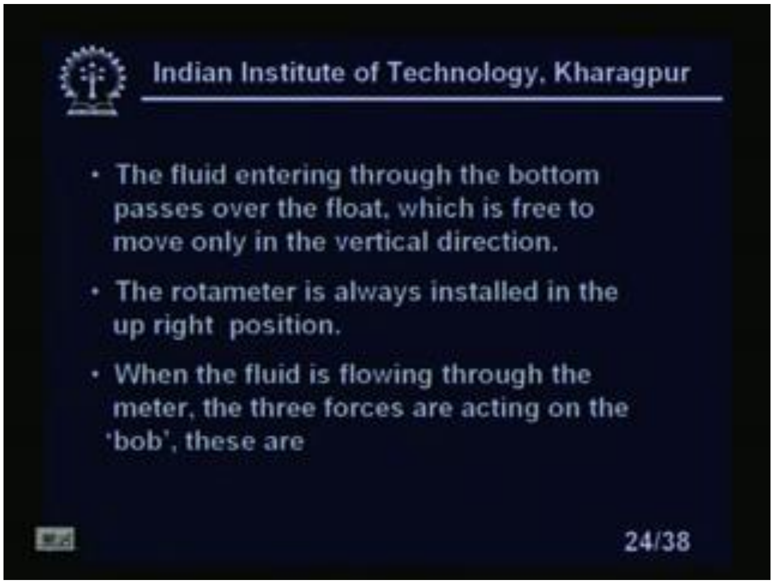

the fluid entering through the bottom passes over the float which is free to move only in the vertical directions the float can move only in the vertical directions right that is a problem rotameter always use to be install in the vertical direction right

rotameter is always installed in the upright positions or in vertical directions when the fluid is flowing through the meter the three forces are acting on the bob these are let us look at the rotameter now

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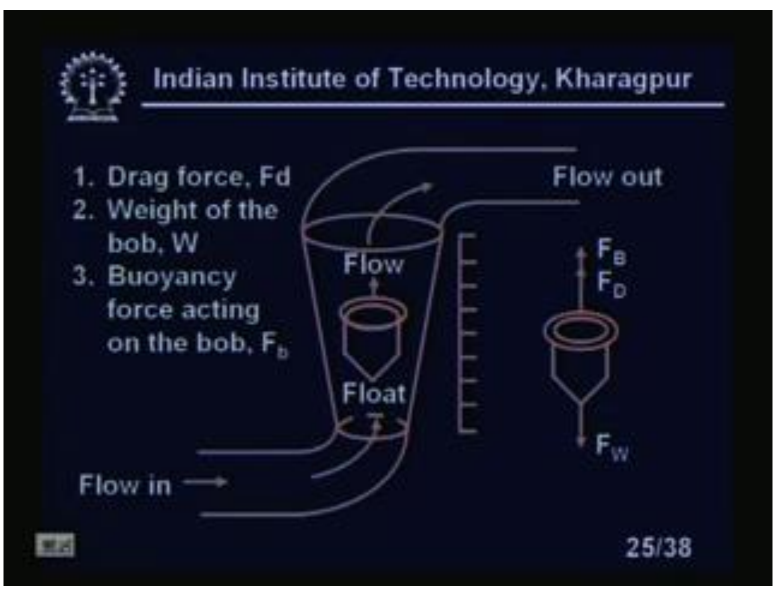

you see this is our rotameters right i have a can i take yes see there is flow in the liquid is flow in this directions and liquid is flowing out this directions so it is to be always install in this directions vertical direction right

there is a graduated square rotameter is {com} (00:38:45) accompanied by graduate {sc} (00:38:47) you see this tapering is so small that it is very difficult to if you look at the rotameters it’s like a very difficult it’s a usually it size like this pen most of the rotameter we find

it’s like this pen the size is very small it’s not that very huge in size you will find this size right and it is slowly increased in taper angle is slowly

so bottom it is a smaller angle included angle so it is slowly increasing right so that means it is increasing here slowly it is increasing in this direction

but this tapering is so small that is with the naked eye it is very difficult to visualize because these rotameter since it is made of hot i mean ah glass or i mean strong glass what they do is you find its puts on a casing also the back side it is getting only some front side you can see right

that you have seen in the case of the in the our first lesson one we have shown some rotameter so liquid is coming in this direction that is through pipe it is coming in this direction it is going up then it is moving in this direction

again i will tell liquid is flowing in this direction it is going inside the pipe inside the rotameter liquid is flowing through this then it is going out right and the float is moving inside the pipe float can only move in this {di} (00:39:59) vertical directions right

float can when the flow increases the float will move like this and when the flow decreases float will come down here and it will totally fit the inside diameter of the pipe float is designed like that it will fit the inside diameter of the pipe right

there are different shape of the float that we will discuss later on [Noise] so three forces you see the three forces are acting on the rotameter what are those forces weight of the system okay mass of the system buoyancy force and drag force

now weight of the system that will act down word and buoyancy and the drag force will act up ward right so this FW will always balanced by FD and FB then FW equal to FB plus FD that is always so rotameter you can see this basically in auto balancing system because you see is FW and FB will remain constant because that is the weight and the buoyancy of a {liqu} (00:41:08) the liquid is same if the liquid is same that means same type of liquid is flowing through the pipe it does not matter what is the velocity density will remains same

if the density is remains same density of the fluid remains same here buoyancy force is also will remains same and since we are not changing the bob that FW also will remains same so FB plus FW will be equal to FD then FD also should remain same

that is the main [Noise] main interesting point in rotameters rotameter is a basically when it is auto balancing systems if we look at its very interesting part this is a auto balancing systems right

