Fluid Flow Operations
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Module – 06
Lecture – 17
Different losses in Pipes - Part 3: Various Losses due to geometric change (continued)

Welcome to a Massive Open Online Course on a Fluid Flow Operations. In this lecture, we will discuss the continuation of the portion of Different losses in Pipes as part 3. Here the Various Losses due to geometric change will be discussed.

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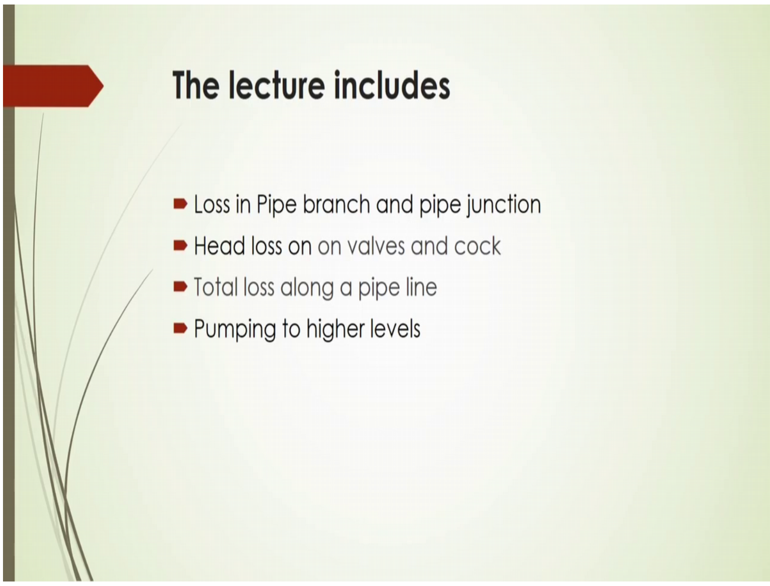

So, the lecture includes loss in pipe runs and pipe junction, head loss on valves and cocks, what will be the total loss along a pipeline when pumping to higher levels, how it will be working.

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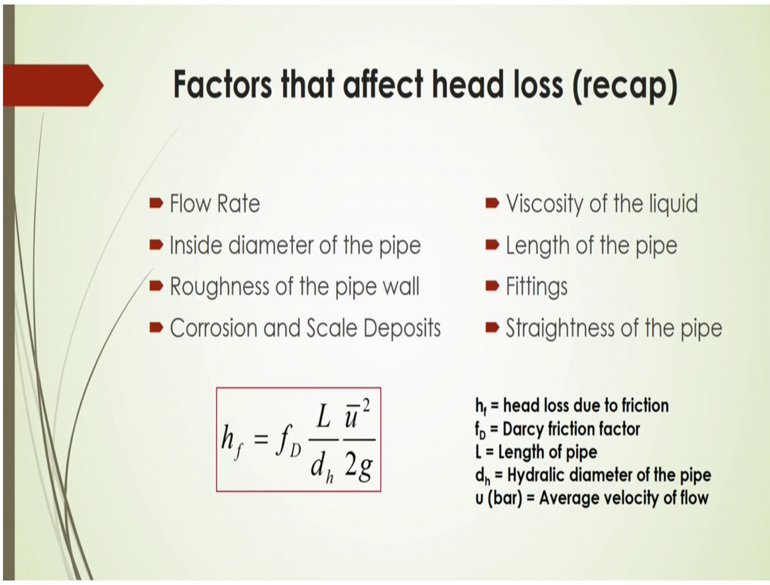

And already we have discussed in the previous class that what are the different factors those effect on the head loss like those factors are flow rate inner diameter of the pipes and roughness of the pipe wall, corrosion and scale deposit is there any or not. Viscosity of the liquid is the major part and the length of the pipe and what are the minor loss or major loss in the fittings and if is there any change of direction of the flow is there any loss or not that we have discussed in the previous class.

