Fluid Mechanics
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Lecture - 27
Fluid Flow Application Part – VI

Good morning I welcome you all to this session of fluid mechanics. Well last time we discussed the different types of flow meters namely venture meter, orifice meter and flow nozzles. Today we will be discussing another type of flow meter, which measures the fluid flow in a fluid circuit that is pitot tube. This pitot tube measures the fluid flow by measuring the fluid velocity the local velocities and then from the velocity they determines the fluid flow rate. And this determination of fluid flow velocity to measure the flow rate by a pitot tube is based on the concept of static and stagnation pressures.

So therefore, we should first know what are meant by static and stagnation pressures. Now static pressure is nothing but the hydrostatic pressure that is the pressure which is exerted when the fluid is at rest as you know that in hydrostatics that when the fluid is at rest the pressures at each point is same from all directions is the Pascal is law. And this pressure is the result of the molecular collisions this is also termed as thermodynamic pressure. You have already read in thermodynamics that when any system is in thermodynamic equilibrium.

So, fluid at rest is in thermodynamic equilibrium. Then the pressure exerted by the system is the thermodynamic pressure; so hydrostatic pressure and thermodynamic pressure is simply known as the static pressure in a fluid flow. But what happens when the fluid is flowing this static pressure is sensed in a direction normal to the direction of velocity normal to the flow velocity direction and it will be proved in later sections the chapter which we will be discussing afterwards that in case of a class of real fluids known as Stokesian fluids which obeys the stoke is law that is why these fluids are known as Stokesian fluids. This law states that the second coefficient of viscosity which has we again describing or discussing we will.

While we will be discussing this viscous flow that in case of Stokesian fluids which obeys the stoke is law the static pressure is the arithmetic average of the 3 normal stresses is the arithmetic average of the 3 normal stresses 3 normal stresses means 3 normal stress components sigma x sigma y, sigma z. If it is in x, y, z co-ordinates then it is the arithmetic average of the 3 normal stresses it will be proved the static pressure is the arithmetic average of the 3 normal stresses.

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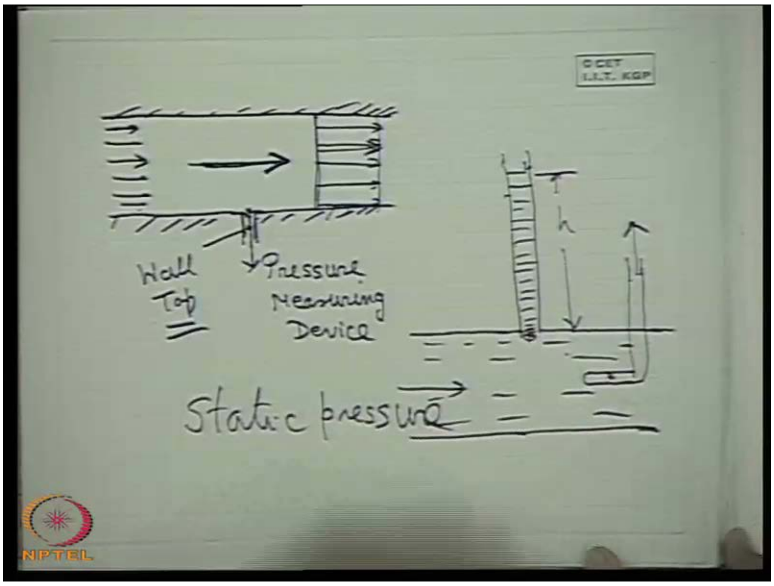

Now let us consider a case like this well if we consider a flow through a duct let us consider the flow through a duct with uniform velocity through a duct now the static pressure is sensed if we make a connection at the wall like this and if it is connected to any pressure measuring device.

Now this type of connection is known as wall tap which measures the static pressure wall tap this is the flow direction. Now it is obvious that in this direction the direction of the wall tap that means in the along the axis of this hole or this connection which is known as wall tap there is no component of flow velocity flow velocity is in this direction. So, this senses the static pressure.

So, another way of conceiving the static pressure is like this that for example, if we have a duct like this where the fluid is flowing then if we just made a connection or wall tap and attach a piezometer as you know what is a piezometer then what happens? So, the fluid at this section will rise depending upon the pressure here and this is the static pressure because there is no component of flow velocity and the height up to which it will rise this height h will be the measure of the static pressure at this point about the atmospheric pressure that is gage static pressure.

Now it will be also seen afterward that in case of a parallel flow that means the flow takes place in one direction for example, fluid velocities is there in one direction now there may be a velocity variation across the section depending upon whether the fluid is viscous or not we consider a uniform velocity distribution that is the hypothetical case that is the case for ideal fluid, but in case of a viscous fluid then there will there may be a velocity variation there may be a velocity variation with zero velocity at the wall that is the most realistic condition no slip condition, but in those cases whether it is a real fluid or ideal fluid.

Then flow is a parallel flow that is a flow velocity exists only in one direction that is in this direction here the static pressure remains uniform throughout the cross section therefore, a wall tap which measures the static pressure at the wall theoretically these measures the static pressure at the cross section itself. Since it is uniform over the cross section, but in case of in well real fluid not parallel flow not in case of a parallel flow where there is a chance that static pressure may vary across the section then we have to insert a probe at a point where static pressure has to be measured and what happens is that it is like that a hole is made at this side of the probe.

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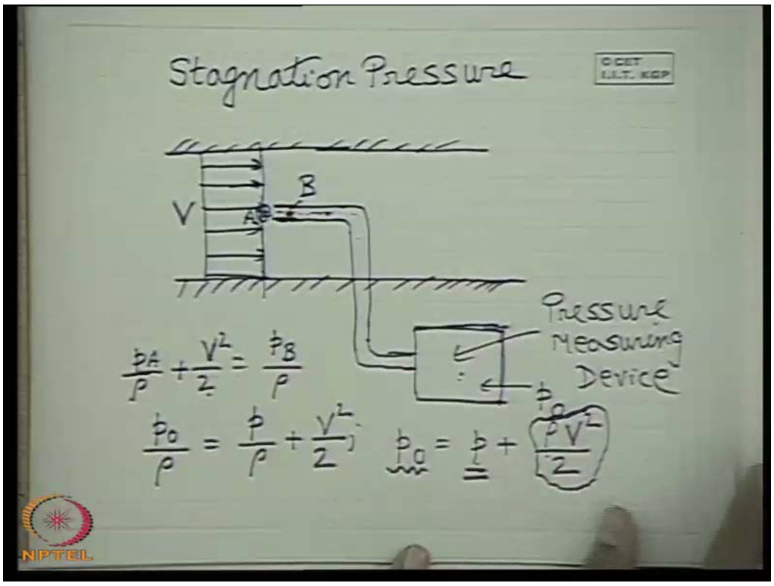

So, that normal to the direction of the flow velocity we can measure the pressure so, this is connected to any pressure measuring device so, this is the way by which a static pressure is sensed in the flow of a fluid. So, this is the concept of static pressure that we have defined now we will go to the concept of stagnation pressure which is stagnation pressure now we will go to the stagnation pressure.

Stagnation pressure what is stagnation pressure now what is stagnation pressure? Let us consider a duct like this let us consider a duct like this where the fluid is flowing for example, at this section the fluid is flowing with an uniform velocity distribution consider an ideal fluid therefore, uniform velocity sometimes in a real fluid we can make a situation where the fluid approaches a duct at uniform velocities, but while it comes in contact with the solid surface flowing through the duct the flow velocity is not uniform for a real fluid however we consider a uniform flow considering an ideal fluid.

Now what you think that if you now just consider like this place a tube which is precisely a probe like this we place a tube like this and we just attach it to a pressure measuring device pressure measuring device so, what is this is a pressure this may be anything a manometer a piezometer or any other pressure measuring device is not very important for us to go into detail of the pressure measuring device. Now what happened the fluid that this is like this the fluid at any point here if you consider a point parallel to the axis this is a very short tube let we consider point A.

Now what happen fluid is coming into this and it is closed at other section this tube pressure measuring that means the when the fluid comes through this and ultimately comes into the pressure it may be a manometer. So, the fluid is brought to rest. That means if we consider this system that means here with in this tube we see there is a column static column of or static mass of fluid. So, if this point just after the entry to the tube you consider B or any point this may be here or here if we neglect any pressure variation in that tube there is a short tube then at any point in the tube.

Where the fluid masses at rest and at any point at the same plane where the fluid has a velocity V that uniform velocity if we write the Bernoulli is equation. Considering the fluid to be ideal that means there is no dissipation of mechanical energy in term into enter molecular energy we can write that P by rho PA by rho rather plus V square by 2 is equal to PB by rho that means the pressure here is more than that at A by these amount by V square by 2 this is because fluid is at rest and if we consider this pressure is same throughout these mass of fluid that means this is the pressure that is being registered or measured here.

So, this will give an indication of P, PB so, this PB now we write it as P0 so, therefore, if we write PB as P0 and a is a general point any point which has a velocity flow velocity V then we can write this equation like this p square by 2 or we can write P0 is equal to P plus rho V square by 2 now we see that this P0 the pressure which is created by bringing the fluid to rest is more than the static pressure which the fluid was having when it had a flow velocity V plus the magnitude rho V square by 2.

So, this is a pressure unit so, this is the corresponding equivalent pressure head corresponding to the velocity head V square by 2 so, this pressure P0 by definition is known as stagnation pressure.