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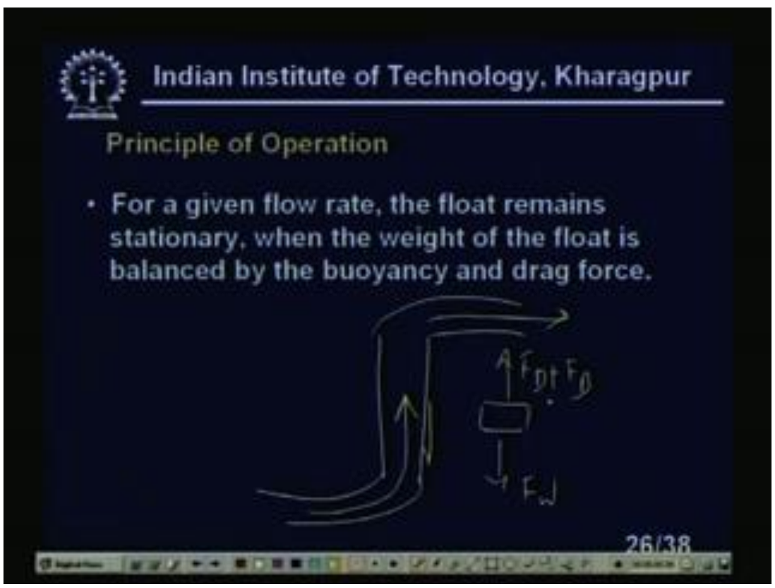

let us look at that principle of operations how it works for a given flow rate the float remains stationary when the weight of the float is balanced by the buoyancy and the drag force

buoyancy and drag force will act up ward because flow of the liquid is always from the lower to like flow of the liquid is always like this one that means i have a rotameter here

so flow of the liquid is always in this direction right {buo} (00:42:19) buoyancy and the drag force so the float will this will act down ward FB that’s we have seen already FB weight and FD and FB like this one

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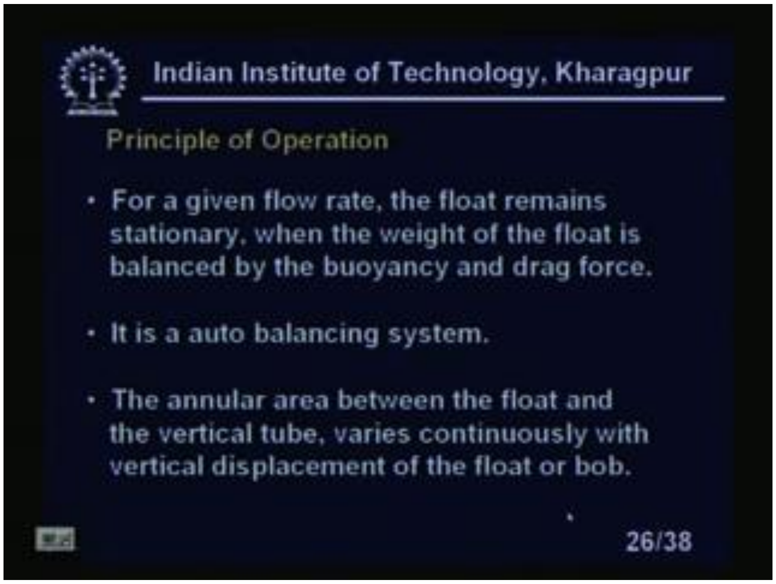

it is a auto balancing system that's you must note how the why i am calling it auto balancing system it will be create from this subsequent points the annular area between the float and the vertical tube varies continuously with the vertical displacements of the float or bob how this annular area is changing means yes obviously it will change

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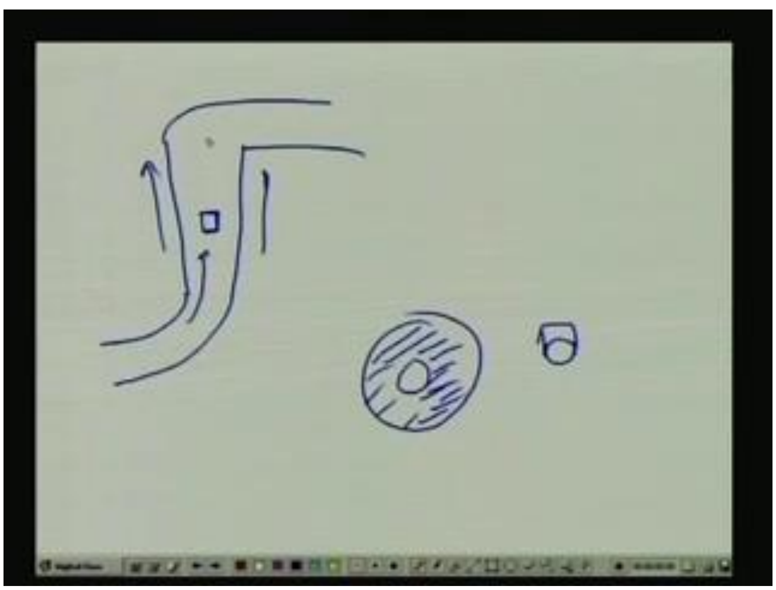

you see look at let we take a white page you see rotameter is looks like this let me take a different color pen um let me take another one so we have a rotameter here [Noise] if i look from the top what will happen it will look like this you see here the liquid is flowing through this so what is this annular area as you move bob what will happen the area cross section if you find leaving this one we increase area cross section will remain i mean it is always increasing as we go up right as we go up the area cross section will increasing

area cross section of the float is also same so the annular area that means if you look at here annular area which is the shaded area [Noise] will change as the this flow goes up the means i am telling that the area of annular area at the position of the float

you had think of the {ar} (00:44:13) annular area at the position of the float that will increase if the float goes up even the at the float {go} (00:44:20) comes in it is annular area will be no more so at that time what will happen float will just fit on this one

in that case it will there is no no annular area so at the flows this float goes up annular area increasing and increasing right this principles we are discussing clear

we are so the annular area between the float and the vertical tube varies continuously with the vertical displacement of the float or bob right