And this head loss is not only obtained in the case of only by regular shape pipes or conduit. It may happen in the non regular shape of that is pipe like different geometrical shape; if it is a square cross section or it is rectangular cross sections or any other oblong shape of the pipe or not.

And in general if we consider the equivalent diameter of the pipe as hydraulic diameter, already we have defined how this hydraulic diameter is obtained. So, if we know that hydraulic diameter then what should be the head loss due to the friction that will be represented by this equation here that is h f will be equals to f D L by d h into u square by 2g. In this case f D is the Darcy Weisbach friction factor, L is the length of the pipe and d h is the hydraulic diameter. This hydraulic diameter depends on the contact of the fluid on the surface of the valve.

And the velocity of the fluid also important if we increase the velocity this fictional loss will increase and also that case some other factor like viscosity that is very important here in that case the viscosity effect will be considered here in this by f D. This Darcy Weisbach friction factor depends on the Reynolds number, where this Reynolds number is a function of viscosity of the fluid. So, from which we can have the effect of viscosity on this head loss.

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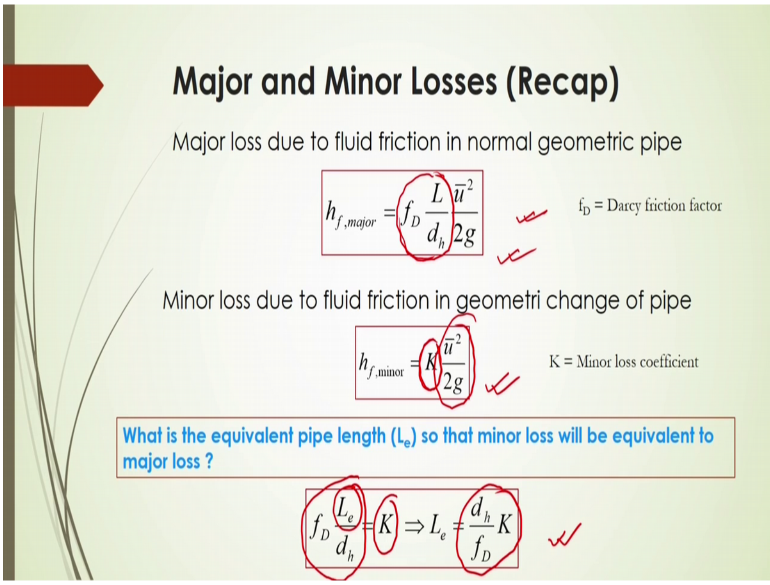

And there are two types of a losses will be there whenever fluid will be flowing through the pipe of any geometric shape. And for major loss due to the friction in normal geometric pipe is considered by this equation; whereas there will be a change of direction because of the bend geometric shape change like bend like a joint, like any fittings, like any branching of the pipe or junction of the pipe there will be some loss because of formation of eddies and turbulence of the fluid. And there will be a friction of that turbulence of the fluid layer to the pipe valve and because of which there will be some certain loss of energy there.

And those loss is generally represented by the minor loss and that minor loss is calculated based on this equation here this h f minor that will be equals to K into u square by 2g. Here this K is loss coefficient that is called minor loss coefficient. So, this head loss is proportional to this u square by 2g and this proportionality constant is considered as the minor loss. This minor loss depends on that different shape of the pipe. And in this equation here this coefficient this f D into L by d h is considered as the major loss coefficient.

Now, if there is a certain flow rate through which this fluid will be flowing through the pipe and this pipe will have a certain length for which you will see that this minor loss and major loss will be equivalent to each other. So, in that case for what length of this pipe will be there so that these two losses will be equivalent. So, in that case if we consider that the equivalent length is L e then the major loss coefficient will be is equal to f D into L e by d h and it will be equals to this minor loss coefficient.

So, from which you can have this equivalent pipe length will be equals to that d h by f D into K. So, from which you can select a pipe length for which you can say that the both the loss coefficient will be equal.