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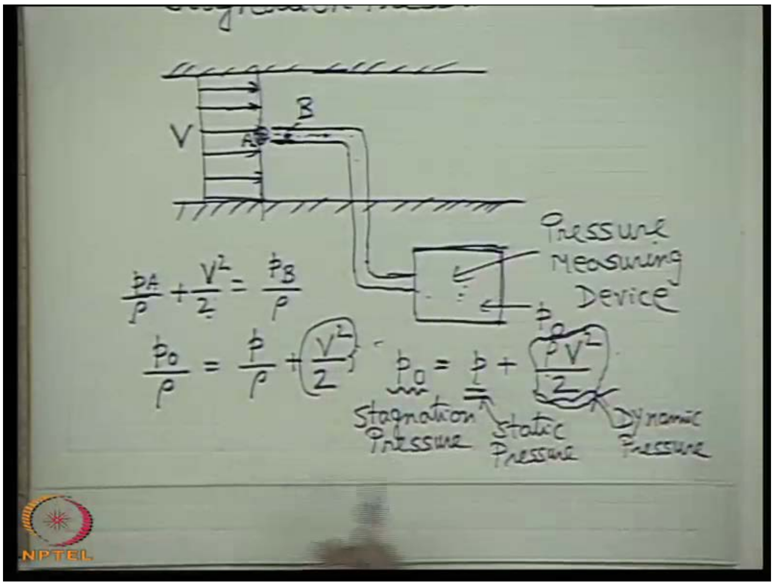

So, this is known as stagnation pressure. So, this is known as stagnation pressure and this is known as static pressure as you know and this part this rho V square by 2 is known as dynamic pressure that means this is the pressure which is created because of dynamic it.

So, this equation tells a very simple physics that the entire kinetic energy at this point is converted to pressured energy that means when the fluid is at rest the entire kinetic energy is converted into pressure energy because energy conservation tests for an ideal fluid. Viscous less fluid or in viscid fluid energy total energy total mechanical energy remains constant. So, therefore, a part of the kinetic energy a part not the full kinetic energy is converted to pressure energy because there is no another form of mechanical energy. In this static mass of fluid except the pressure energy so, the total conversion of kinetic energy into pressure energy. So, therefore, a stagnation pressure is defined in short that it is the pressure which the fluid will exert if it is brought to rest isentropically.

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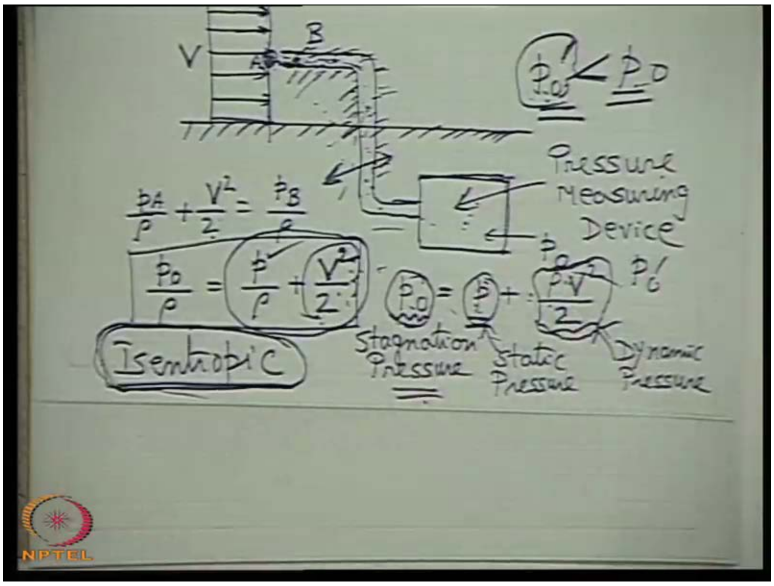

If it is brought to rest isentropically the word isentropically is used as you know the isentropic process is a process which is a reversible and adiabatic process that means there is no heat transfer with the surrounding why because there should be another restriction that when the fluid is brought to rest then there should be a proper insulation into the tube no heat transfer no energy interaction should take place with the surrounding energy should not come in or energy should not go out no question of what transfer comes here so, only heat transfers can take place and it is very simple from physical sense that.

When the fluid is brought to rest that means the pressure kinetic energy is brought into pressured energy, but what happens that a part of this pressure energy kinetic energy may be converted to heat and may be transfer to the surrounding so, if it is made insulated that no energy interaction is taking place between this system and the surrounding and if it is free from any dissipative effect which is known as reversible process. In thermodynamics well when there is no energy transfer with the system between the system and the surrounding and when there is no internal dissipation the flow is known as a reversible the process is known as a reversible process.

And also if the adiabatic process is adiabatic the entropy of the process remains throughout the same throughout the process same and the process is known as isentropic process. So, that is why the conversion from a flowing fluid to a static fluid for an in viscid fluid without any interaction of energy with the surroundings is known as isentropic process.

So, therefore, the pressure which could have been experienced or which could have been exerted by the fluid or which could have been obtained from the fluid if the fluid is brought to rest isentropically is known as the stagnation pressure, but simply without going through all this details we think that a stagnation pressure is that the static pressure plus the dynamic pressure that means if I know that the static pressure of P at any section in a fluid flow and corresponding velocity is V.

Then the stagnation pressure is P by rho plus V square by 2 this is by definition, but the actual now there is a difference that the pressure which is measured actually for a real fluid because an isentropic process is a hypothetical process obviously an in viscid fluid is an hypothetical fluid. So, for a real fluid the pressure which is measured when the fluid is brought to rest for example, by inserting a measuring device with a probe like that let this pressure is P0 dash it is always less than P0, but this is not the stagnation pressure.

So, literally we can think that fluid is stagnating fluid is made to rest and this is the pressure measured that is the stagnation pressure no stagnation pressure by definition is this one that means if it could have been brought to rest isentropically that means mathematically if the entire kinetic energy could have been converted to pressure why this measured pressure for a real fluid when it is brought to rest is less than this because a part of the kinetic energy is converted into intermolecular energy due to the fluid friction. Which will cause a rise in the temperature of the fluid because of insulation the intermolecular energy the rise in intermolecular energy may not cause in terms of heat transfer that is a different issue, but a part of the kinetic energy will be converted into intermolecular energy.

So, we will not get the pressure as big as this P plus rho V square by 2 so, the measured pressure will be less than this, but stagnation pressure by definition is P by rho plus V square by 2 that means P0 is P plus rho V square by 2 this is the definition of stagnation pressure. Now the question of measurement of stagnation pressure comes if we place a tube or the sensing probe facing the direction of the flow so, that it can take the component of the flow velocity which is arrested and it is measured, but the measured pressure is never the stagnation pressure, but in loose term we tell it as a stagnation pressure.

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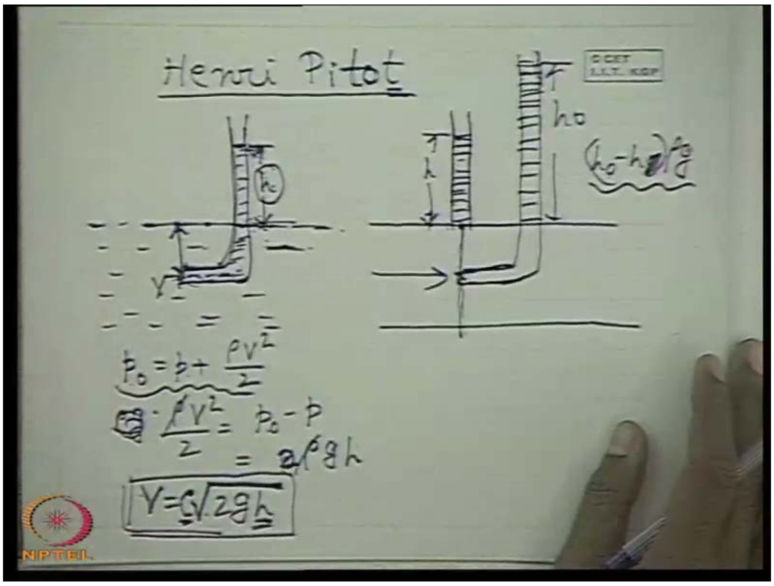

Now 1st the concept the idea of measuring stagnation pressure was given by a scientist known as Henri Pitot the t is not pronounced so, it is pronounced as pito P. It pitot, but it is pronounce as pito Henri Pitot is the scientist who 1st discovered this or get the idea. Now 1st of all let us appreciate the idea consider the flow with a free surface that means flow in a river why because Henri Pitot 1st made these idea clear by measuring the velocity by this pitot tube so, Pitot tube measured the velocity of the fluid so, the velocity of the fluid in a river he 1st used this concept in a river.

Where there is a free surface it is very simple at any point he just inserted a tube it is a classical concept this is done long back so, at this time this is nothing but this was a great thing at that time so, he just and what happens the liquid in the river rises from the free surface obviously if at any point it has to rise because it has a flow velocity so, therefore, it rises to a velocity h.

Now the pressure here is equal to this height, that is the height from the free surface therefore, static pressure corresponds to this height of the fluid or the liquid here water from the free surface so, this height therefore, is the extra amount from that static pressure so, this height is responsible for this stagnation pressure therefore, this is the measure of the stagnation pressure of course, not the stagnation pressure by definition certain less than the stagnation pressure, but we will call this as the stagnation pressure.