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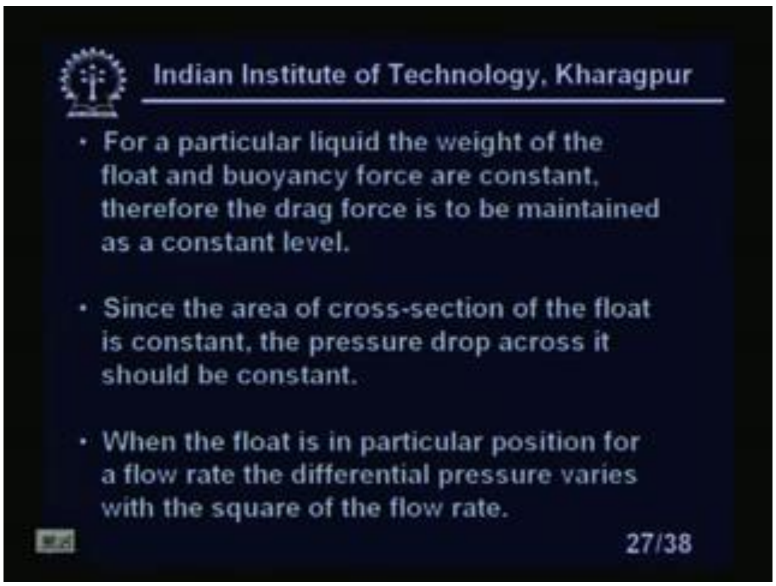

for a particular liquid the weight of the float as i told you the weight of the for a particular liquid weight of the float is constant buoyancy force is also constant therefore the drag force is to be maintain as a constant level that for must be constant also for a particular liquid the weight of the float and the buoyancy force are constant therefore the drag force is to be maintain at a constant level right since the area of cross section of the float is constant the pressure drop across it should be constant since the area of cross section of the float is constant the pressure drop across it should be constant right this is a key point

now when the float is in particular position for a flow rate the differential pressure varies with the square of the flow rate clear when the float in a is in a particular position for a flow rate the differential pressure varies

what is the differential pressure across the flow across the float differential pressure across the float when the float is in particular position a flow rate for flow rate the differential pressure varies with the square of the flow rate right

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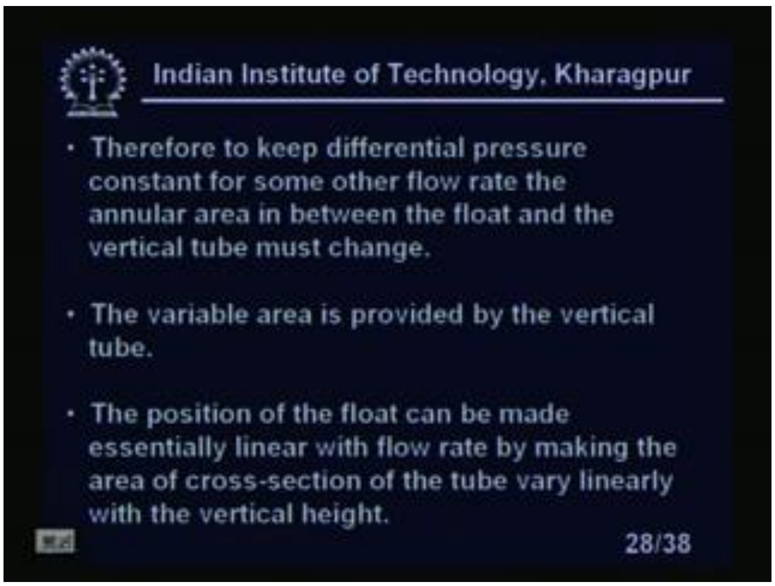

so now therefore to keep this differential pressure constant for some other flow rates when the differential pressure differential pressure must be constant otherwise the drag force will not be constant that force must be constant because it is equal to FW plus FD FW plus ah sorry

i mean ah FW equal to FD plus F buoyancy weight must be counter balanced by the balance in the drag force so drag force must be constant

so to keeps in the differential pressure is constant so obviously what will happen the area of the annular area must change that means the float must move up and down right therefore to keep the differential pressure constant for some other flow rate the annular area in between the float and the vertical tube must change must change means if the differential pressure as the flow increases differential pressure is constant

so to keep that drag force constant what will happen the flow area must change right right now the variable area is provided by this vertical tube this variable area as i told in the earlier when see between the float annular area that's if it if you doing the tap or then there is type of thing will not be achieved

so the position of the float can be made essentially linear with the flow rate by making the area of cross section of the tube vary linearly with the vertical height right

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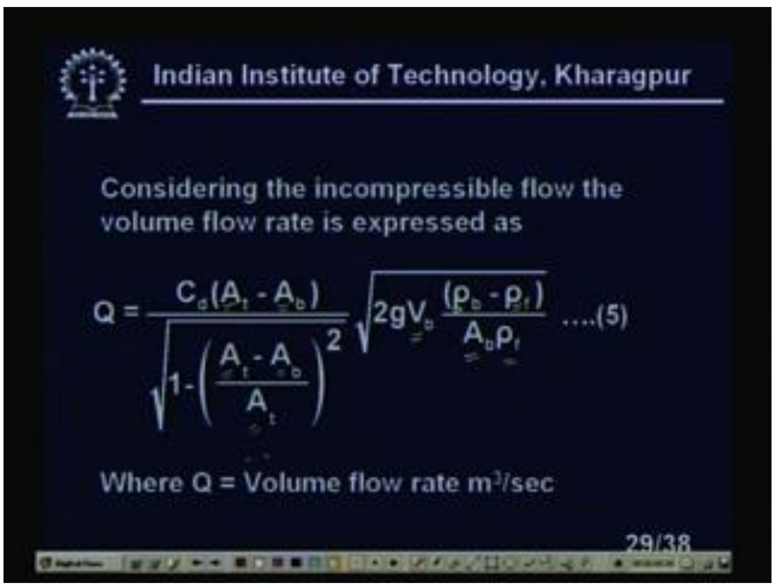