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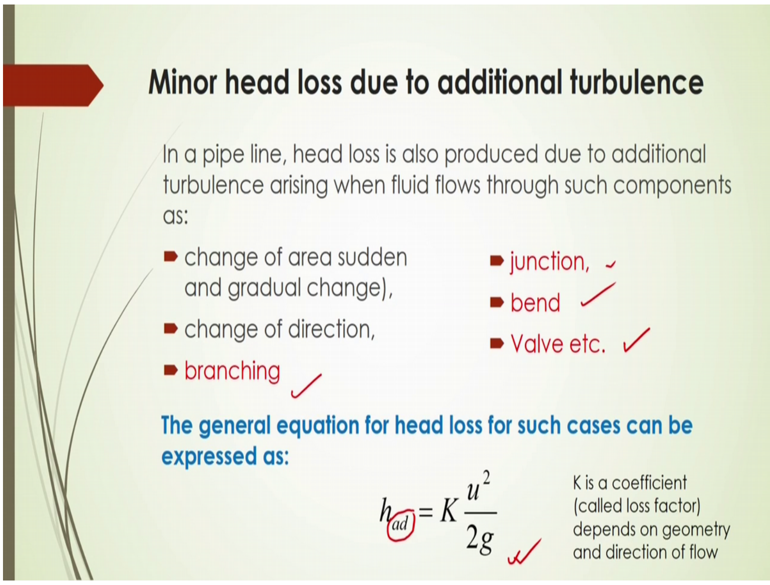

Now, we know that this minor head loss is generated due to the additional turbulence created by this fluid flow whenever it will be flowing through the bend or junction or through valve or by change of direction of the fluid or any sudden expansion or contraction of the pipe or not. So, we have already discussed the minor loss coefficient for the change of area sudden area change and also gradual change and also change of direction in the previous lecture.

In this lecture, then we will consider this branching junction bend or in valve how this head loss will be calculated and what should be the corresponding minor loss coefficient. The general equation for head loss for such cases can be expressed as by this equation as h ad; ad means here additional turbulence that will be is equal to K into u square by 2g, where this K is a coefficient which is called the loss factor or minor loss coefficient that it depends on the geometry and direction of the flow.

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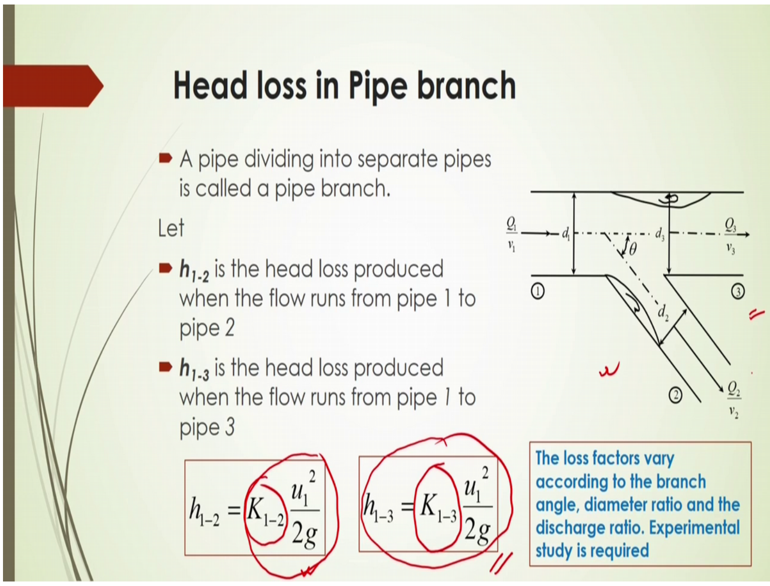

Now, if we consider a pipe branch in which the pipe divided into two parts as shown in figure here. Let this h 1 – 2 is the head loss that produced when the flow runs from pipe 1 to pipe 2. Here pipe 1 to pipe 2 and here h 1 – 3 is the head loss produced when the flow runs from this pipe 1 to pipe 3. So, the head loss can be expressed as by this equation here h 1 – 2 for the pipe of 1 and in between 1 and 2 and it is equal to K 1 – 2 into u 1 square by 2g. Here u 1 is the velocity of the fluid which should be flowing through the pipe 1.