So, this is the measurement of stagnation pressure, but what happens if the fluid flows through a duct what happens if the fluid flows through a duct. Fluid flows through a duct.T0 hen the static pressure cannot be given by this difference height below the free surface so, in that case a single tube cannot measure this h here we can write h for example, if we write the equation P0 considering P plus rho V square by 2 if I consider this as the P0 rho gh P0 minus P.

So, rho V square by 2 is equal to P0 minus P we consider this as P0 minus P is what P0 minus P rho is rho gh rho is the density of the fluid therefore, we cancel this so, V is equal to root over 2gh, but this is calculated on the basis of the ideal flow equations. And we take the h for the real fluid with the same logic as we have described earlier for venture meter we just multiply with a coefficient which takes care of the friction so, V is equal to c into 2gh because this h is measured the head that is the pressure difference in terms of the liquid that for a real fluid.

So, c is root over 2gh so, V this is the velocity this is the correction factor we get for a single tube we get this because P0 minus P is h that is the difference height above the free surface, but in case of a duct what happen we cannot have this by a single tube in that case what we do in case of parallel flow. Where the section this is the static pressure at any section remains constant so, to find out the velocity at any section what we do we insert a Pitot tube along with a wall tap that is the wall tap tube so, this measures for example, this is a piezometer pressures are not very great so, this gives a pressure reading like that let this is h that is the static pressure at this point and if it is constant across this section for a parallel flow.

Then it is the static pressure at that section means this point also now this is inserted at this point so it gives the stagnation pressure which must rise because of the dynamic head to a height let this is the height h0 so, here we will have to precisely takes h0 minus h into rho g into rho g is the difference between the static and stagnation pressure so, therefore, we will have to calculate this not with h, h0, h0 minus h rho g very simple.

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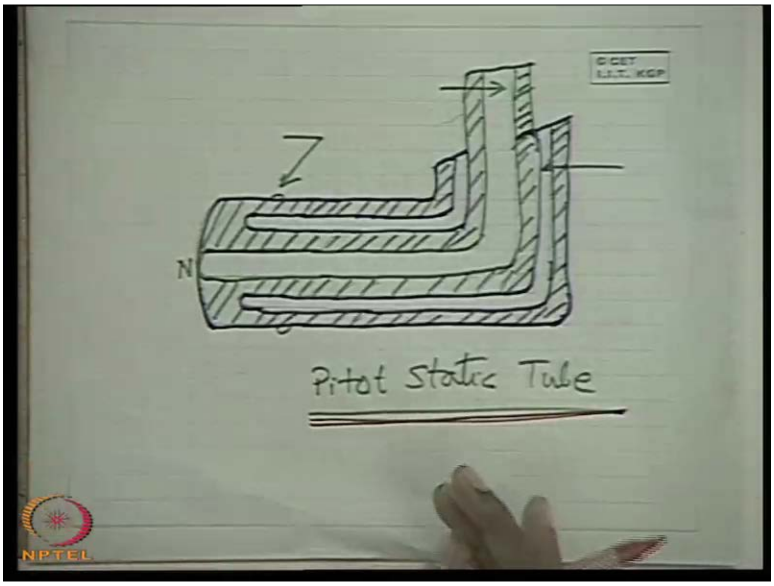

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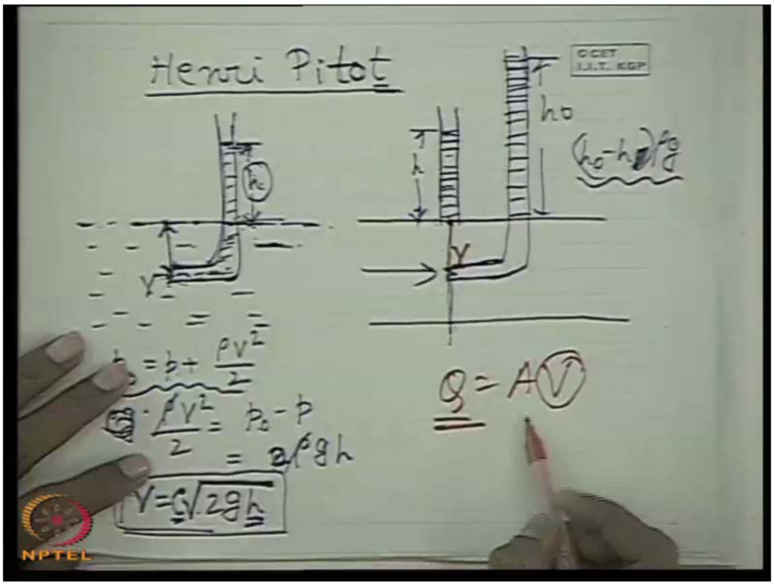

Now these 2 tubes are combined into where combine into a single tube to give a good measuring instrument today is use to a large extent which is known as pitotstatic tube which is used today to a large extent in all laboratories the simple measuring is instruments for fluid flow velocity and finally, the flow rate as you know if the velocity of fluid is found at each and every point we can find out the flow rate.

For example if this is a uniform flow you know the velocity if you find the velocity V then the flow rate is a into AV so determination of flow rate is nothing if we know the velocity we can find out if there is a velocity variation if we know the velocity at each and every each and every point then we can find out the flow rate by integrating the velocity and infinite small area in the location so, these things you know.

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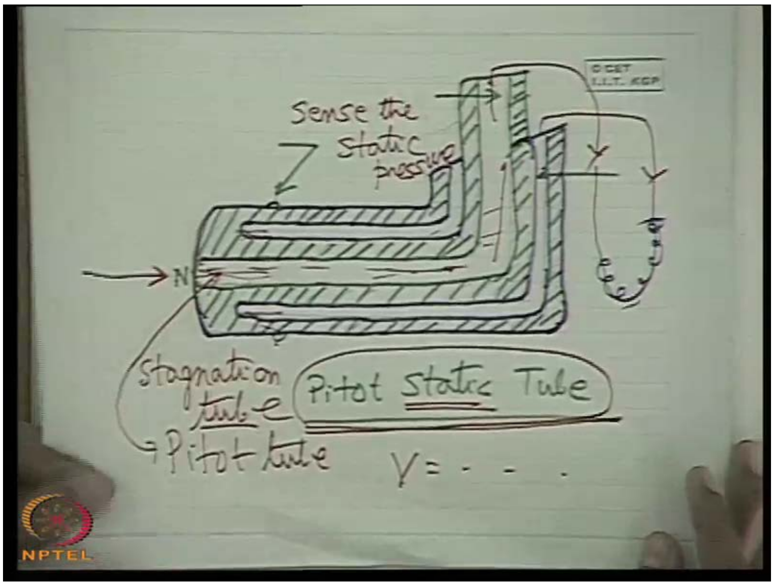

So therefore, this pitotstatic tube is widely used today in all laboratories to measure the fluid flow velocities or the flow rate so, these 2 tubes as I have described is made into a single tube to give so, this is the typical structure the shape is like this is nose so, this faces the fluid flow and this central tube is the stagnation tube this is known as stagnation tube or stagnation pressure measurement stagnation tube which measures the stagnation pressure which measures the stagnation pressure so, the fluid flows like this so, this part is the stagnation there is no flow there is a central static fluid.

And side this annular tube is the static tube so, this is the hole which senses the sense the static pressure sense the static pressure and this is the static pressure tube so, these holes are at this side so, this is inserted this is very small, but exaggeration I have made this amplification for this clarification this is very small tube these dimensions are negligibly small compared to the dimension of the duct so, that this does not put any disturbance to the flow field otherwise the flow field is disturbed, but how ever whatever small this dimension may be the flow field is usually disturbed.

So, what happens then this part is connected to one end of the manometer and this part is connected to another end of the usually a manometer is used in measuring the difference of pressure with a manometric fluid in case of flow of liquid like water oil a this is mercury So, therefore, from the manometer deflection we can find out the pressure difference between this tube and this tube that is the stagnation and static pressure and we can find out the flow velocity.

So, this is simply known as pitot static tube. pitot static tube measures the flow velocity which is combination of the pitot tube for measuring the stagnation pressure or this we can know simply pitot tube which is the measurement of stagnation pressure stagnation tube pitot tube along with the measurement of static pressure by the annular tubes through the surface holes they are combined in a single instrument and known as pitot tube is nothing great, but it was measure it was discovered long back by the scientist pitot and it is named after him as pitotstatic tube.

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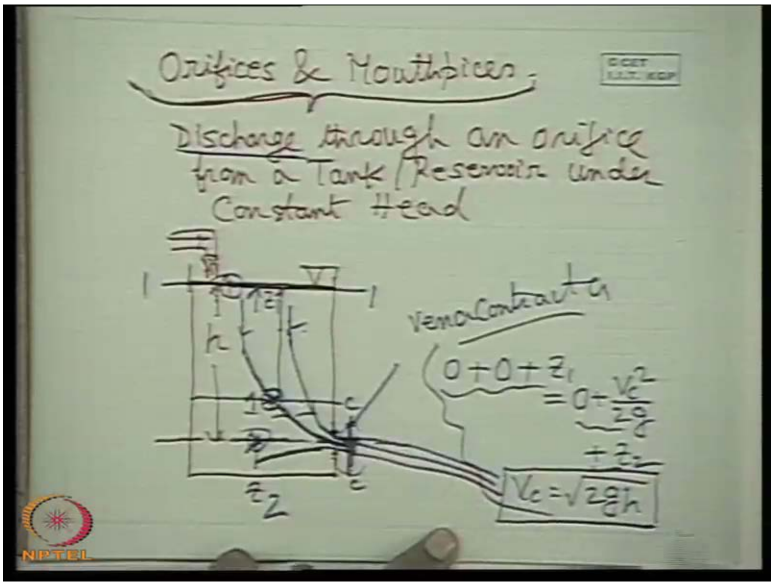

Alright now after this we will come to the next section which is very simple orifices and mouth pieces orifices and mouth pieces this is the most simple chapter of this fluid mechanics which probably requires the knowledge level of class 8 or class 9 I think so, nothing more than that orifices and mouthpieces what is an orifice. Orifice yes please tells me if you have any query please orifices and mouthpieces. Now an orifice now what we will discuss orifice is a small hole shaped edge hole or aperture in a tank or in a reservoir.

