Fluid Mechanics

Prof. S. K. Som
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 5

Fluid Statics Part – II

Good morning to all of you. I welcome you to this session of fluid mechanics. We will be continuing our discussion on fluid statics. So, last class if you recall, we were discussing the basic equations or fundamental equations of fluid statics. And we finally recognize that in an expanse of fluid at rest, the pressure varies only in the vertical direction the pressure does not vary in the horizontal plane. In a horizontal plane that means if we recognize a Cartesian frame of reference, with vertical axis as one of the coordinate axis then we see that a pressure seizes to be a function of other coordinate axis or space coordinates in a horizontal plane, pressure simply varies in the vertical direction. And it decreases with an increase in the z or the vertical coordinate that means upward; in upward direction the pressure decreases. This is because the slope of this pressure with this upward direction coordinates gives a negative value.

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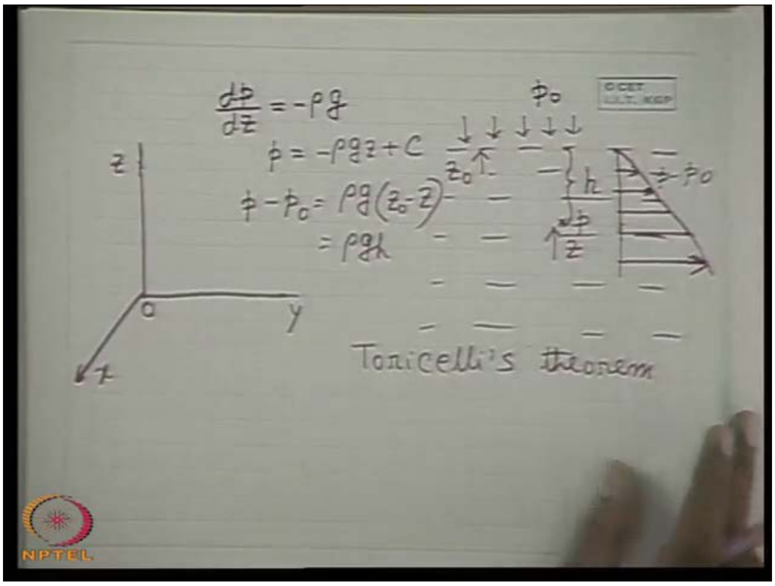

And if we now recall this mathematically, then we see that if we recognize this x, y and z coordinate, we have seen that the basic equation is like that d P d z that means P is a function of z only, and its slope is given by minus rho into g, provided the body force is the only gravitational force. That means in this expanse of fluid at rest no other external force is acting, that means only external force acting or the body force acting is the gravity force. And then the pressure varies only in the z direction by this equation.

And also we recognize that in case of an incompressible liquid, the solution for this is-P is equal to; that means when rho is constant, minus rho g z plus a constant. And we recognize that if we have an expanse of fluid at rest with a free surface, if this be a free surface where the pressure impressed is the ambient pressure P0, then we can find this value of C and if we define the z coordinate of the free surface as z0 from any frame of reference. And at any point where we are finding out the pressure P the z coordinate is z, then these equation can be written that P minus P0 is simply rho g into z0 minus z; alright?

Z0 minus z is simply the vertical depression of this point from the free surface. If we define it as h it is simply rho g h. Therefore, we see that if we express the P minus P0, the difference in pressure from that of the ambient pressure exerted on the free surface of an expanse of fluid, it is a linear variation P minus P0. It starts from 0 and linearly varies with the depth, linearly varies with the depth. And this formula was first found by the scientist Torricelli and that is why it is known as Torricelli 's theorem

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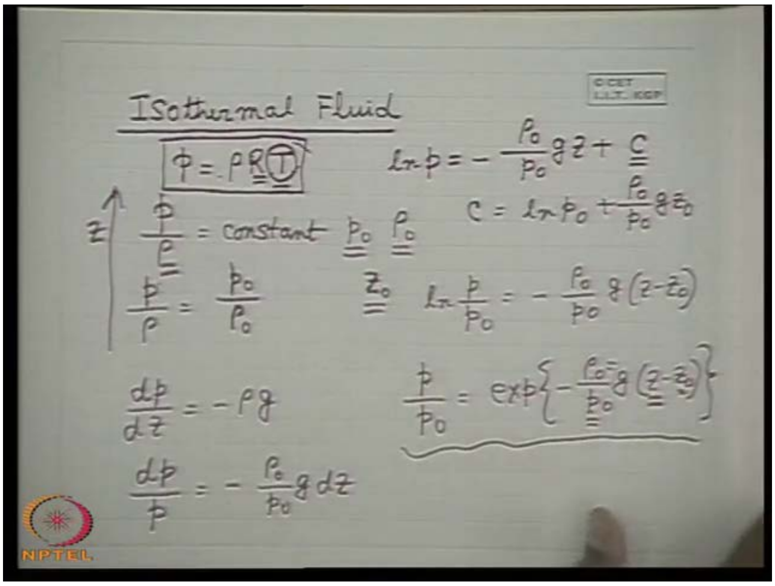

Now, we will find out the similar explicit relationship of P with z for compressible fluids. This is simple mathematics not much fluid mechanics is involved. Now, we first consider an isothermal fluid. Compressible fluid means whose density changes, an isothermal fluid that means a fluid at rest, a fluid at rest where the density changes, but temperature remains constant. Now, you know for any system the equation defining the pressure, density and temperature is known as the equation of state. Equation of state defines a functional relationship between pressure, density and temperature.

So, if we consider the compressible system or the gas as a perfect gas, this functional relationship between pressure, density and temperature-equation of state is given by P is equal to, probably you know these things from your physics knowledge, in physics or thermodynamics, where R is the characteristic gas constant, so for an isothermal fluid T is constant. Therefore, the relationship between pressure and density is that P by rho is constant. Now, it becomes simply school level mathematics. We can write the pressure P. Let us write P like this, P by rho in terms of a reference pressure P0 by rho 0 where P0 and rho 0 is a reference state. That means at some location if pressure is P0 and density is rho 0, which we take as reference state then P by rho, these are the variables, is P0 by rho 0.