So, in that case K 1 – 2 is the minor loss coefficient of these flow when it will be flowing from pipe cross section 1 to the pipe cross section 2. And similarly for pipe branching from 1 to 3 then head loss will be equals to h 1 – 3 that will be equals to K 1 – 3 into u 1 square by 2g. Here also we are getting that minor loss coefficient and it is denoted by K 1 – 3. So, for 1 – 2 and 1 – 3 the respective minor loss coefficient should be considered because the pipe branch may have certain angle from it is main pipe.

And because of which there will be a change of direction of the fluid and for which you can get this minor loss and that coefficient will be denoted by this specific notation of K 1 – 2 and K 1 – 3. And in this case this loss factors or minor loss coefficient very accordingly to the branch angle, diameter, ratio and the discharge ratio and for this to find out this you have to have the experimental observation to interpret this a minor loss coefficients.

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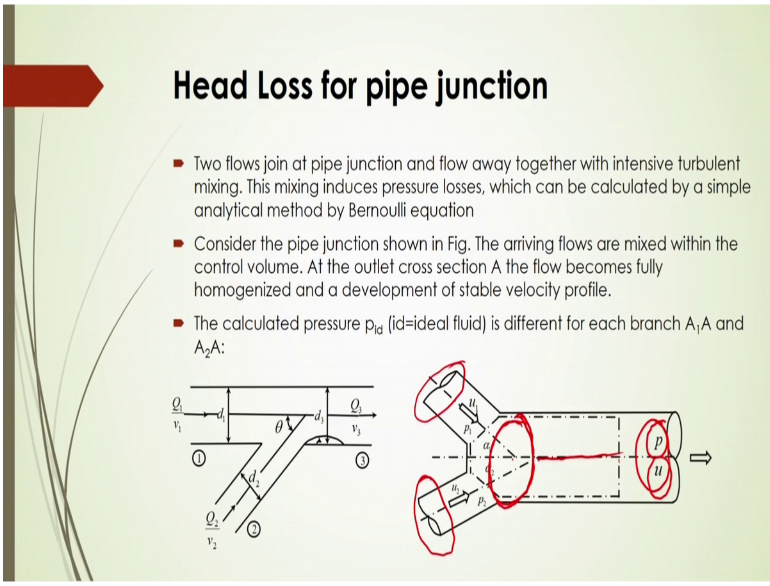

And if the two flows join at pipe junctions and flow away together with intensive turbulent mixing that is here two pipes are coming together and joining and forming one pipe cross section. So, in this case the mixing induces pressure losses which can be calculated by a simple analytical method by Bernoulli's equation here.

In this case if we consider the pipe junction that shown in this figure the arriving flows are mixing within the control volume at the outlet cross section A the flow becomes fully in that case homogenous and a development of stable velocity profile will be there. So, here see in this figure it is shown that from this pipe and from this pipe flows are coming to each other and joining here at this region this is called mixing zone.

At this mixing zone this flows or fluids are being coming and mixed at this region and after that it will be flowing through the pipe and it will go to a certain distance from its entrance to get the fully developed flow condition. And in that case in that region the fully developed flow velocity will be considered as u and their pressure would be as p. Whereas, whenever it will be coming from the other pipe branches, like here, it will be having the velocity of u 1 p 1 as a pressure and velocity u 2 and p 2 and velocity and pressure there in the second branch. So, we are getting this velocity and pressure in this inlet pipes and the outlet pipes will be as general velocity as u and p.