considering the incompressible flow the volume flow rate is expressed as it is expressed as this is the equation Cd equal to At minus Ab two gV Vb rho b rho f Ab rho f At Ab

so let us look at what are those so this is the flow coefficient or the this such coefficient At is the area of the tube area of cross section of the tube area of cross section of the float sorry bob or float whatever area of cross section of the tube area of cross section of the float area of cross section of the tube

this is the volume of the bob okay this is the density of the material of the bob this is the density of the fluid this is the area of the bob and this is the density of the fluid okay

we have written all this in the in the all the legends are given in the next slide let us look at where keys is the volume flow rate in meter meter cube per second

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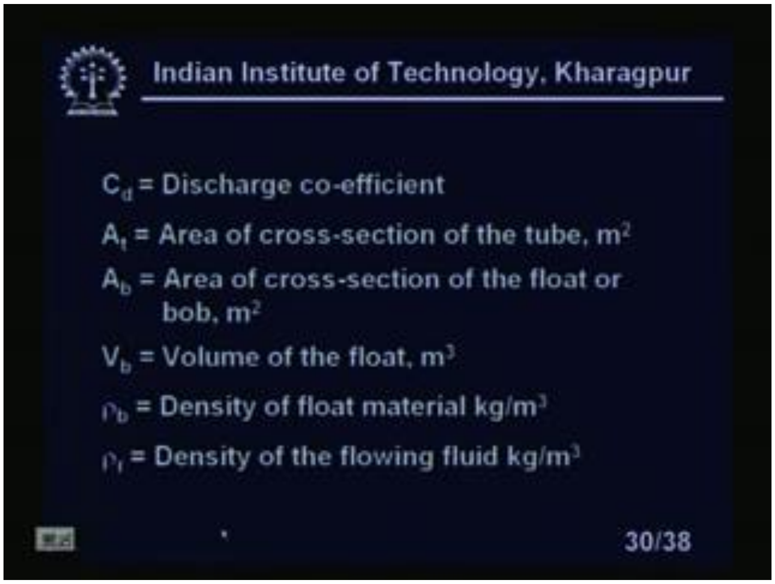

then Cd is the discharge coefficients At is the area of cross section of the tube in meter square Ab is the area of the cross section of the float or the bob in meter square Vb is the volume of the float in meter cube

rho b is the density of the float in of material kg per meter cube rho f is the density of the flowing fluid in kg per meter cube okay

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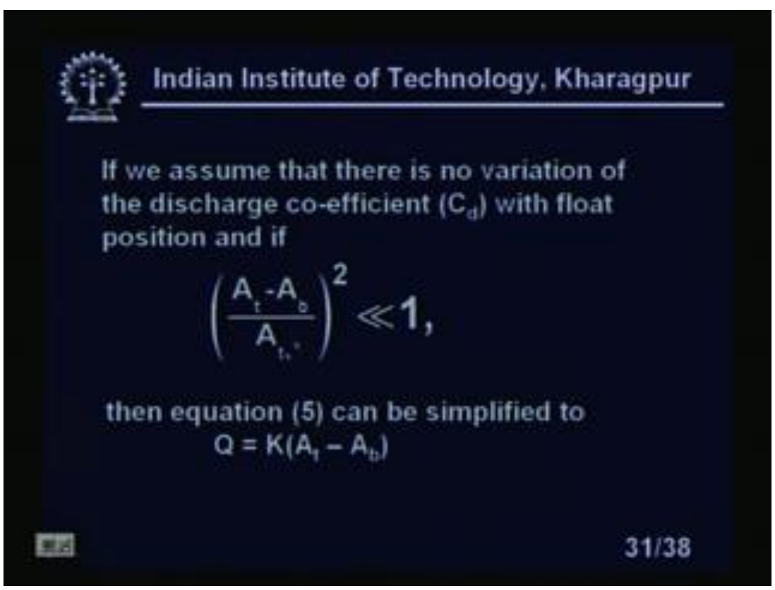

now if you assume that there is no variation of the discharge coefficient with the float position we assume that discharge coefficient does not changes with the float position we changes obviously and if we assume that At minus Ab square by two is much much less than one if i go to the previous slide is more clear okay

i am assuming that the Cd is constant okay and this portion that's At minus this portions that means i am talking of this portion this At minus Ab by At whole square is much much less than one then [Noise] okay

is At minus Ab less than the equation five can be simplified to Q equal to K At minus Ab because all that items to be constant is not a in that equation so the volumetric flow rate equal to K At minus Ab