First we will discuss the discharge through a orifice discharge through an orifice through an orifice from a tank from a tank under constant head from a tank or reservoir whatever you write they are same from a tank or reservoir under constant head 1^{st} I thought that it may not be taught in the class, but complete the course curriculum. I this is so, simple let us consider a tank where there is a reservoir at the side of which there is a small orifice let there is a small orifice at the side of hole there is a small orifice that means a small aperture or hole whose cross section may be circular or may be of anything else.

And this tank is maintained with a constant head that means the height of the free water surface from the axis of the orifice this is maintained constant let this height is h how this is maintained constant? if the orifice the water is discharged from the orifice the water is also there is any inflow of water there is an inflow of water so, that the height is maintained constant this is shown like this and the constant height that means which is known as head, but this is the pressure head at any point any point at this axis.

Now what happens the water comes out from the orifice this is a very common experience. Now you will see this streamline converges like this streamline converges and ultimately it forms a section where the streamlines gets parallel and this is the section known as venacontracta let this section is cc this is known as vena contract a this is very close to the orifice the downstream of the orifice. Where it becomes parallel and then it falls against the gravity this is the solid jet so, the streamlines are not visualized by naked eyes without giving any dyeing agent it is coming as a solid jet so, it is obvious that the streamline which was initially like this flowing like this these gets a chain the water from here this takes a turn because it gets an aperture that is a discharge exit area so, it takes a turn.

And then ultimately it comes parallel again there is a turn in the streamline it gets parallel again and it attains a minimum section which is lower than the area of these orifice this section is known as vena contract a then it comes out from origin. Now our concern is to find out the discharge through an orifice how can we find out the discharge we can apply the Bernoulli's equation at any point at the orifice. At any point at the orifice or vena contract which is very close to the orifice we will rather take vena-contract and a section here let this section is one. So, now what is the pressure rate at one please tell me above the atmospheric pressure 0 what is the velocity head here 0 what is the data made here if.

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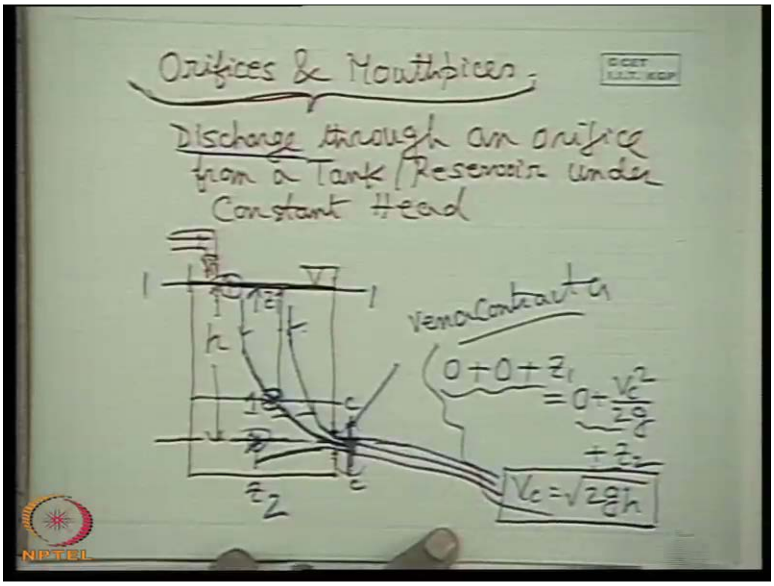

We now consider the data made from any reference data let these be z1 so, z1 in terms of the head energy per unit if I write then at this section if we consider this axis this is z2 then we can write here the pressure is 0 Vc square by 2g plus z2 so, therefore, this is equal to root over 2gh it is very simple, but here what we have assumed we have assumed the fluid to be ideal obviously for an ideal fluid this potential head or data made is utilized to generate velocity that is the maximum velocity generated at the minimum area.

So, this is in terms of the potential energy here at any point this is in terms of the pressure energy that means if we write the Bernoulli's equation here and here same equation we will get this is in terms of the potential energy. Sometimes we can choose a streamline which has been done in my book and took and take any point here as one and any point here in this cross section and use the Bernoulli's equation same thing you will get.

So, for this point you define a data made and for this point the pressure static pressure will be the pressure corresponding to the height of the liquid above and whatever we choose the point any 2 points, 1 point has to be in this section. Vena contract a section you always get these formula for an ideal fluid that Vc is root over 2gh.

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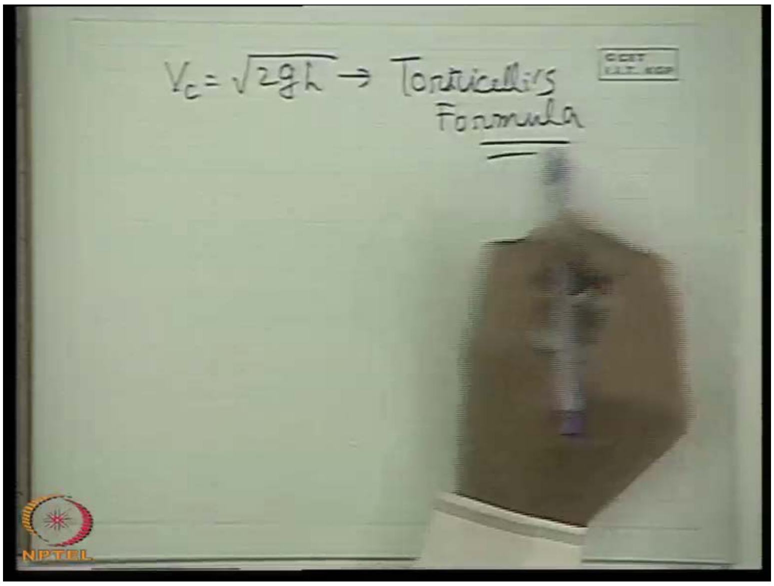

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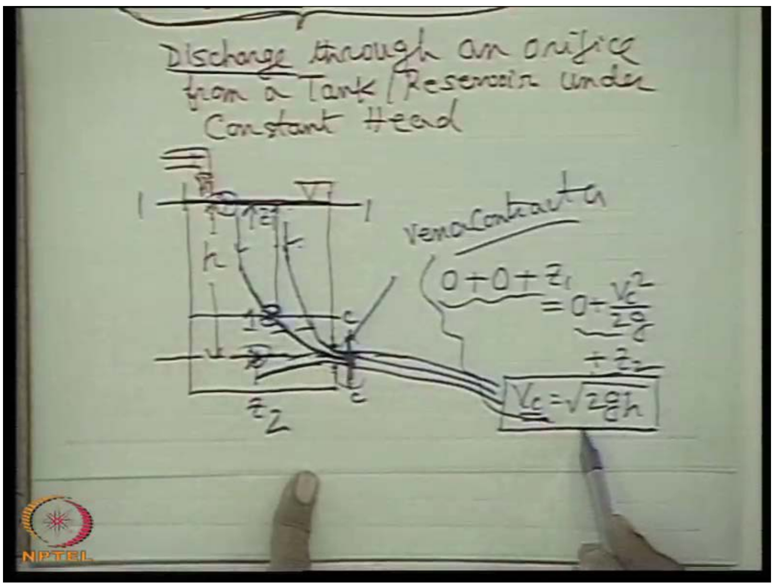

This formula Vc is root over 2gh for an ideal fluid which is so, simple even a school level boy will think this is so, simple was 1st found by 2r, 2, l Torricelli's formula this is known as Torricelli's formula for the discharge. But now if the friction is considered this is this is the deal velocity that is for an ideal fluid due to friction the velocity will be reduced obviously the entire potential energy will not be converted into kinetic energy or pressure energy will not be converted into kinetic energy because of the fluid friction.