Now, the simple task is to solve this simple mathematics, d P d z, is very simple, minus rho g by substituting the value of rho. If you substitute the value of rho from this equation, here you get d P by P rho is P rho 0 by P0, is minus, what, rho 0 by P0 rho 0 by P0 g d z. Now, if we integrate this, we get l n P is equal to, we get integrate very simple, rho 0 by P0. These are the constant defined by the reference state plus some constant.

Ok, this constant we can found, we can find, if we define that the z coordinate at these reference state of P0 and rho 0, where pressure is P0 and rho 0 we define the z coordinate for the reference states the z coordinates from any reference coordinate axis is z0 then we can find out the value of C as l n P0 plus rho 0 by P0 g z0, that we can find out the value of C. And these values of C if we substitute here, simple school level thing, we get l n P by P0 is minus rho 0 by P0 into g z minus z 0. This is the simple expression or you can write in terms of the exponential function, l n means that it is the exponential function, that is exponential function of minus P0 by, rho 0 by P0 g times z minus z 0, so we get.

So there is nothing. Fluid mechanics it is only a mathematical exercise through which we can find out the variation of pressure with the vertical height z, that vertical height z, in case of a compressible fluid, where density changes along with the change in the pressure. Or other way you can tell the pressure changes because of the change in density in a fashion that the temperature remains constant. And we consider the system of compressible gas or a compressible system behaves as a perfect gas, where the equation of state, that means the relationship between pressure, density and temperature has this form P is equal to rho R T so that we can use that. And therefore, the nomenclature P0 rho 0 and z 0 are the reference state that means at some location z 0 we know the value of pressure as P0 and density as rho 0. So, this is the expression. In the similar way we can find out the expression where the temperature changes, where the temperature changes, rather we can write non-isothermal case, non-isothermal case.

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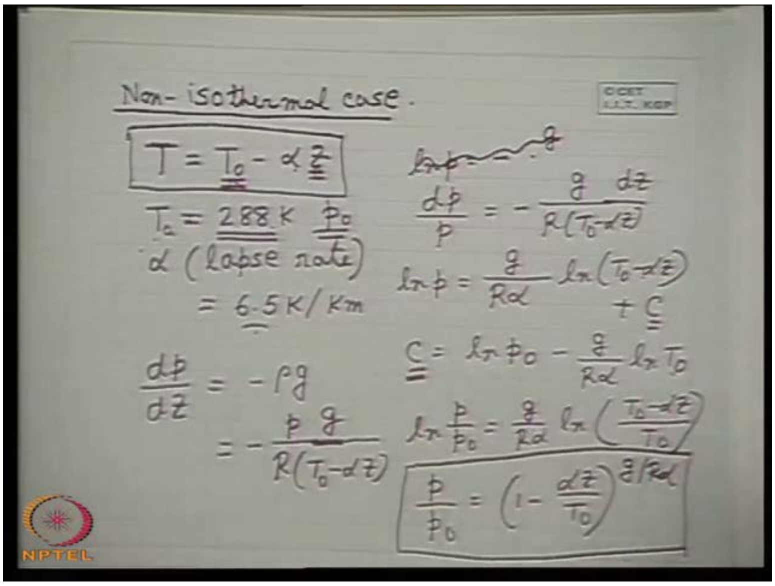

Now, this is very important where the temperature changes. But in this regard I like to tell you one thing that in our atmosphere, the temperature up to a certain height changes linearly with the altitude. And if we express the temperature in that level of atmosphere from the earth surface, where temperature changes linearly with the altitude, we can write this way. This is the temperature at the sea level and z is the altitude from the sea level. In our usual atmosphere the value of T0 at the sea level is approximately 288 P0. And the value of alpha, this is known as, this is the terminology lapse rate that up to the altitude, which this linear decrease in temperature takes place. The lapse rate that is constant in this equation that is equal to 6.5 P0 per kilometer.

So, this way if we define the temperature change as the temperature decreases with the altitude, then the rest part that we have to find out the explicit relationship of pressure with the altitude becomes simple mathematics. That means minus rho g. Now rho is what? From the equation of state, along with that if we assume that the atmosphere varies sorry, behaves as a perfect gas where rho can be expressed as P by R T and in place of T if I write T0 minus alpha z, that is times the g. That means what I have done rho is P by R T and T is varying with z. T0 is a constant, which is the value when z is equal to 0 and z is measured from the earth surface at sea level and this is the temperature at any altitude z. So, T0 is usually 288 Kelvin, it is a typical value and alpha is this one. So, T0 alpha is the constant parameter.

Now, next rest part is simple mathematics that you go on. Integrating this, if you integrate this taking P here d P by P then you get l n P is equal to minus g by R. Sorry, I think we I must write another line, otherwise it will be difficult for you. D P by P is equal to minus g by R, T0 minus alpha z d z. So, if you integrate it then here it will be l n P and if we integrate it will be l n T. L n T0 minus alpha z with respect to d z and alpha minus alpha. So, minus-minus plus and alpha will come, this coefficient in the denominator, the usual rule of integration and simply T0 minus alpha z as the whole argument l n. So, this will induce a constant C and this constant you can very well determine as you say that T0 is the temperature when z is equal to 0. That means I can write C is equal to l n P0. If we consider the P0 is the atmospheric pressure at sea level corresponding to T0 and z is equal to 0, then I can simply write C is equal to minus g by R alpha l n T0.

So if I substitute this value of C here, then I get a simple expression l n P by P0 is, what? L n g by R alpha l n T0 minus alpha z. Minus l n T0 I take inside l n. This minus l n, this is l ; this by this that means T0 minus alpha z by T0. This l n things I can remove and I can keep it in terms of, I write it, alpha z by T0, comes within the bracket, raised to the power R alpha. That means these gives a power law type of variation. So, this is nothing but a simple mathematics. Well, any difficulty?

Now, I will come to the pressure and it is measurement. Now, you see the pressure at of any system is usually measured in two scales. When we talk about a zero pressure means complete vacuum, there is no material the pressure is zero. Our atmosphere, earth atmosphere at sea level has got a pressure which is known as local atmospheric pressure, local atmospheric pressure. That depends upon place to place that is why it is known as local atmospheric pressure. That any point on the earth surface there is a pressure of the air exerted at that point it is known as local atmospheric pressure.