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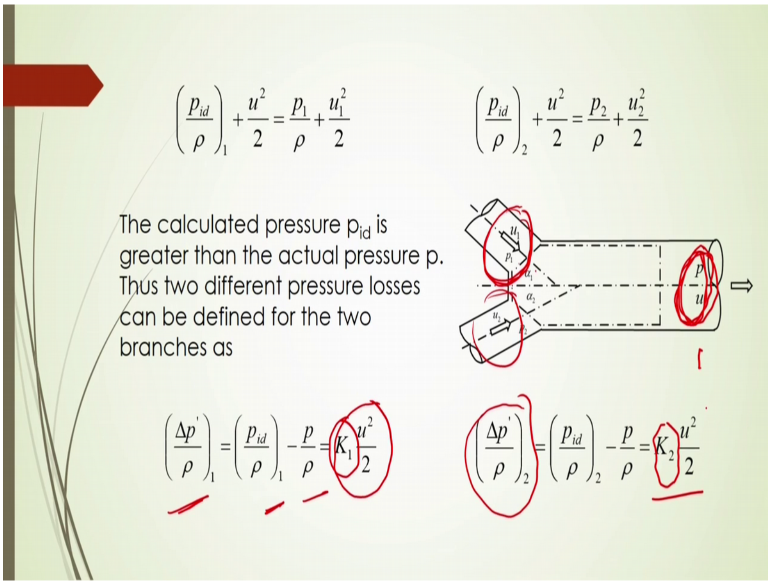

Now, if we consider the Bernoulli's equation here for this pipe then we can write here p id by rho; that means, here at the sections of p that is pipe then what should be the p pressure let it be pressure p id or p. So, you can say here p id by rho at this directions 1 plus here in this angle here p i d here this p id this pipe initial pipe p id by 1 plus u square by 2 that will be is equal to p 1 by rho plus u 1 square by 2.

So, within these sections we are getting this Bernoulli's equation as here p id by rho at section 1 plus u square by 2 is equal to p 1 by rho plus u 1 square by 2. Similarly, for these two sections if we consider then we are having p id by rho at section 2 plus u square by 2 is equal to p 2 by rho plus u 2 square by 2. So, in this case the calculated pressure p id is greater than the actual pressure p here.

Thus to different pressure losses can be defined for the two branches as; here delta p dashed by rho 1, that will be is equal to p id by rho that is at section 1 minus p by rho. So, that will be equals to K 1 in to u square by 2. So, this is your K 1 which is called minor loss coefficient at the section 1. Similarly, for section 2 we can have this delta p dashed by rho at section 2 that will be equals to p id by rho 2 minus p by rho that will be represented by K 2 into u square by 2. So, this K 2 will be its minor loss coefficient between these two sections.

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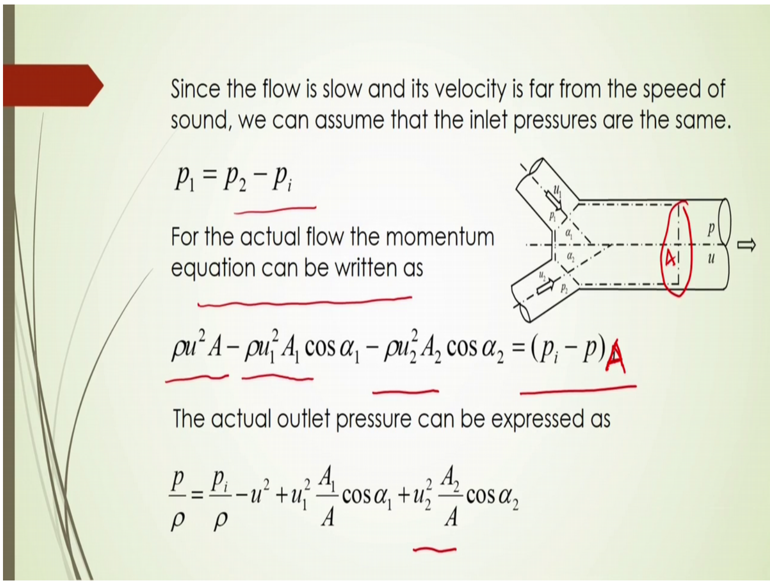

Now, since the flow is slow and its velocity is far from the speed of sound we can assume that the inlet pressure are the same here. So, p 1 will be equals to p 2 minus p i and for the actual flow the momentum equation can be written as here in this case rho u square A minus rho u in u 1 square to A 1 to cos alpha 1; where is that alpha 1? This is alpha 1 shown in figure here and minus rho u 2 square into A 2 into cos alpha 2 that is angle that is created by this pipe 2 with this horizontal line and that will be equals to p i minus p and here into A p i minus p into A. This is a cross sectional area of A here, this is cross sectional area A.