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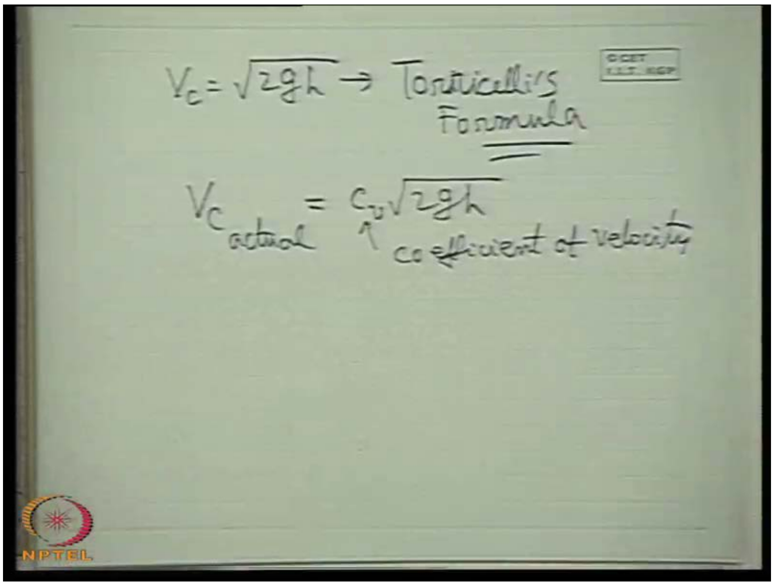

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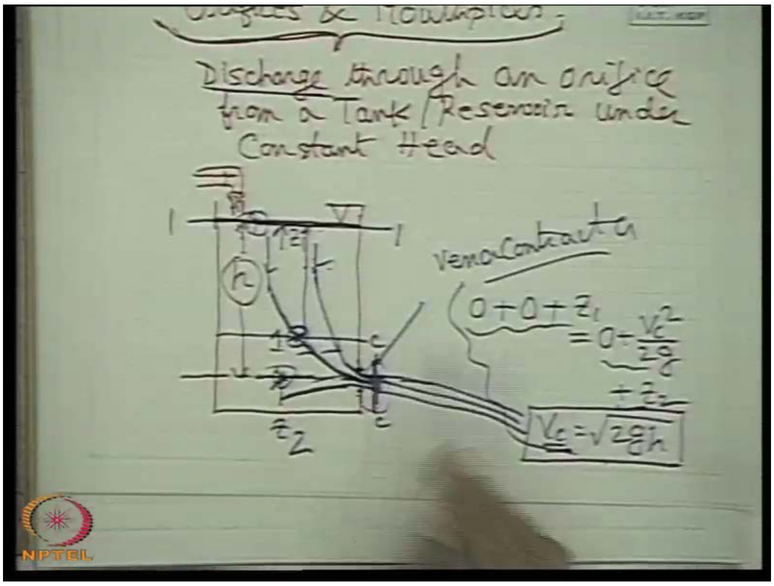

So, therefore, the Vc or the discharged velocity which is Vc actual which is that will be is equal to some constant into root over 2gh this constant is known as coefficient of velocity. Now this coefficient of velocity depends upon the height or the head above the orifice axis of the orifice and depends upon the velocity discharge depends upon the discharge velocity is head and same thing depends upon the geometry of the orifice that means the area of the orifice and the shape of the orifice well.

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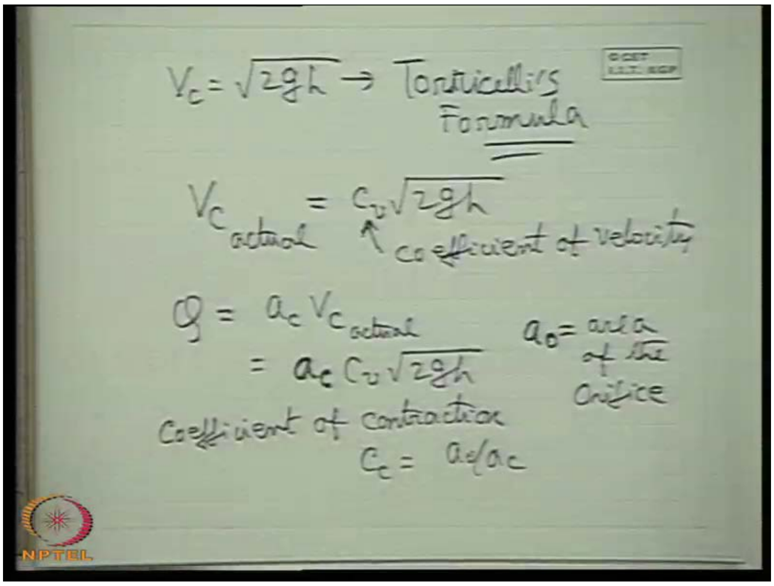

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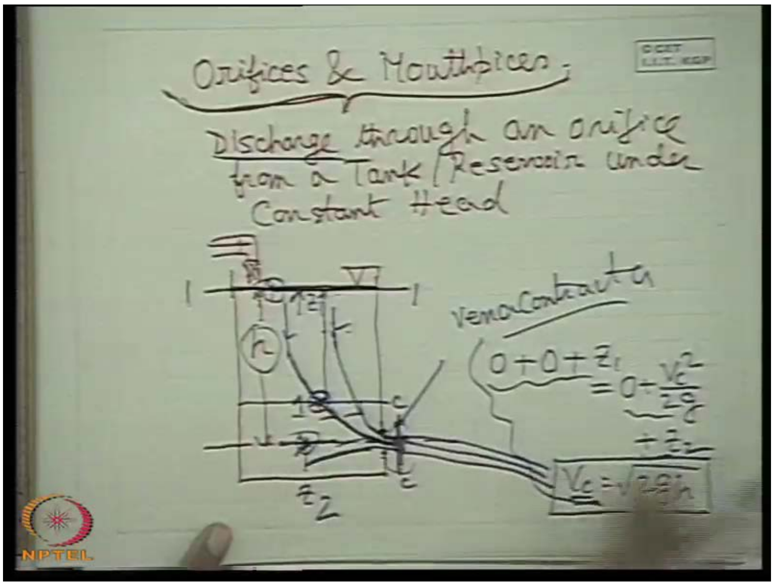

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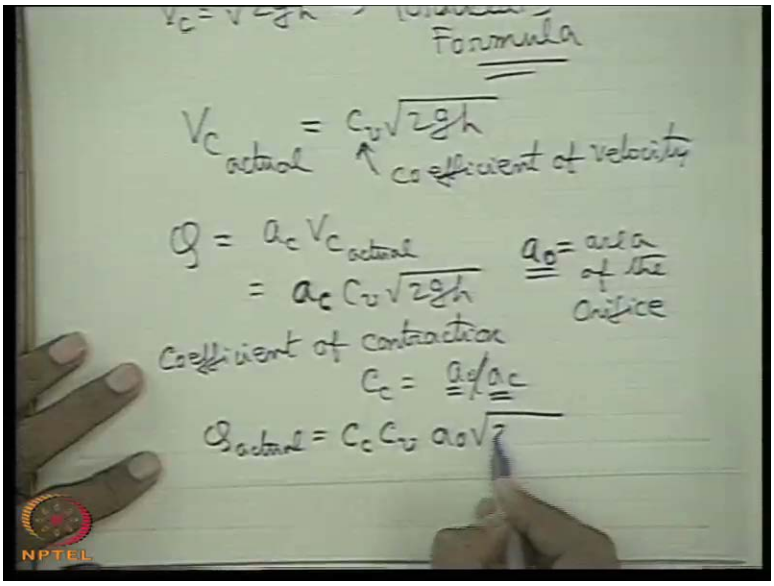

Therefore now we can write Q as ac into Vc actual now I can write Vc actual that means is equal to ac into Cv because I have got the actual velocity because I know Cv now this ac is the area of the vena contract a we have already recognized earlier that coefficient of contraction is defined coefficient of contraction Cc is defined as a0 by a c where a0 is the area of the orifice. Orifice is very small in dimension compared to the head or height of the water surface in the tank or the area of the tank so that we are not now much bothered about the shape of the orifice.

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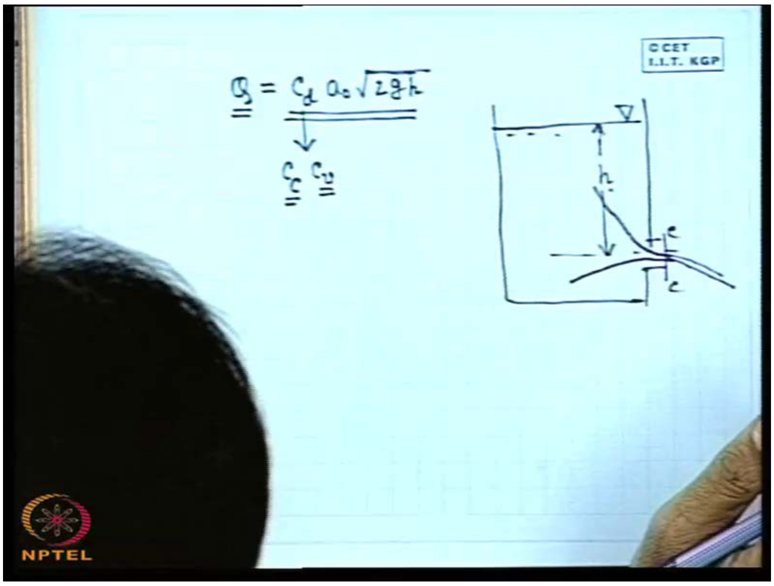

It is only the area a0 why the shape of the orifice and other things because the entire orifice is at a height h. So, the different points at the different locations of the orifice is not varying in it is head h so, we are not bothered about its shape and anything in simply the area of the orifice a0 so, ratio of area of the orifice to that of the vena contract a is Cc therefore, we can write this Q is equal to Q actual is equal to why I write Q actual I will tell you if I express the Cc into Cv into a0 into what.

Therefore we see that the discharge from a small orifice at the side of a tank is given by then Q is equal to Cd into the area of the orifice root over 2gh where h is the height of the free surface above the orifice for example, if this be the orifice then this is the h that means this is the free surface well and from the center line of the orifice this is the height of the free surface from the orifice.