Now, if the pressure of a system is higher than the local atmospheric pressure, then it is sometimes measured in terms of the difference from the local atmospheric pressure. And that pressure is known as gauge pressure usually, a gauge pressure. If the pressure of a system is below the local atmospheric pressure, because local atmospheric pressure has got some absolute value, is more than zero, the minimum value of the pressure in the absolute scale is 0. Well, so if the pressure is below the local atmospheric pressure, then also sometimes it is measured in terms of the difference between the local atmospheric pressure. And if you make the difference as the pressure of the system minus the atmospheric, in this case it is negative that is why it is told as negative gauge pressure or vacuum pressure.

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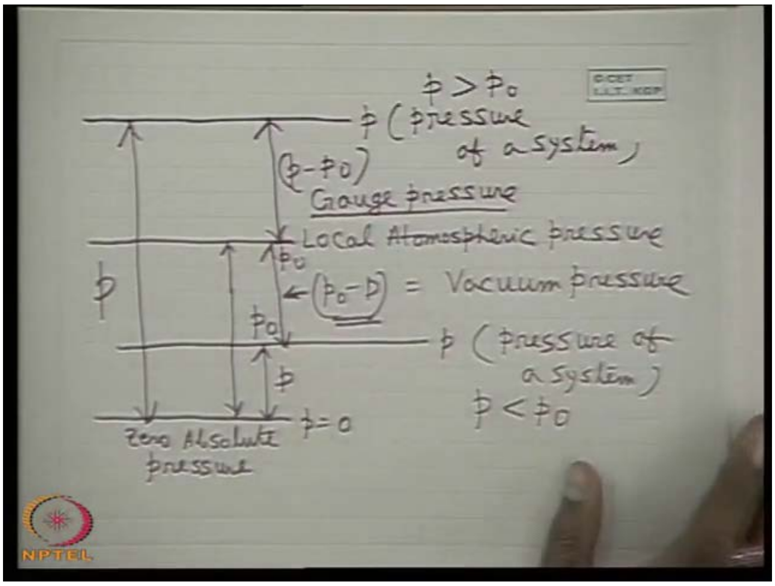

So, these are the terminologies-either absolute pressure, which is measured with respect to a 0 datum, or the gauge pressure which is measured with respect to the local atmospheric pressure. If it is above it, the gauge pressure is positive gauge pressure; usually the word positive is not used. And it is below the local atmospheric pressure, it is negative gauge pressure or vacuum pressure. So, these are the terminologies. You can show it like that, that if it is a 0 absolute pressure, absolute pressure or a complete vacuum, 0 absolute pressure complete vacuum.

Let us see that this is the local atmospheric pressure, this is the local atmospheric pressure, local atmospheric pressure line, local atmospheric pressure, very simple. That means this is the value of the local atmospheric pressure that is P0. Let this is P0, this is P is equal to 0, then if a system pressure is like this, if that be the pressure P, the pressure of a system, pressure of a system that is absolute pressure of a system, then what is P according to the scale? This is P, this is P. Now, this is P minus P0, which is the gauge pressure g a u g e. This is known as gauge pressure; that is positive gauge pressure.

Now, if a system pressure is like this, if a system pressure lies here that is P, it is the pressure of a system. Here pressure of a system P is greater than the local atmospheric pressure. Here the pressure of a system P shown as less than the local atmospheric pressure. So, this is its value-P absolute pressure. Now, this difference, that means this one that is P0 minus P, this is the vacuum pressure, vacuum pressure. The positive value is the vacuum pressure or it is the negative gauge pressure if you, this one, if you express it as P minus P0.

So, in the measurement of pressure if the pressure is or in specifying a pressure, if the pressure is tell in terms of gauge pressure or simply this unit, then gauge, then it is known as the pressure above the local atmosphere and vacuum pressure means that is the pressure below the local atmospheric pressure.

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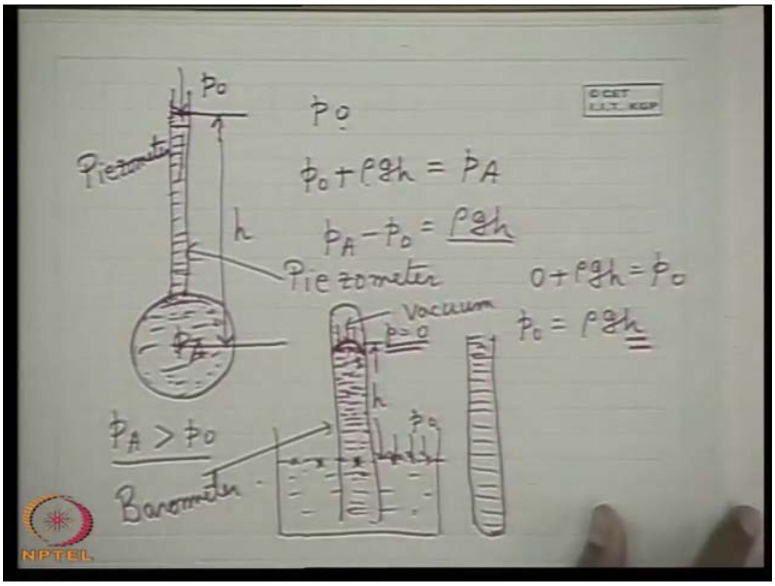

Now, I come to the measurement of liquid pressure, which is very simple. I think I will give you only simple cases, you just read from the book. Now, the very first simple case if you consider a system for example, like this a closed system containing a liquid at a pressure P A. Let the system has got a fluid liquid or fluid whatever you tell. You consider a liquid which has got a pressure P A, which is higher than the local atmospheric pressure. So, it was Torricelli first to found his principle that the liquid at any point the pressure, at any point in a liquid is equal is proportional to the height above it. So, what happened if you just open an attach a long vertical tube open at the other end what will happen? Because of this high pressure liquid will go up and it will stand up to certain height depending upon the value of P A, relative to P0.