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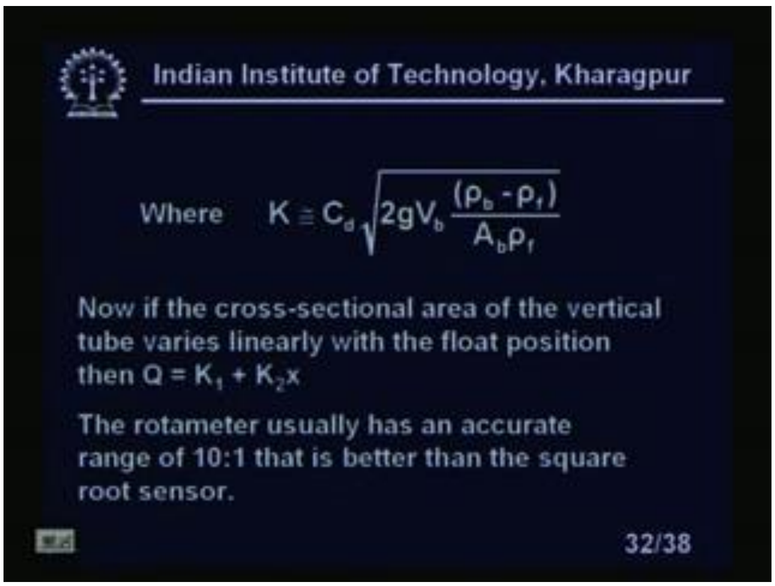

where K is equal to Cd root over another square root two g volume of the bob Vb rho v minus rho f upon Ab into rho f right this is our constant K

so now if the cross sectional area of the vertical tube varies linearly with the float position with the if we vary the cross section of that i mean tube in such weight varies linearly with the i mean with the float position

then i can write the volume flow rate equal to Q equal to K one plus K two x okay to constant and x x is the position of the float right position of the bob right

so the rotameter usually has an accurate range of ten is to one that is better than the square root sensor so that is quite obvious so it is a square root sensor much better than the square root sensor square root sensor we have seen that at the ah um twenty five percent less than twenty five percent of the maximum full skill range the error is this reading is very much erroneous that is not the case in the case of rotameter right

now shape of the {rotam} (00:51:28) so what will see that ah in the case ah previous we find that [Noise]

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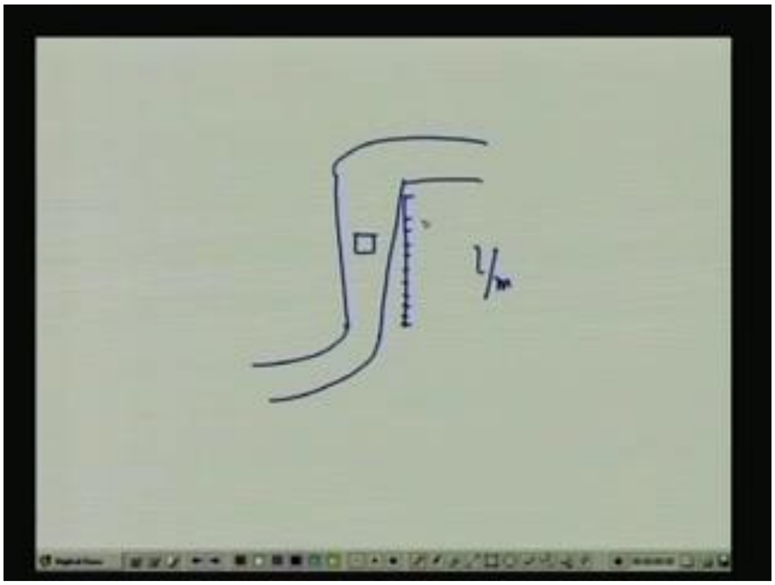

that's we have seen also that and we take a ah a different color so we have seen that its tapered like this one okay the float is moving like this one so it's in a casing okay and it is graduator scale is there right [Noise]

so this is liter or we need all liter per second whatever the way you like actually represented right so this is the float so this is calibrate in the i mean volumetric flow rate or i mean velocity

so is the volumetric flow rate it is calibrated so whenever by looking at the position of the bob i can if i look at here i can tell that the what is the flow velocity right so this is very important in the case of ah rotameter

so it is basically used for ah the basically used for the monitoring instrument or indicating instrument but not for the in transmission instrument right but that does not neccesarily mean that's accuracy is poor accuracy is quite good in the case of rotameter

as i told you i mean you will find that it is extensively used in the case of anesthesia as you know that ah when the patient i mean under operation first they put an injection physicians for ah to go the patient under this say that ah the patient will go some subconscious state right to maintain that state they must have continuously supply the gas so that the patient will remain so to how much gas they will put to the patient nose so that will be the measure by the flowmeter that the rotameter and there are the float ah ah let me go back again i am sorry [Noise] shape of the rotameter you will find

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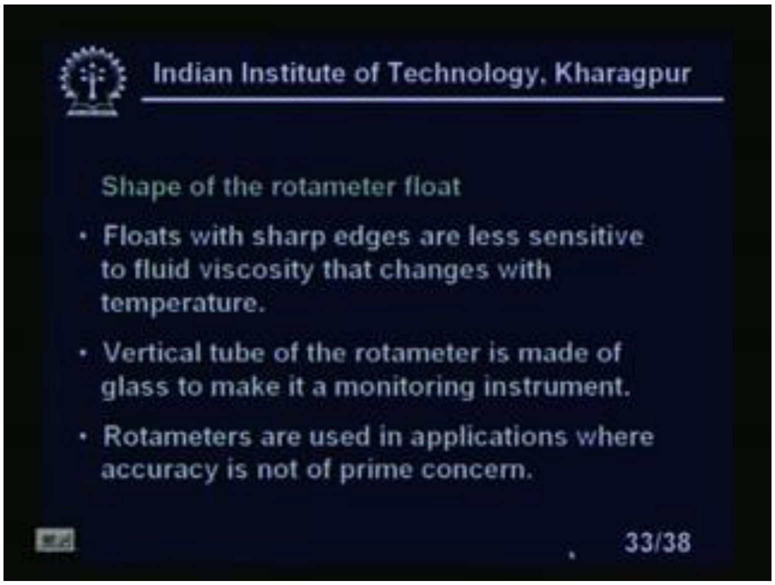

ah that ah the float is actually they are using some light heavy plastic short of thing so by looking at the position of the float i can tell how much gas is i am giving to the patient that because this very important

those who who are the anesthesia for the actually looking at and determining the regulating the valve there controlling the how much liquid is flowing how much fluid is going to the patient right

now floats with sharp edges are less sensitive to fluid viscosity that changes with temperature right so the ah you find that’s because viscosity of the liquid as you know the changes with temperature right so the but if i make the float the sharp edges that will almost independent to viscosity right

vertical tube of the rotameter is made of glass to make it a monitoring instrument rotameters are used in applications so the accuracy is not of prime concern but it’s not that in accurate also otherwise it cannot be used in biometric application such like very crucial when the because if you give more gas ah to the patients we patient will die and if you i mean ah and if you reduce this supply of gas to the patient

so what will happen patient will come out of the subconscious state i mean physicians cannot operate so till the operation is complete the patients will be on the that state

now here now we will solve one problems on the Venturi meter you see here now problem looks like this