Now, the actual outlet pressure can then be expressed as p by rho m is equal to p i by rho minus u square plus u 1 square into A 1 by A into cos alpha 1 plus u 2 square into A 2 by A into cos alpha 2. So, in this case we are just substituting this value here for a p i by rho.

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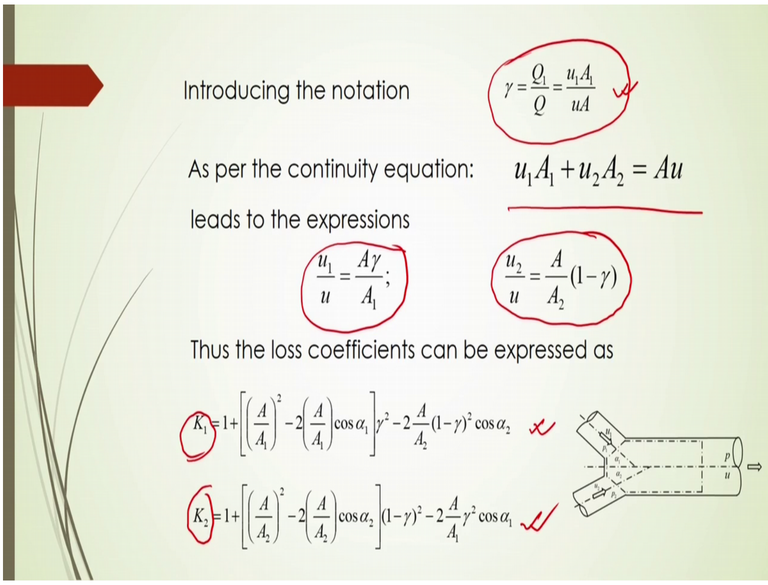

Now, if I introduce the notation as gamma as Q 1 by Q that will be is equal to u 1 A 1 by u A based on the mass conservation equation and we can write this u 1 A 1 plus u 2 A 2 that will be is equal to A into u and defining this gamma and substitute this equations then we are getting this u 1 by u that will be equals to A gamma by A 1 after simplification. Similarly for the ratio of u 2 by mainstream u that will be equals to A by u A 2 into 1 minus gamma.

So, after some substitution of this u 1 and u 2 we can have this minor loss coefficient of K 1 and K 2 in terms of cross sectional area of the pipe and the angle of the pipe wave and also the ratio of the flow rate of each pipe to its main flow stream after joining. So, these two equations can be used to calculate the minor loss coefficient whenever two pipes are joining to each other and forming one pipe cross sections and having the uniform or fully developed flow as u.

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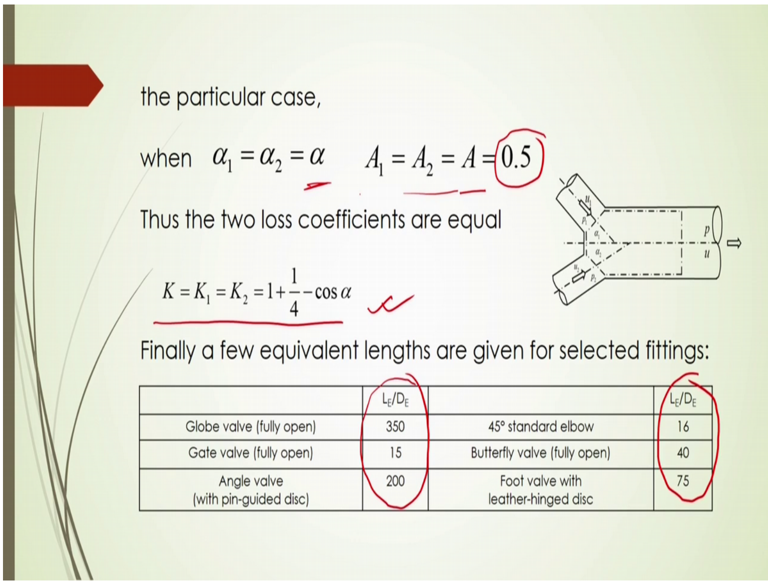