So, what then we can tell if I measure this height h from this place or centre, let as take this centre where the pressure is P0. If this height is h, then here the pressure is P0, which is the ambient pressure impressed on this free surface. Then we can write P0 plus rho g h that is the pressure here rho g h. If we consider this liquid is a constant density in case of liquid, it will be like that it is a fluid constant density. So that the pressure variation here follows the rule rho g h is simply equal to P A. That means we can measure the gauge pressure by simply noting this height h, rho g h, this type of, this type of a tube attached to a system and open at one end and to measure the pressure from the height of the liquid standing on this tube. This is given by Torricelli and this tube is known as piezometer, piezometer. This type of tube is known as piezometer or piezometric tube, piezometer or piezometric tube.

But now, we see that it is not always possible to have a piezometric tube to measure a pressure of the system. Because of two things: first thing-if the pressure is very high so that if we have a piezometric tube we may have to have a liquid column whose height is very high and which is very difficult to read. Similarly, if the pressure is very low, then the height of the liquid column will be very less, because the same liquid will go up so about the density of these liquid we have no control it is fixed.

Moreover, if the pressure is below the atmospheric pressure we cannot attached a tube like that that situation will be very difficult in that case here we will rush into it here we will go in creating air bubbles then that situation will be different, so this is a very simple case where we can do it where this P a is slightly more than P g.

Probably this principle you know is applied to measure the local atmospheric pressure, which you have read at your school level a recapitulation of that, that if we have a liquid in a container and if you take a tube like this, which is open at one end and make full with this liquid. The purpose is to drive the entire air within it. And then you just close it by your hand and then invert it here. Then what you will find is that the liquid will not fall down to the beaker. This is because liquid, for example, this is the interface that depends upon the liquid, usually we take mercury to measure the atmospheric pressure, the interface is like that so the shape of the interface will depend upon the relative value of the molecular cohesion and adhesion. So, you see the liquid will stand like that. Why? Because, here there was no air, so this is vacuum, almost vacuum. I will come after that, is almost vacuum; that means pressure is almost zero. But here the pressure is P0.

So, from this side if I equate the pressure, here this will be responsible for this height of the liquid. That means pressure here is what, zero pressure impressed on this free surface plus the rho g h. We know the pressure for this height h is rho g h and that becomes equal to the local atmospheric pressure. Because pressure at this point and pressure at this point remain same, because they do not differ in their vertical displacement.

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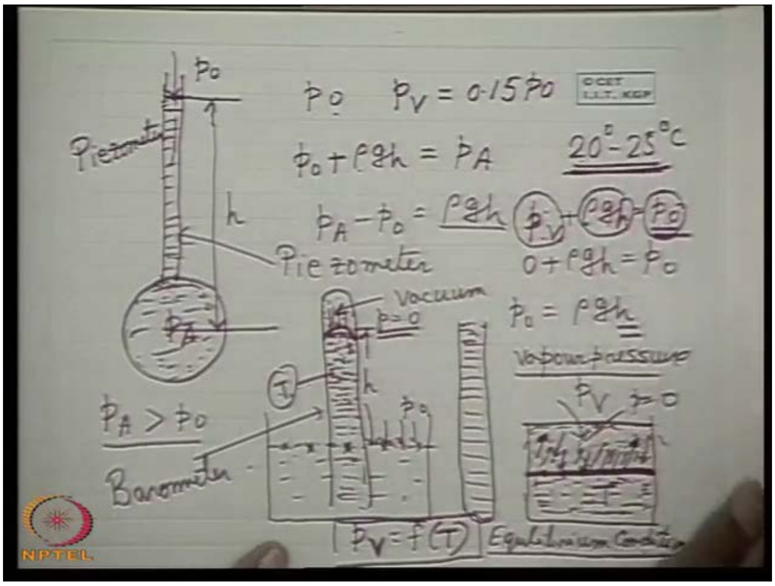

So long the points in same expanse of liquid or a fluid do not vary in their vertical displacement, pressure remains same. That means this point pressure and this point pressure remains same, so simply P0 is rho g h. This principle was utilized to measure the local atmospheric pressure by measuring this height and this instrument is known as barometer.

Now, what happens exactly this gap is not completely vacuum or P is equal to 0. Because of the evaporation of the liquid from the surface, this gap a pressure is generated in this gap. In this occasion, I like to tell a brief, what is about this, this is known as vapor pressure. You must know what is a vapor pressure? So, to explain this I think vapor pressure or rather I can explain here itself, vapor pressure; vapor pressure, vapor pressure, just few words. Probably you know it from your school level, what happens is that if you take a closed container and have any liquid partially filled and, first let us consider this is completely vacuum. That means somehow we make it vacuum, by some vacuum pump and there is no pressure.

Now, what happens? A free surface of the liquid, either in contact with any other gas or vacuum, it will start evaporating. That means liquid molecules started convert, start converting into gas molecules. And they ultimately move from the liquid surface being detached from the liquid surface they come into this empty space as vapor molecules. That means the vapor of this liquid. And at the same time what happens, when a sufficient amount of vapor molecules are generated, vapor molecules because of the strong cohesive forces again come back and strikes the liquid surface. So, there are both ways motion. That is one way is the liquid molecules converted into vapor molecules goes into the space; another way vapor molecules strikes back the liquid molecules and condenses on it.

Now, as initially what happened, the number of liquid molecules going into vapor molecules are very large as compared to the number of vapor molecules coming back and striking the liquid molecules. What happens? The space will be slowly and gradually filled with the liquid vapor molecule or simply the liquid vapor. A time will come when this generation of the vapor molecules that is the going of the vapor molecules from the liquid surface to this space and the coming back of the vapor molecules as liquid to this space will be balanced. And that condition is known as equilibrium condition. It reaches very fast, equilibrium condition and at that condition this space will be saturated with the liquid vapor. And at that condition what happens is, this liquid molecule going from the liquid to the vapor phase and vapor molecules coming back equalizes that no evaporation will take place and the bulk of the liquid will remain same. So long if equilibrium does not occur, there will be a little loss in the liquid phase, because it is going into the vapor phase.