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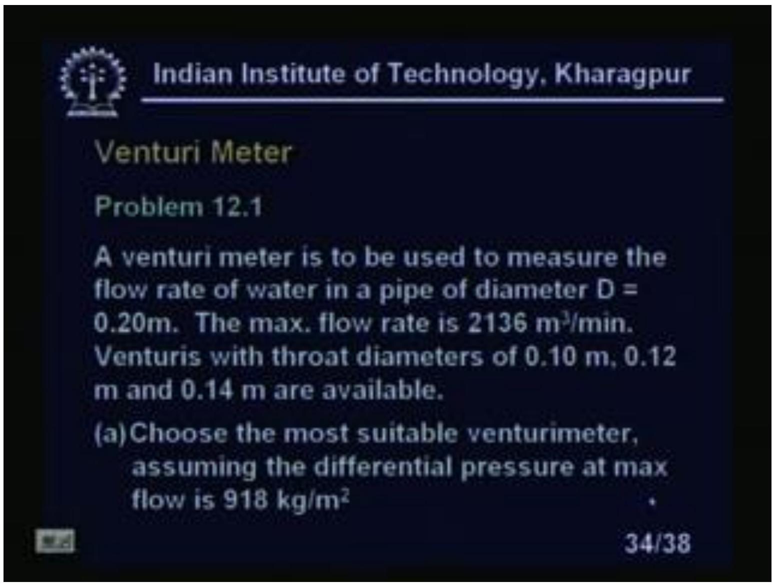

a Venturi meter is to be used to measure the flow rate of water in a pipe of diameter D will be point two meter the maximum flow rate is two one three six meter cube per minute Venturis with throat diameters of point one zero meter point one two meter and point one four meters are available

choose the most suitable Venturi meter assuming the differential pressure at maximum flow is nine one eight kg per meter cube

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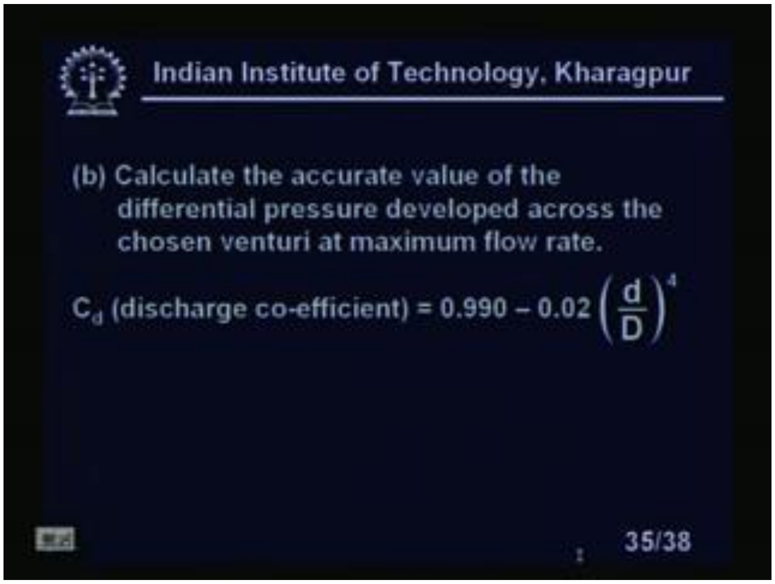

and calculate the accurate value of the differential pressure developed across the chosen Venturi at maximum flow rate right this is our now we are given some ah chart also

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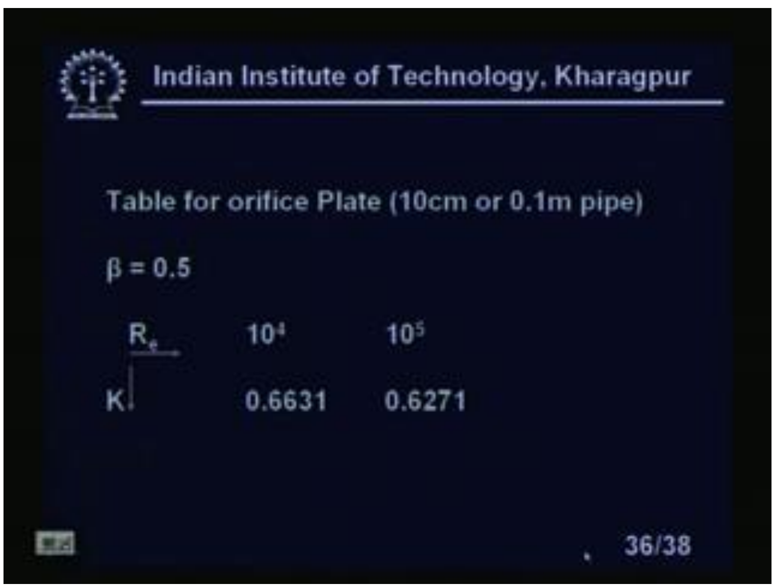

yes it tells for orifice plate this is beta equal to ah we have seen that some chart for Reynolds numbers how much the ah flow coefficient changes