Now, in particular case if we consider that when alpha 1 that will be equals to alpha 2 that is two angles are same that is represented by only alpha and also this two cross sections of the pipes are same as A and it will be 50 percent of this main cross sections then we can have this two loss coefficients are equal and that will be equals to K is equal to K 1 is equal to K 2 that will be equals to 1 plus 1 by 4 minus cos alpha.

So, this is very interesting that if you choose the pipe cross sections of equal cross sectional area then one only one minor loss coefficients to be considered that will be equals to 1 plus 1 by 4 minus cos alpha. If it is suppose 45 degree separation then for a 45 degree standard elbow in that case how it will be there. So, cos 45 degree that will be is equal to 1 by root 2 in that case 1 plus 1 by 4 minus root 2 that will be your minor loss coefficients.

A few equivalent lengths are given for the selected fittings here and in case of fittings you will see you will get this loss coefficients for that already discussed earlier. So, here this due to this fitting this what will be that globe valve or gate valve and angle valve that we will be discuss later on. How this minor loss coefficients are there, so, it will be discussed for the different valve in the next.

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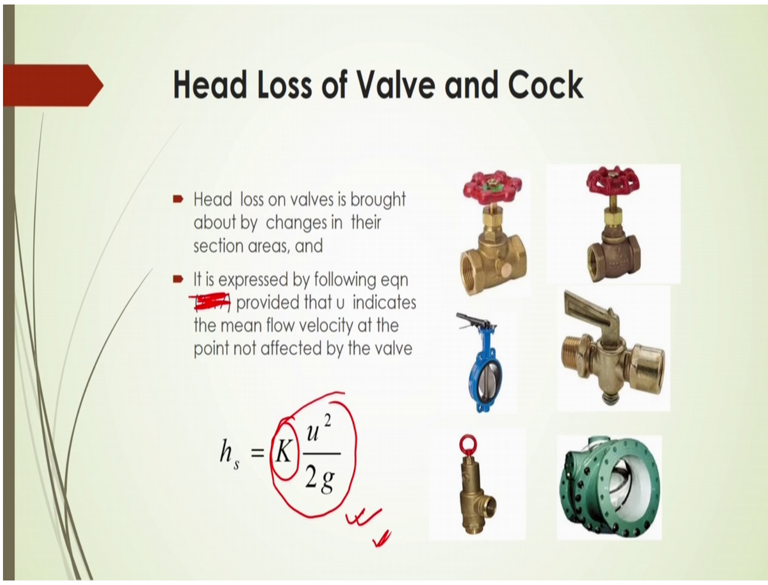

Now, in this case you will see the head loss of valve and cock. In this figure there are different kinds of valve it is shown here the head loss on the valves is generally brought about by changes in their section areas. And it is generally expressed by this equation and provided that u indicates the mean flow velocity at the point not affected by the valve here. So, h s will be equals to here this K into u square by 2g for this valves also. So, this K will be the minor loss coefficient for this valve that depends on the type of valves and cock.