So, the conservation of mass of the entire component remain same but they will be distributed into liquid and vapor phase. When equilibrium condition is attained the liquid remains as it is. This will be saturated with the vapor and at that condition the pressure which is exerted by the vapor molecules, so this is not an empty space; that is known as the vapor pressure, which is very important, vapor pressure, which is purely a function of temperature only, temperature of the liquid. So, for a given temperature of a given liquid, the vapor pressure is fixed which is found from the thermodynamic table.

Now, I have explained this taking this is a complete vacuum. But it may not be necessary that it should be a complete vacuum, there may be air in it this space. So, what happens in that case, we will consider the partial pressure of the vapor in this atmosphere of air and the vapor pressure, which is a function of temperature. That means if this be the liquid temperature under equilibrium, the pressure of the vapor will be Pv. In that case, it will be the partial pressure of the vapor. So, this is precisely the vapor pressure concept probably, which you have at your school level. So if you think so then this place is not completely vacuum, this place, the pressure will be vapor pressure. Vapor pressure means vapor pressure of the liquid; it depends upon the liquid and the existing temperature T.

So therefore, if I write this P plus rho g h is equal to P0 that means to find out the local atmospheric pressure I will have to find two things: one is what is the liquid and what is this existing temperature. Then from the thermodynamic table I'll have to find out Pv and add it and then only we can find out P0. But intelligently the liquid, which is used, in this case mercury, whose vapor pressure at the existing temperature, usually we use the room temperature is 20 degree Celsius to 25 degree Celsius, it varies like that, this vapor pressure is very small as compared to the local atmospheric pressure. It is sometimes 0.15 times the local atmospheric pressure. Pv for mercury is 0.15 times the local atmospheric pressure at this range of temperature. So that we can neglect this Pv and simply from the height, measurement of this height and then multiply with rho the density of the mercury at that temperature, existing temperature. This range we can find out the local atmospheric pressure.

This is simple and you have read it at school level. Now, again you see that if you come back to our earlier discussion that this is not very simple to measure the pressure of a static system by only attaching a piezometer. If the pressure is higher, much higher than the atmosphere what you will do? If the pressure is below the atmosphere, what you will do?

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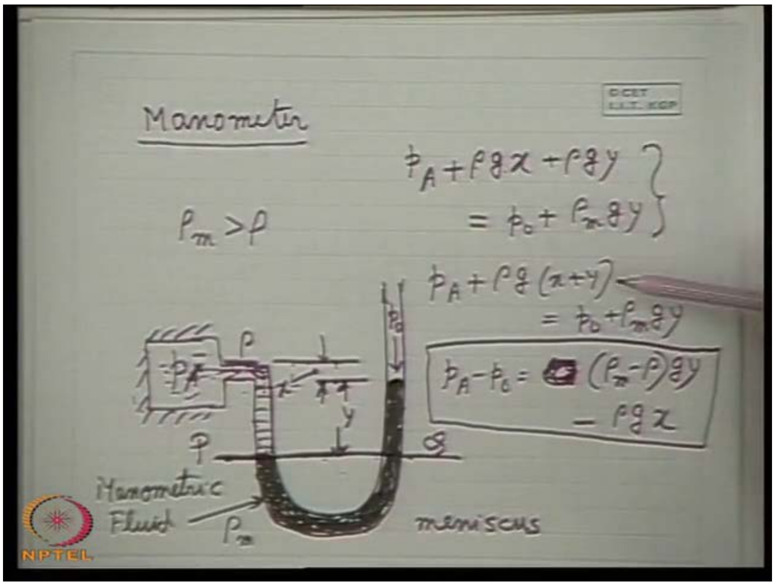

This is modified by a measuring system known as manometer, known as manometer. Manometer is very simple. Now let us consider again a system, let us consider the system like this, where we have a pressure. Let us consider a system in a body where the pressure is, this is the fluid pressure is PA. So, manometer is just like that the tube is a U-tube, a tube in the form of a U is used as transferring tube. This is known as manometer, the U-tube is attached. And what happens if the pressure is very high? We take the advantage of a another high density liquid which is filled in this tube, a high density liquid.

Let us see that this is a high density liquid, which is filled in this tube. So, what will happen that if it is attached to a system having a high pressure, this is a high density liquid. So, what will happen this liquid here will fill up and push it down. Usually, if in a tube if you fill it with any liquid, they will fill up the same height, because the pressure on both sides will be same and neither of the side can have a higher vertical displacement or a lower vertical displacement with respect to the other. But when this pressure is more this will be displaced like this. And this fluid obviously will be having a higher density than the system fluid. This fluid is known as manometric fluid, manometric fluid. The fluid used in the tube manometer, this is known as manometer, this is known as manometric fluid.

Let its density is rho m. Let the density of system fluid is rho. So, obviously rho m is greater than rho. Now, what we find that, if we now define this, well, this is as y it may not go up to, sorry, this height, sorry, it may not go up to this height. Let me see that we can, let we can give it as y in general. This may be little higher than the y, so my drawing is such. Let this is x. Let this is x, let this difference in this surface is y. This separation of the surface between the two liquids is known as meniscus, meniscus these are the terminology.

This is a free surface, this is the meniscus. This side it is open to air, but this side it is with this immiscible liquid. So, these liquid properties are the it is immiscible with the system liquid of higher density. So, the system liquid will push it like that, so this is the meniscus in the left hand side, which will be at a lower height or lower vertical depression. Or the lower vertical displacement from the free surface of this manometric fluid on the other limb, that is y. Let still, this pressure this at this point pressure PA. This is x, this may be little lower than that, or may be higher than that, just I'm giving one example. Now, how to find out the pressure? The simple theory is that you will select a horizontal section. Let this is Pq. Now, you see the theory is that, from our fundamental equation of fluid statics that in the same expanse of liquid at these two points at the same horizontal level, the pressure is same. That means pressure at this point is equal to pressure at this point, because this two points do not vary in the vertical displacement. See the pressure decrease, increases if we go here, and again when you go up pressure decreases. So, ultimately this two points pressure remains same.