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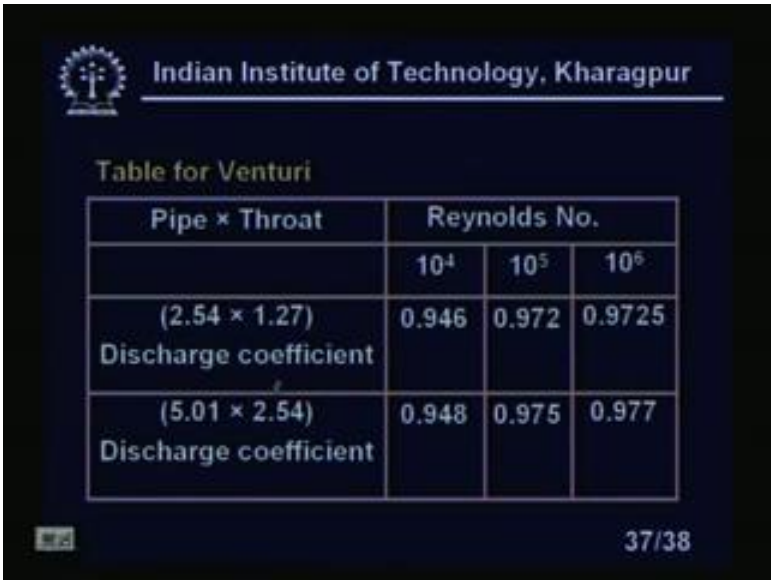

Pipe × Throat	Reynolds No.		
	10^4	10^5	10^6
(2.54 × 1.27) Discharge coefficient	0.946	0.972	0.9725
(5.01 × 2.54) Discharge coefficient	0.948	0.975	0.977

so table for Venturi also we are given this is a pipe and throat diameters for the different Reynolds numbers how the discharge coefficient changes okay

that is we have given these are tables are necessarily for solving the problems of the Venturi meter or orifice plate meter right this is another chart we are given

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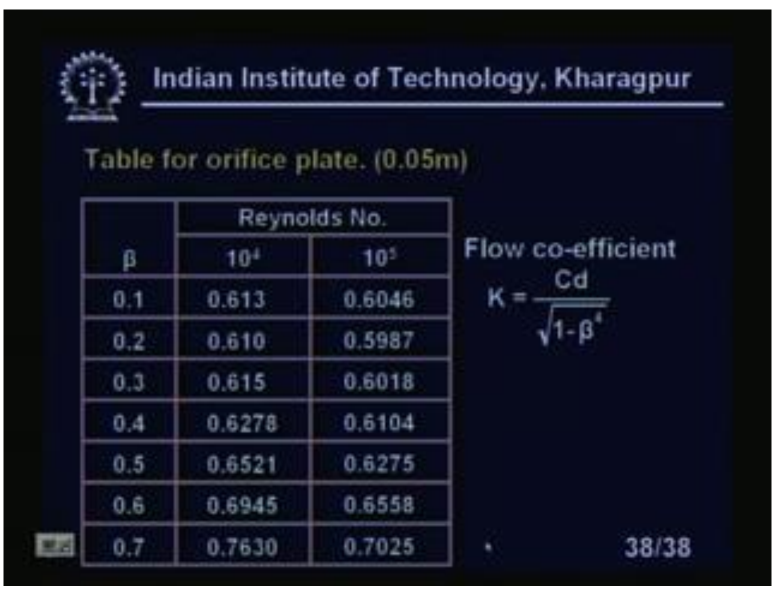

β	Reynolds No.	
	10^4	10^5
0.1	0.613	0.6046
0.2	0.610	0.5987
0.3	0.615	0.6018
0.4	0.6278	0.6104
0.5	0.6521	0.6275
0.6	0.6945	0.6558
0.7	0.7630	0.7025

last chart we are giving that is the the Reynolds numbers have the beta changes you know if orifice plate of point zero five mille {met} (00;56:13) ah meter that is a dimensions of the orifice ah so we find that the how much the Reynolds number changes right so let us solve the problem

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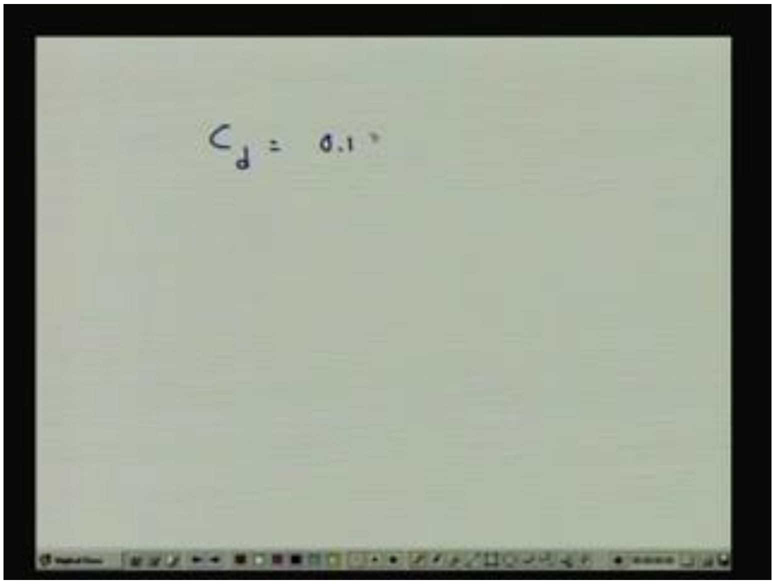

here you see the problem is like this one ah here Cd we can see for Cd is equal to point one okay it is not right yeah for point ah sorry let me take new page