So, we have we have found that or we have proved that the discharge rate of discharge through this orifice is given by Cd into area of the orifice root over 2gh and the streamlines if we see that we have just discussed like this converges to a small section a smaller section which is the vena contract a section and then goes like this. So, this is the vena contract.

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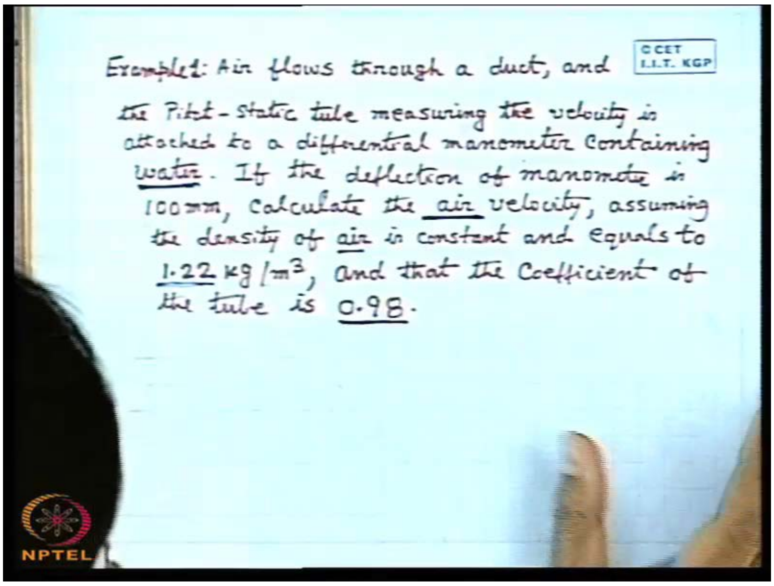

A section and this Cd as we have seen earlier is composed of the 2 thing one is the coefficient of contraction another is the coefficient of velocity which takes care of the friction and which takes care of the contraction of the streamline to a minimum area which is less than that of the orifice and h is the height above the orifice and orifice is so, small that at each and every point is under the same height h from the free surface so, that each and every point on the orifice is acted upon by the same potential head h so that the discharge coefficient is given by this formula which is known as Torricelli's formula that we have already appreciated.

Now for a better understanding of these things which we have discussed so, far we will go through some examples well let us start with the example number 1 so, this is the 1st example let us see that what it is air flows through a duct and the pitot static tube this is an example with this stagnation pressure and static pressure problems. How to measure the velocity of a fluid and the respective discharge by a pitot static tube? So, again I start the problem air flows through a duct and the pitot static tube measuring the velocity is attached to a differential manometer containing water well.

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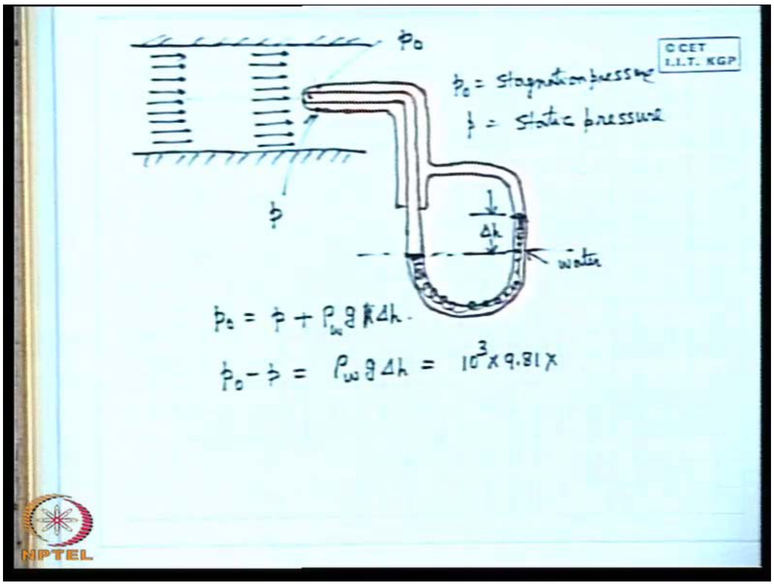

If the deflection of manometeris hundred millimeter that is the deflection of the manometer for the manometric liquid calculate the air velocity assuming the density of air is constant and equals to 1.22 kg per meter cube this is the density of the air and the manometric liquid is water attached to a differential manometer containing water is the manometric liquid air is the working fluid measuring the velocity attached to a measuring the velocity is attached to a differential manometer density of air that means it is given calculate the air velocity that means the working medium is air the flowing fluid is air and the manometric liquid is water well the density of the flowing fluid that is air is constant and equals to 1.22 kg per meter cube and that the coefficient of the tube which is very important is 0.9 8 now how to solve this problem?

So, let us now see that the problem we draw this duct 1st let us see that this is the duct through which the fluid is flowing well this is the duct this is the duct through which the fluid is flowing and let us see that this is the flow velocity let us represent the flow velocity like this that means flow is in this direction. Flow is in this direction from left to right well this is the direction of the flow left to right. Now a pitot static tube pitot static tube is attached to this to measure the velocity at the point So, therefore, now we will construct a pitot static tube or we will place a pitot static tube so, let us show that pitot static tube like this now this is a pitot static tube let me draw which has been drawn earlier also we have shown the pitot static tube earlier also.

So, this is the typical pitot static tube this is the central part of the tube which senses the stagnation pressure that means this is facing in the direction of the velocity and this is the typical u tube manometer well and this is the typical u tube manometer so, u tube manometer you just see that this is the pitot tube pitot static tube well this is the pitot static tube now let you see that this is the typical arrangement and you just show that this is the liquid column that is the water this is water well and this is the deflection delta h well this is the deflection delta h. Now look that this central tube senses the stagnation pressure so, this is height so, that this end is getting depressed and this end is going up.

So, this the delta h the deflection in the liquid in the manometric tube well and this part is filled with air now here the pressure is the stagnation pressure here at any point the pressure is the stagnation pressure that is P0 here the pressure is P0 and here at any point which senses the static pressure the pressure is P0 is the stagnation pressure P0 is the stagnation pressure stagnation pressure and P is the static pressure. static pressure well, now if we write the manometric equation here one thing is that if we neglect the density of the pressure due to this column of the air in both the sides because of the low density of air corresponding to that of the water.

Because the density of the air is thousand time less than that of the water so, that we can neglect the air pressure due to this column of air very much and we can tell that the P0 which is sensed there is just sensed at this level and obviously the P the static pressure which is sensed here through this tube is sensed at this meniscus level so, that if we write the hydrostatic pressure equation. Considering this as the plane where the pressure is same in the same expands of the liquid as we have read earlier in the subject of hydrostatics then we can write that this side pressure is P0 and this side pressure is P that static pressure plus rho of w that is the manometric liquid which is water into g into h.

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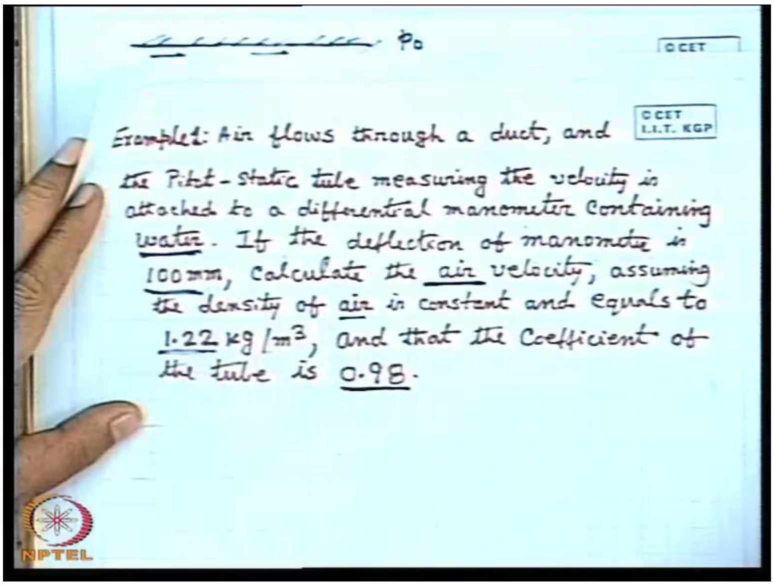

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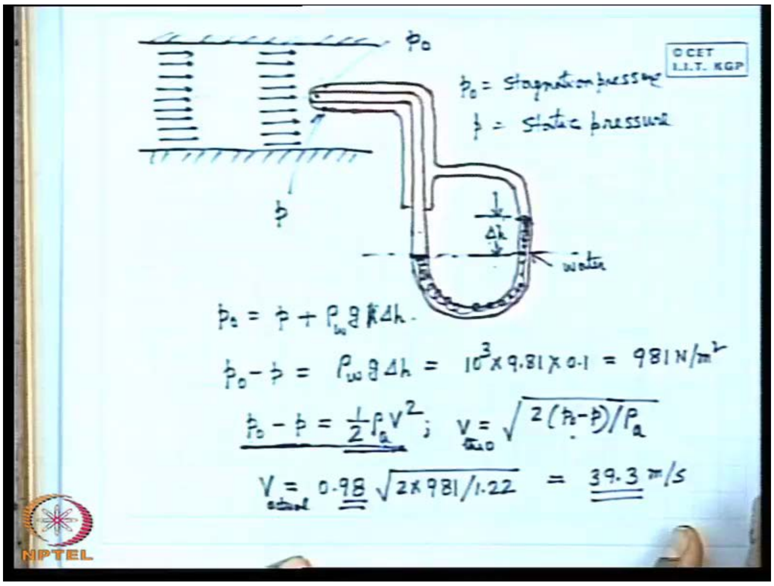

It is delta h therefore, p0 is equal to p plus rho wg delta h well so, that we can get the difference in the stagnation and static pressure as rho wg into delta h and in this problem it is given water so, 10 to the power 3 is the density of the water into the g is 9.81 into the delta h which is given as in the problem you see that delta h is given as 100 millimeter the deflection of manometer is 100 millimeter So, therefore, we can put it in terms of meter 0.1 and this gives us 0.98 well Newton per meter square this is the difference between the stagnation and static pressure. Now if we write the velocity we know that the difference in stagnation and static pressure as we have recognized earlier from the definition of stagnation pressure is the pressure equivalent of the velocity.