That means pressure in the same expanse of fluid, you have to remember this very much categorically, is same provided, they are not varying in the vertical displacement. That is at two same horizontal level, pressure are same. So, if you now equate the pressure at this two point P and Q from this sides, what you will get? From the left side P A plus rho into g x, that is the pressure of this height of liquid column, then plus rho into g into y. Or simply we can write x plus y, this is the total height of the liquid column rho g x plus y. And that must be equal to the pressure from this side, which is the atmospheric pressure P0 plus, this is the P0 straight away acting on this interface, plus rho m into g y, so if I write that PA plus rho g into x plus y is equal to P0 plus rho m g y.

So, PA minus P0 is equal to rho g into sorry I can write this way, rho m minus, more conventional way, g into y, then PA minus P0 minus rho g x. So, this equation, from these equations, I can find out the value of PA over P0. That means that gauge pressure of the system. This equation is known as manometric equations, this equation is known as manometric equation by which we can make out the pressure. That means the pressure balance from the two sides of the manometer we can make. These are known as the manometric equations. Any doubt in this? Please see here. Any doubt? Any doubt?

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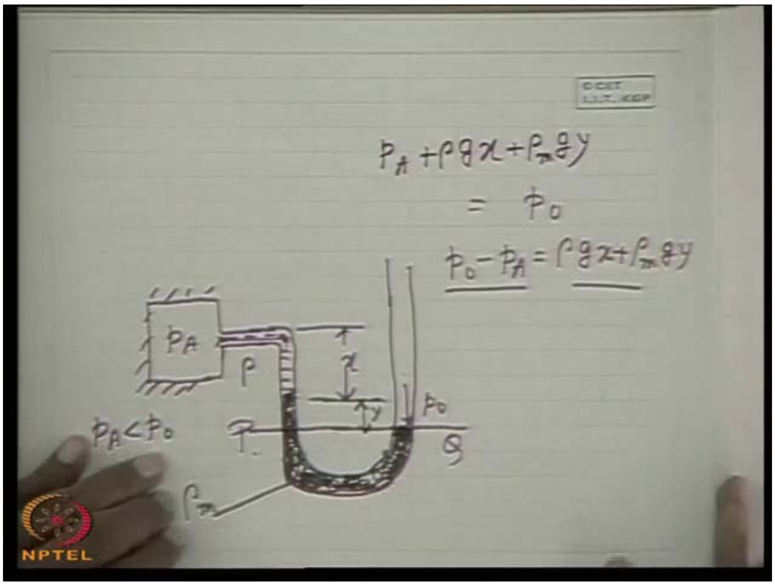

Now, if the pressure is below that of the atmosphere, very simple case. Now, consider the system where the pressure is below the atmospheric pressure, a very simple case. The pressure is below the atmospheric pressure, how the manometric liquid or manometric fluid will adjust? Now, if the PA, PA is less than P0 atmospheric pressure. So, what will happen? If I attach it to a manometer, that is a U-tube, transfer into U-tube. So, what will happen? If we attach it to a manometer and this PA is less than P0, then atmospheric pressure will be more. Therefore, this tube will adjust like this. So, this will be the adjustment in that case. So this will be the adjustment in that case. So this will be the manometric, this will be the manometric fluid.

Well, so this will be the manometric fluid and this will be the depression or the elevation or whatever you call, a deflection; rather deflection of the manometric tube. This is the interface or meniscus and this is the free surface. That mean the liquid will be like this. That means this side the pressure is P0. In that case if I define this as x and this as y; y is the deflection of this ,this is the manometric liquid whose density is rho m. This is the manometric liquid and similarly this is rho. Now, the equation., Now we will select the same line P Q and we will find out the pressure from here. This side PA plus rho into g into x. That means PA is the pressure here, come straight here. So the pressure here is the rho g x of this column of liquid. Then pressure here will be plus rho m g into y. Then we come to this point P, from this side and from that side what you will do, this is simply equal to, this point into this point, is equal to P0

Pressure is P0 because it is open to the atmosphere, so free surface pressure is P0. So, we get the value P0 minus PA is equal to rho g x plus rho m g y. Alright? So by this we can find out depression of the system, which is below the atmospheric pressure. This thing settles like this.

Now, after that I like to discuss that how to find out the difference. Now, you see in all the cases in this case, earlier case, a manometer always measure the difference in pressure. That means though we are telling that we are measuring the pressure of the system, this is the pressure of the system, with respect to atmospheric pressure, we are always measuring the gauge pressure from the manometer deflections. That means reading the deflection of these meniscus and the free surface, knowing the densities of the manometric fluid and the working fluid, we can only workout the difference or find out the difference of this pressure from the ambient pressure, until and unless we know the ambient pressure. I cannot find out the absolute pressure. Therefore, by definition manometer is a device which measures the difference of pressure between the two systems or between the two points in a system of fluid at rest or even for a fluid in flow or the pressure of a system with respect to the atmospheric pressure that means the difference of a, difference of pressure of a system with the atmospheric pressure.

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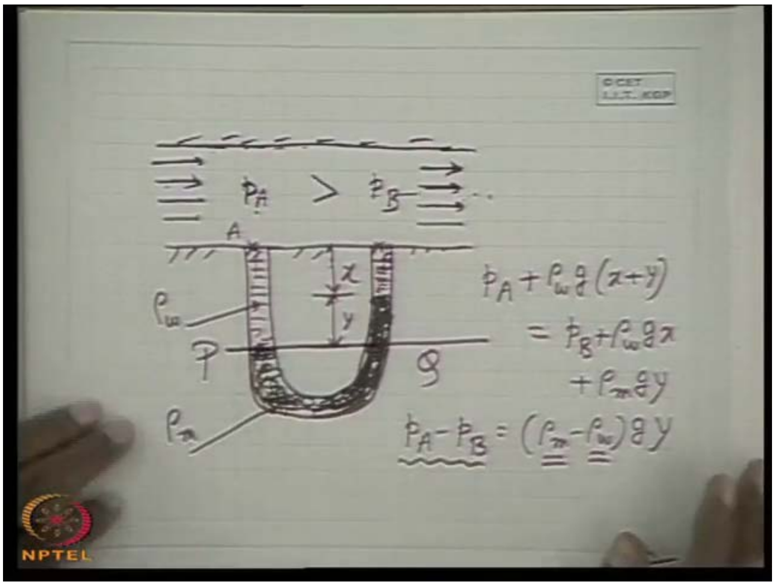

Now, let us see that if we want to measure the pressure difference between two points in case of a fluid flowing through a pipe line. Let us see that the fluid flow through a pipe. Let us see how the manometer is utilized to measure the pressure difference. We want to measure the pressure difference at this two sections A and B at the wall. So, let us consider this is a pipe or a channel whose cross-sectional area is constant here, we consider. So pressure here and pressure here and simply this pressure is PA and this pressure is PB. And PA is greater than PB because the fluid is flowing in this direction and if the fluid flows through a uniform cross sectional area, you will come to know it later, then the velocities of the fluid at each section will be constant.