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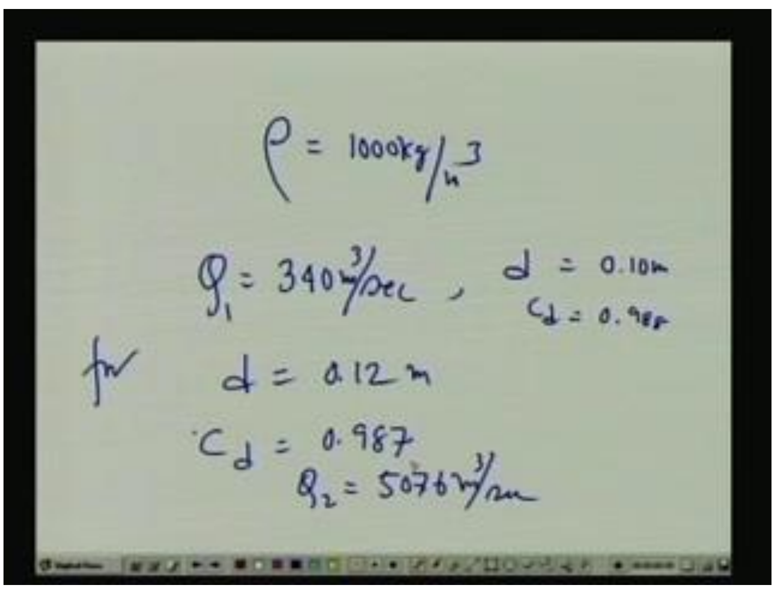

so rho equal to one thousand [Noise] kg per meter cube so from that if i apply the our Venturi meter formula will find that Q equal to i am getting [Noise] three forty meter cube per second

now here i am taking that d ah ah equal to point zero one meter for which Cd is coming from the chart point nine eight eight okay Venturi meter always you know the flow coefficients is very high right then we have we can find for d equal to point one two meter we have calculated from the formula that that Cd will come point nine eight seven [Noise]

so the Q two the this is a Q one if i assume the Q two will be equal to ah five zero seven point six meter cube [Noise] per second right

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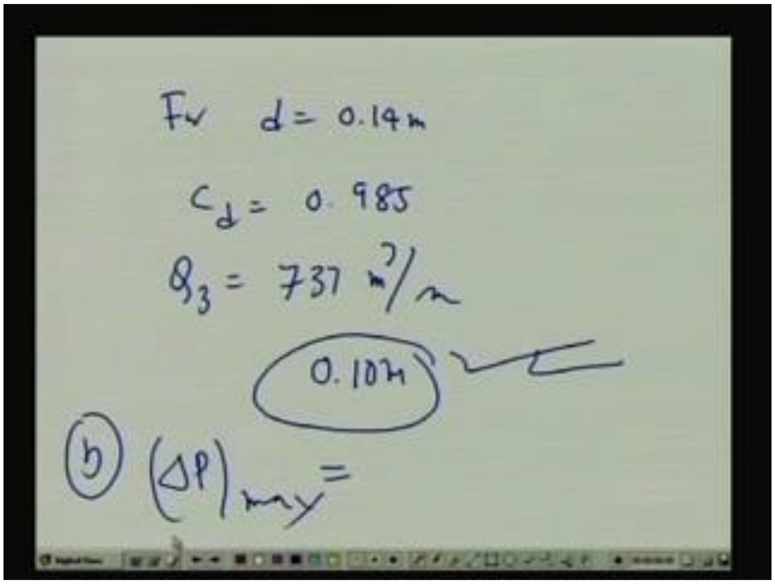

so if we take a new page now for D equal to [Noise] point one four meter will find Cd equal to point nine eight five meter point nine point nine eight five so Q three equal to equal to seven three seven meter cube per second

so we can see that the point ah the orifice meter with point one zero ah meter diameter is the {be} (00:58:37) best chose right

because that is the most close one and in this case for this type of situations now in the case ah we can calculate that the delta P ah max if i apply this again this our main formula

so now will apply this one point two zero that means it will be ah will if i take a new page it will like this one

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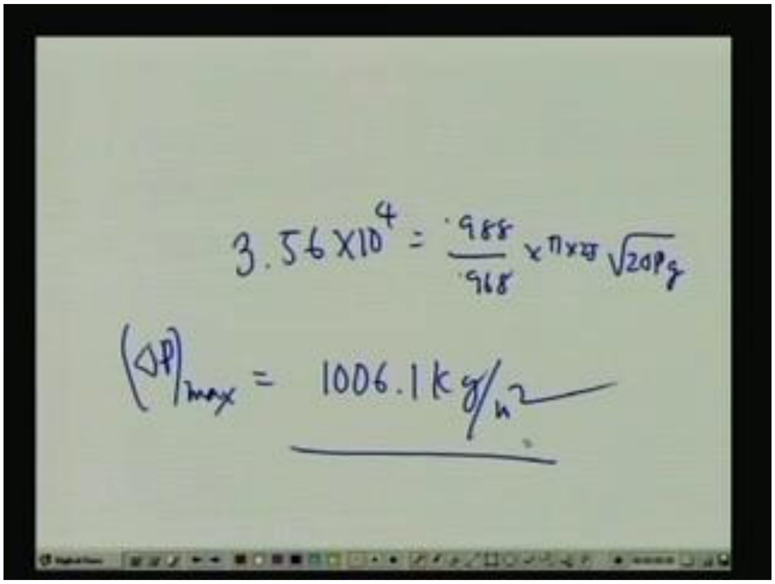

so it will be three point five six into ten to the power four point nine eight eight by point nine six eight you will find so you will put the all other pi twenty five root over two delta Pg you will find that the delta P max will be one zero zero six point one kg [Noise] per meter square right

so this is our equation right so this is so best chose is point one zero meter and delta P max will be one thousand six point one kg per meter square this ends the lesson thirteen thank you