That means if the velocity at that location is v then half rho V square equals to P0 minus P this is the way the stagnation pressure is defined that is P0 is equal to P plus half rho V square well so, if we use this then we get here I write V is equal to root over 2P0 minus p by rho and this rho mind that this is the density of the air because when we write this equation this comes from the Bernoulli’s equation applied to 2 sections where the pressure is stagnation pressure that section where the pressure is static pressure along with the velocity V therefore, here the density which will come that will be then that will be the density of the flowing fluid that is rho of air in this case air is the flowing fluid.

So, therefore, if you write v will be equal to this is the theoretical velocity. This is theoretical velocity so, the actual velocity will be multiplied with a coefficient then C will be multiplied with a coefficient now this coefficient is 0.98 as it is given in the problem the coefficient of the tube you can realize there is a you can see that the coefficient of the tube is 0.9 8 therefore, 0.9 8 times 2 into P0 minus P.

Already we have calculated earlier 981 Newton per meter square alright divided by 1.22 is the density of air which is also given in the problem that this is the density of air 1.22 kg per meter cube so, that if you calculate this thing it will come out to be 39.3 meter per second.

So, therefore, you see the application that a pitot tube is attached or pitot tube is placed here to find the velocity of the local position this local velocity of this position. So, the central part of this sense the stagnation pressure the annular part of the tube sense the static pressure this is attached to a differential manometer with a manometric liquid usually when air is the working fluid the manometric liquid taken is water well.

So, that we get a differential head difference between the meniscus level delta h which is nothing, but the difference between the stagnation and static pressure which is again equivalent to half rho V square where rho is the density of the working fluid and from there we can calculate the velocity this is the theoretical velocity because this is the Bernoulli's equation where friction is neglected so, this is being multiplied by a coefficient of the tube which is the frictional losses in the tube which depends upon the design of the tube for a given fluid it depends upon the design of the tube so, for a tube this is being calibrated so, that the coefficient of this tube is given before and by calculating the actual velocity from this formula.

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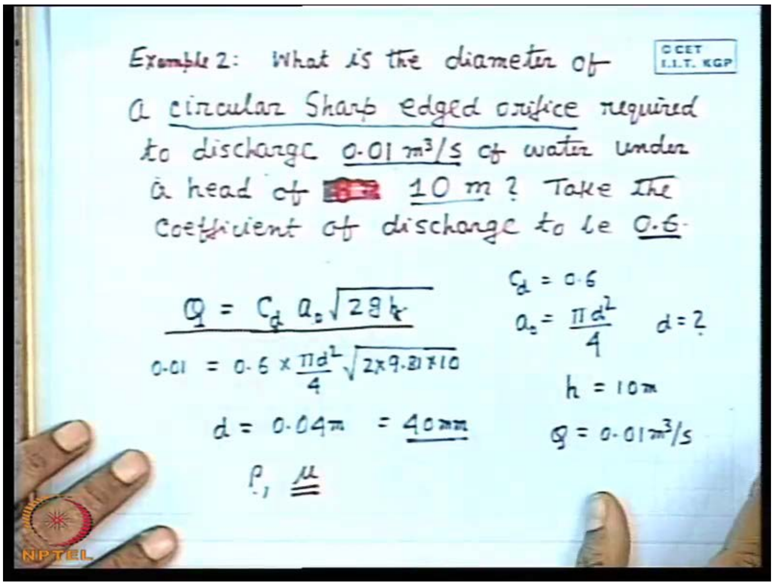

Well now next we will go to another example regarding the orifice which we have Torricelli's formula which you have we have just discussed. Example 2 this problem is like that what is the diameter of a circular sharp edged orifice required to discharge 0.01 meter cube per 2nd of water that is the discharge rate under a head of 10 meter take the coefficient of discharge to be 0.6 so, it is a straight forward application of Torricelli's formula as we know the discharge through an orifice under a constant head in a tank is given by Cd that is the coefficient of discharge into the area of the orifice into root over 2gh.

Alright here is a straight forward applications we get we have Cd is 6.6 now it is a circular orifice sharp edged circular orifice so, that the area of the orifice will be pi times d square where d is the diameter of the orifice by 4 so, that we can write pi d square by 4 d is given d we have to find out d is not given so, h is given under a head of 10 meter h is given so, our problem is to find out d that means we have to apply this formula straight forward to get d well let us do that now Q is also given Q is 0.01 meter cube per 2nd alright.

So, I write Q is equal to 0.01 is equal to Cd is 0.6 then the area is pi d square by 4 alright then root over 2g is 9.8 1 and h the head is 10 meter. Now this we write all the values are given only the value of d has to be found out so, if 1 makes the calculation he will get d from here as 0.04 meter which is equal to 40 millimeter therefore, we see for a circular orifice a 40 millimeter diameter is required to discharge this much that is 0.01 meter cube per 2nd of water under a head of 10 meter this is the direct application of the Torricelli's formula that the rate of discharge is given as Cd into a0 into root over 2gh.

Now here I like to mention one thing that in this equation Q is equal to Cd into a into root over a0 into root over 2gh the liquid property that is the density and the viscosity is not coming explicitly you see that means whatever may be the liquid Q that is the discharge rate can be found out if I know h and if I know the discharge rate coefficient of the orifice. Now the question comes how then the density and viscosity is a very important property comes into picture because obviously this comes from our common sense that when different fluids are used or liquids are used with different viscosities even under a given head the discharge rate will not be same.

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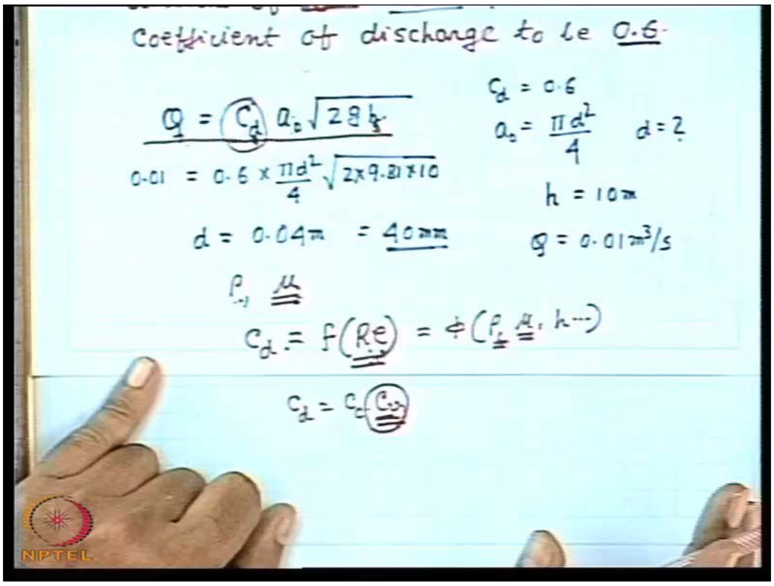

So, the answer to this question lies in the fact that the c d that the Cd is a function of the viscosity usually Cd becomes a function of the Reynolds's number the Reynolds's number where the Reynolds's number contains the viscosity and also the density so, this is a function of Reynolds's number that means this is indirectly a function of the density viscosity and the liquid head height and all these things.

So, therefore, we see the viscosity and density this 2 liquid properties are impeccably expressed through the coefficient of discharge usually when the Reynolds's number is low for a high viscosity liquid then the value of Cd is low so, one will expect then in that case the actual discharge for a given head or given height for that liquid through orifice of given area will be less because of the fluid friction because if you recollect the Cd is a composed of Cc into Cv so Cv is the coefficient of velocity which takes care of the fluid friction.