So therefore, it is the pressure difference which makes the flow possible. So, when flow takes place in that direction, pressure here will be higher than the pressure here. So, what is done? If we just now attach a manometer connecting the two ends between A and B with a manometric fluid, what will happen? We will see a situation like this, situation like this. This is the manometric fluid, this is the manometric fluid, well this is the manometric fluid, this is the manometric fluid well this is the manometric fluid and this fluid is the fluid of the system that is flowing sometimes we call it as a working fluid, sometimes we call it as the working fluid and denote by the density of the, density of the working fluid. This is working fluid and this is manometric fluid whose density is rho m manometric fluid.

So pressure A is higher. So, the meniscus, both the sides the meniscus will be defined. That means because both the sides, this will be in contact with the liquid and this is of higher density, then only what we do? We can create a bypass line, secondary line where the fluid is at rest, while the working fluid flows like this. If we do not have these high density fluid, if we simply connect it with a U-tube the working fluid comes through the U-tube, higher pressure and goes like that. That means you will be creating a bypass channel like that, where the main flow is taking place, taking place like that. And the part of the flow goes through this bypass line, but whenever we use a very high density fluid, which gives a well defined meniscus with this fluid, then what will happen?

Automatically, this will come to a static equilibrium because of the pressure balance. Then the situation will be like this. Let the difference in the meniscus or the elevation reads as y and let this is x. Then again if we select that this is the P Q line, where you will equate the pressure from both the sides, what you will get? From the left side PA, please tell me what you will get, PA plus rho w. Here I have given the nomenclature rho g rho w g into x plus y x plus y is equal to, here P B plus rho w g into x because this column of liquid also exerting pressure in this side plus rho m g y.

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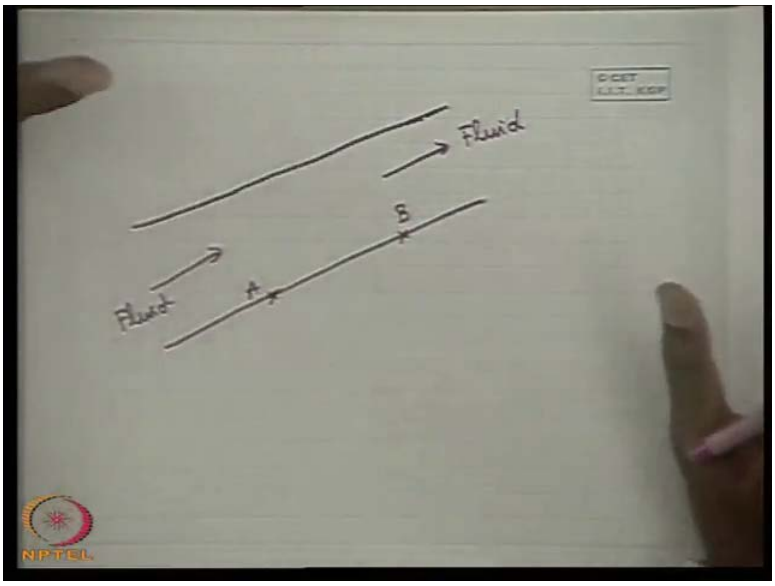

That means if you make this PA minus P B it will be equal to, because rho w g x cancels from both this side, rho m minus rho w. That means by simply noting the deflection of the meniscus in the two limbs in the, of the manometer and if we know the density of the manometric fluid and the working fluid, we can find out the pressure difference. In case of a flowing fluid this pressure is known as the static pressure.

Well, now another very important thing is that, which you must know, that if the fluid flows through an inclined tube, what happen? Inclined tube in this direction, if the fluid flows like this what will happen? If the fluid flows like this in an inclined tube what will happen? If the fluid flows from a lower to a upper direction that means against the gravity. Now, if I want to measure the fluid pressure difference between A and B, well I think these I will discuss in the next class.

Time is short now today. So, better we keep it, keep our discussion up to this. I will discuss it in the next class. I'm sorry because, within another five minutes time interval I cannot make it complete, so better we will discuss this in the next class, so today up to this. So, I can allow for some time for discussion. Please ask, any discussion, any query, if any query is there. No query? I think this thank you. We will meet you in the next class.

Thank you.

Good morning. I welcome you all in this session of fluid mechanics. Last class if you recall we were discussing about the manometers. The manometer is a device which measures the pressure of a system in terms of its difference from the atmospheric pressure or the pressure difference between two points, whether the fluid is at rest or fluid is in motion. And at last we discussed how the manometer registers the pressure difference between two points when the fluid is flowing through a pipe.