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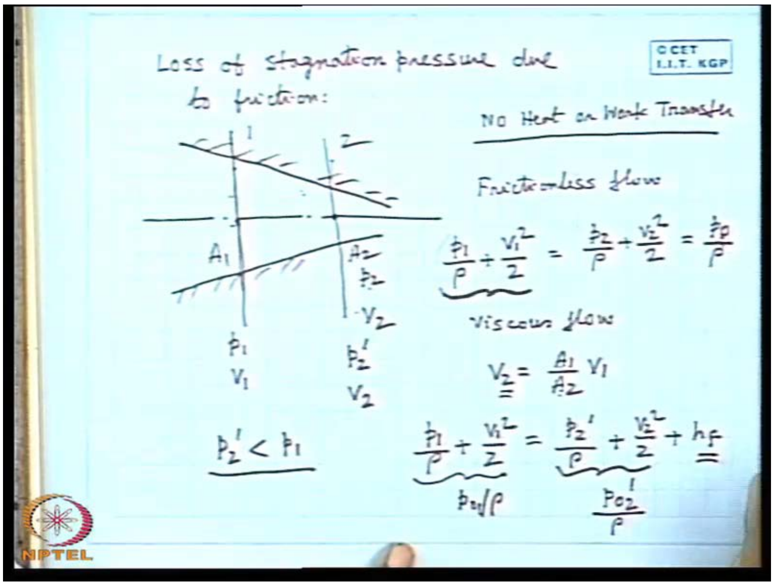

So, for a given orifice the fluid friction depends upon the viscosity of the fluid for a half edged orifice the friction at the orifice edge is very small, but never the less the friction losses are there and also because of the motion in the tank so, that the value of Cv is taken care of the value of c v takes care of rather takes care of all these things which may change due to the change in the viscosity of the fluid so, that with the Reynolds's number this Cd changes and therefore, these 2 properties rho and mu are inherent in this definition of the Cd then we see a straight forward applications of these circular sharp edged orifice required to discharge required a given discharge under a given head.

So, next we will come to another thing is that very important thing I like to discuss in this context is the loss of stagnation pressure loss of stagnation loss of stagnation pressure due to friction due to friction loss of stagnation pressure due to friction which is an important thing I must tell that how this stagnation pressure is reduced due to friction let us consider the flow through a convergent duct it is not necessarily to be a convergent duct, but let me consider a convergent duct for our simplicity or for our better understanding let us consider 2 sections.

Let us consider 2 sections 1 and 2 and at section 1 let the pressure is P1 and the velocity is V1 and at the section P2 section 2 let us consider may a pressure is P2 and velocity is V. And we consider the flow so, that no heat or work transfer takes place no heat or work transfer that means the flow is adiabatic there is no heat transfer and no work transfer that means from outside there is no interaction in the form of energy transfer with the fluid neither heat is added nor heat is rejected neither work is added nor work is rejected. So, then what happens if we write the Bernoulli's equation in case of a frictionless flow in case of a frictionless flow frictionless flow in case of a frictionless flow in case of a frictionless flow.

And if we consider the change in the data made is negligible between the section 1 and 2 or in case of an horizontal convergent duct then we can write P1 by rho plus V1 square by 2 obviously is equal to P2 by rho plus V2 square by 2 because there is no loss and moreover the data made with the potential head is negligible or there change is 0 and these 2 things equals nothing, but the P0 by rho that means where P0 refers to the stagnation pressure at this sections and at this section that means the stagnation pressure at this section and this section remains same which means that the stagnation pressure is not changed if the friction is not there.

This is the same thing that if we tell that is stagnation pressure is the equivalent total mechanical energy except the kinetic energy that means stagnation pressure refer to the pressure equivalence or energy pressure energy equivalence pressure mechanical energy equivalence pressure if we describe the kinetic energy part so, long the eh if we discuss the potential energy part that means if the potential energy changes are neglected then the total mechanical energy remains same in a frictionless flow so, that the stagnation pressure remains same, but if you consider a viscous flow.

Which happens in a reality if you consider a viscous flow and in that case if I define P2 dash is the pressure here and V2 is the velocity. velocity will remain same why because of continuity if area of cross section here is a1 and the area of cross section here is a2 then because of the continuity we can tell V2 is a1 by a 2 into V1 alright V2 is a1 by a2 into V1 so, therefore, from the continuity the average flow velocity will remain same then what will happen in that case P1 by rho plus V1 square by 2 if I write the Bernoulli's equation.

Then this side it will be P2 dash by rho plus V2 square by 2 plus the frictional head loss h which is lost due to friction that is a part of mechanical energy converted into intermolecular energy which means that P2 dash is less than P1 this we have recognized. Now therefore, we see the stagnation pressure corresponding to this section is this total mechanical energy that is except the potential energy that is P0 by rho whereas, the stagnation pressure at this point if we define d dash p 0 this is P0 one P2 dash divided by rho

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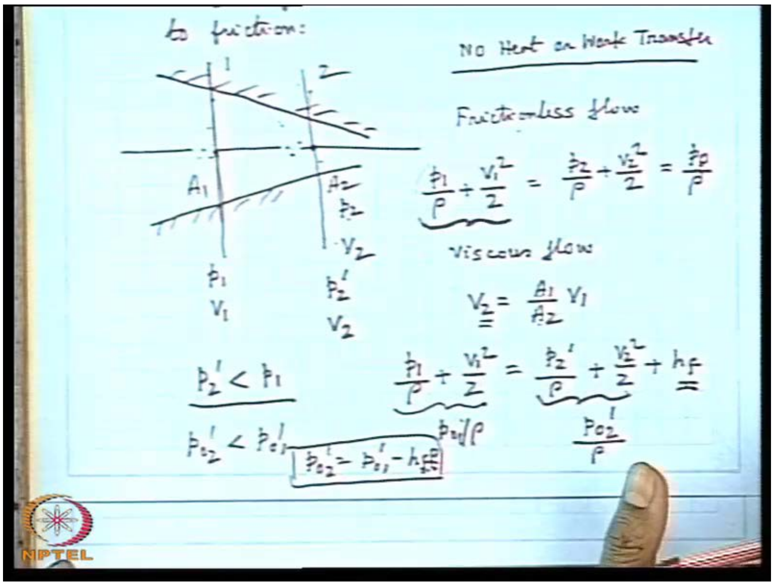

Then we see that P02 dash is less than P01 dash because this is less than this by this amount h f that means we can write that P02 dash is P01 dash minus hf that means the stagnation pressure is reduced because of the friction and the reduction is equivalent to in terms of rho that means we have to multiply rho here otherwise if you express in terms of the stagnation pressure head by rho then it will be simply hf. That means the stagnation pressure or stagnation pressure head is reduced by the amount which is equal to the frictional head loss or the energy loss due to friction mechanical energy loss due to friction.

So, this is the concept the stagnation pressure remains unchanged if the flow is in viscid or frictionless flow there is no dissipation and provided there is no interaction of energy from the outside this happens in case of an adiabatic flow and without friction and this is known as isentropic flow afterwards in the study of gas dynamics we will see that in isentropic flow the stagnation pressure remains unchanged this is the theory, but when friction comes into picture the stagnation pressure is reduced by the amount which equals to the head loss due to friction or energy loss due to friction so, this is an useful concept that a stagnation pressure goes on changing because of the friction.

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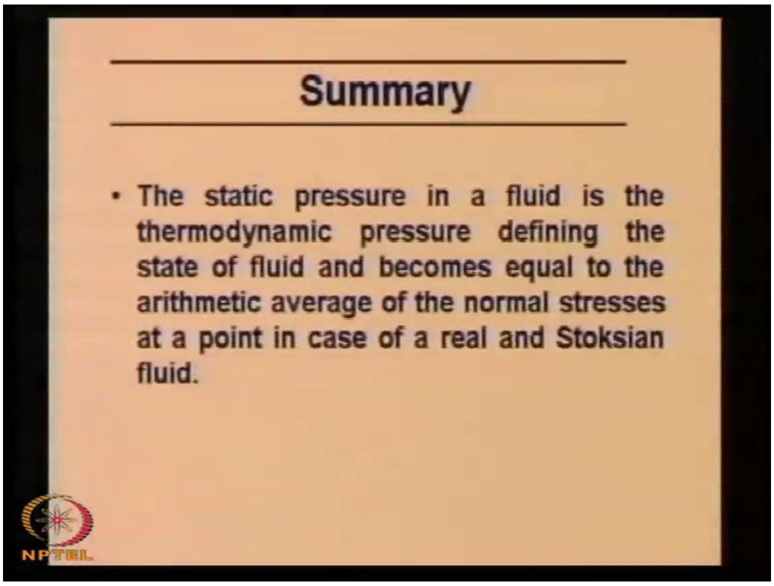

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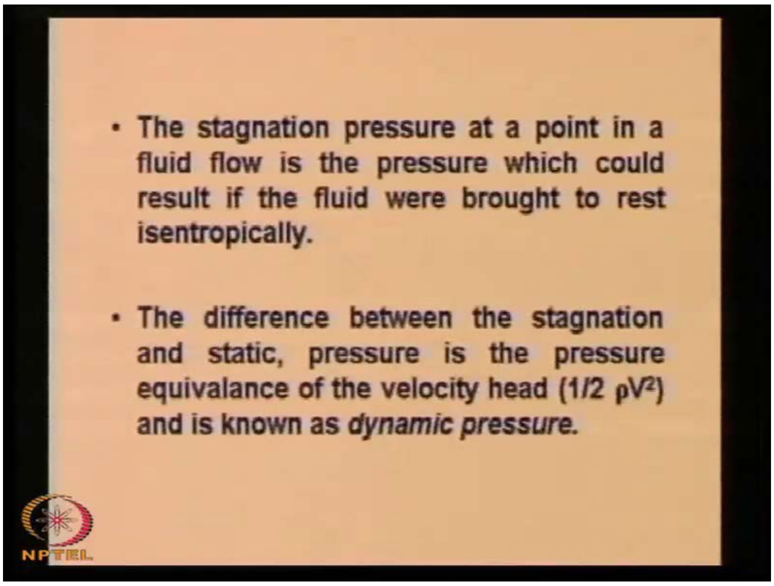

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