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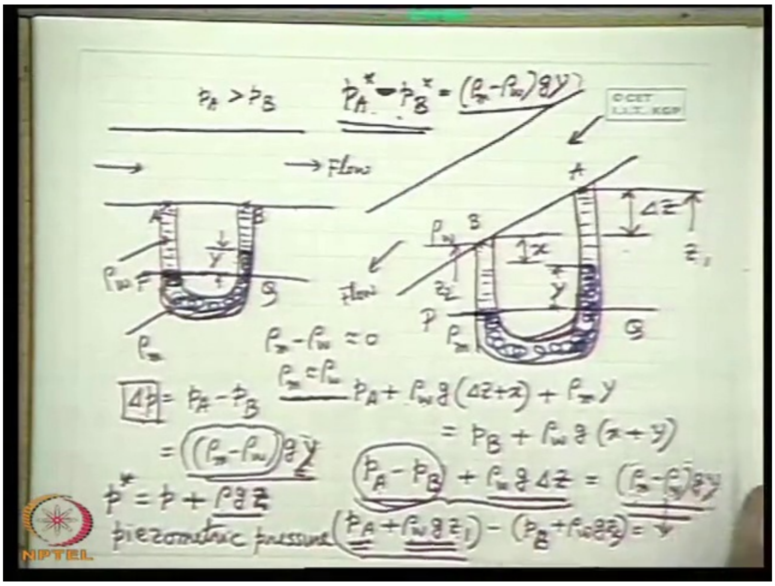

Let us recall this again, that if we recall, this is like that, that if there is a pipe where the fluid is flowing in this direction, this is the flow direction. Then if the two points A and B are connected, if the pressure PA is greater than PB, then the difference of pressure is measured by connecting a manometer, which is essentially a U tube like this. Sorry like this and we use a manometric fluid, which is, which is having a density higher than that of the working fluid, that is the fluid flowing through this pipe. And we register a, this is the fluid, a deflection, that means the interface, that means the separation surface between the working fluid and the manometric fluid. The interfaces stand like that and this is known as the, let this is y and if we take the manometric fluid density is rho m and the density of working fluid is rho w, we have found that the delta P that is equal to PA minus PB becomes equal to rho m minus rho w g into y. That means observing this deflection, manometer deflection, that means the difference in level of the meniscus y we can find out the pressure difference. How to find it? By writing the manometric equation. That means we take this P Q line as the same horizontal line, in this same expanse of fluid which is the manometric fluid and then what we do? We write the pressure here, equate the pressure here, from this limb and equate the pressure here from this limb and find out this equation.

Now what we started that, what is the situation? We see a very interesting thing, that when the fluid flows through an inclined pipe, let the flow direction is like this. The fluid flows through an inclined pipe, where we are interested to measure the pressure difference between this two points A and B and let us connect the manometer like this sorry a U tube like this. Let us connect a U tube like this, U tube manometer and then what we do? Then the manometric fluid will be having a deflection definitely like this. Let us have a deflection of the manometric fluid, so we just, this is the working fluid, this is the working fluid, let this deflection as it is we call it as y.

Let from B this distance is x and A and B there is a difference in vertical height between the section A and B let it be delta z, just I give this nomenclature delta z. Now, from simple manometric equation, that means if you take this line as the P Q horizontal line. And if we equate the pressure from both the limbs, now from this limb, if we come from this limb here first PA plus, if the working fluid density is rho w, the same nomenclature, and rho m is the density of the manometric fluid. That means rho w delta z plus x. That means rho w into g into delta z plus x, that means this is the pressure of this column of liquid plus rho m into y, y is the deflection this is y, this is y.

So, this becomes equal to what PB that means the same pressure is here at the same horizontal level within the same expanse of fluid. So this is PB plus this pressure due to working fluid of height this x plus y. That means rho w g x plus y. So, if we equate this we will see PA minus PB, so rho w g x cancels from both; this sides PA minus PB. So, plus rho w g delta z is equal to rho m minus rho w into g into y. Therefore, we see that if we compare this two equations, we see that the from the deflection y manometer deflection that means the difference in level of the meniscus if I equate this rho m minus rho w into g y this gives an additional term from the pressure difference rho w g delta z in case of a horizontal pipe A and B are the same horizontal level so delta z is 0 so we can put delta z 0 this has a special case becomes this. But what is the physical interpretation of this term actually?

Now, if I express the vertical elevation of A and B, this we will come afterwards in our studies, in our course, and z two from a reference datum, from any reference datum, from any reference datum if I just specify the elevation of A as z1 and elevation of B as z2, then I can write this as PA plus rho w g z1, this quantity, minus PA PB sorry PB plus rho w g z2 is equal to this one rho m minus rho w, this one will come like that.

So therefore, we see this manometer deflection multiplied by the difference of density into acceleration due to gravity gives the difference of static pressure plus some term, which is rho g z1, where z1 is the elevation of that point from a reference datum. So, this term is known as P star that is piezometric pressure. That is piezometric pressure is defined the static pressure plus the equivalent pressure corresponding to its vertical elevation from a reference datum. So, this is a very piezo important definition which we will come across afterwards piezometric pressure, so always piezometric pressure is defined as static pressure plus the pressure equivalent of its elevation from a fixed datum rho g. Therefore, it registers a piezometric pressure difference PA star minus PB star.

That means the same equation we can use for an inclined pipe, where if we find this quantity, this will give you the piezometric pressure difference instead of static pressure difference. So, if you will have to find out the static pressure difference, of course you will have to deduct this thing. But sometimes directly we want the piezometric pressure difference. In that case the manometer reading from, the manometer reading y we can straight away find out the piezometric pressure difference. In case of a horizontal pipe the Piezometric pressure difference becomes equal to the static pressure difference, because delta z is 0.

Now, next we come to the next part, that here we see that the basically the pressure difference between two points in a fluid flow is measured by a manometer basically, by this equation. Either it is a static pressure difference or it is a piezometric pressure difference, depending upon whether the pipe is horizontal or inclined.

Now if we want to measure a very small pressure difference, then what we have? We should have, we should have a substantial value of y for a small pressure difference. In other word you can say if you want to increase the sensitivity of the manometer, that means for a small change in delta P, if we want to have a substantial value of y or readable value of y, what we should do? We should make this part very small, very small so that even for a small delta P we have a large y. That means rho m minus rho w should be very small, nearly equal to 0. Or rho m that is the manometric fluid density will be very close to the density of the working fluid.

But in practice it is very difficult to have a manometric fluid whose density is close to the working fluid and at the same time defining a meniscus, good meniscus that means a separation of surface between the two liquids has to be defined. So well defined meniscus should be there, otherwise we cannot read y. So, a well defined meniscus between the immiscible liquids and also close density values are not practically feasible, so that without going for changing the properties of the liquid, go for some other changes in the construction of the manometer to measure small pressure differences.