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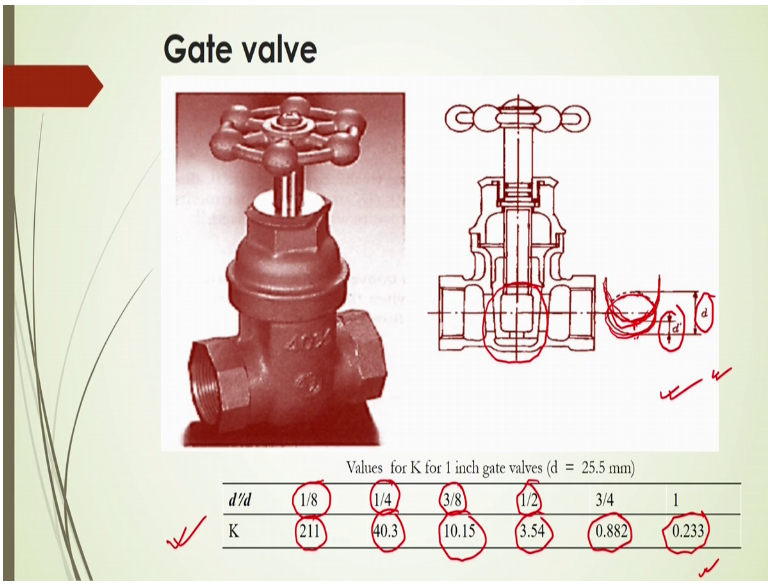

Now, if we consider the gate valve as shown here figure see this gate valve this is the main junction through which this flow will be getting struck or getting controlled here. So, in this to know such there here this is your cross sectional area through which this pipe of cross section area and this is the nose by which the flow will be controlled. Now, in this case what will be that diameter of the pipe and what will be the gap between these nose to this pipe valve this is denoted by d dashed.

So, in this case this d dashed by d that will affect the minor loss coefficient. At different d dash by d ratio we are getting different value of minor loss coefficients. So, you have to use these minor loss coefficient based on this opening or gap of this nose controlling nose to this pipe valve here. So, for this gate valve you can calculate the minor loss coefficient or you have to consider this loss coefficient of these values whenever you are going to design any gate valve.

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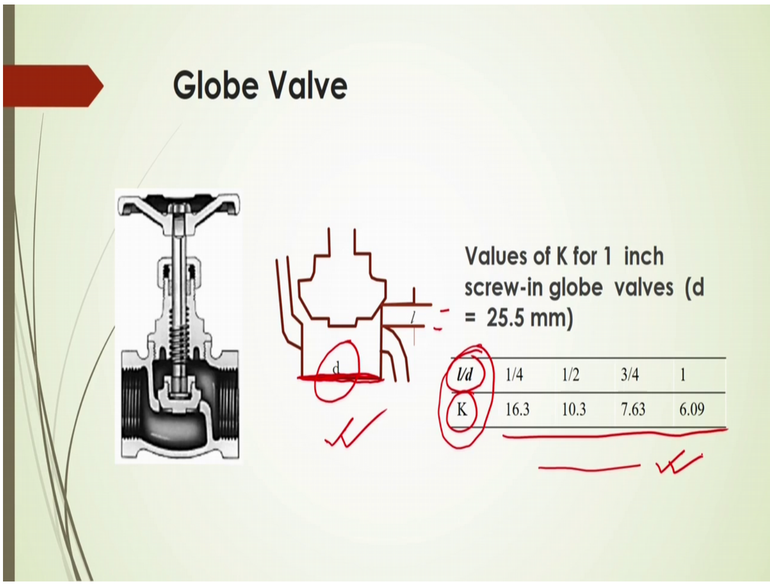

Similarly, the globe valve what should be the minor energy loss there if we know the loss coefficient as given here. Like this 16.3 for l by d, if it is 1 by 4 as shown in here figure. This d is this diameter of this valve and here in this case this l is like this gap. So, based on this as per represented here in this figure we can have for different ratio of l by d we can have this a minor loss coefficient here.

So, values of this minor loss coefficient for 1 inch screw globe valves is considered d is equal to 25.5 millimeter. So, for those cases only this K minor loss coefficient will be depending on this l by d ratio as per given in table here.

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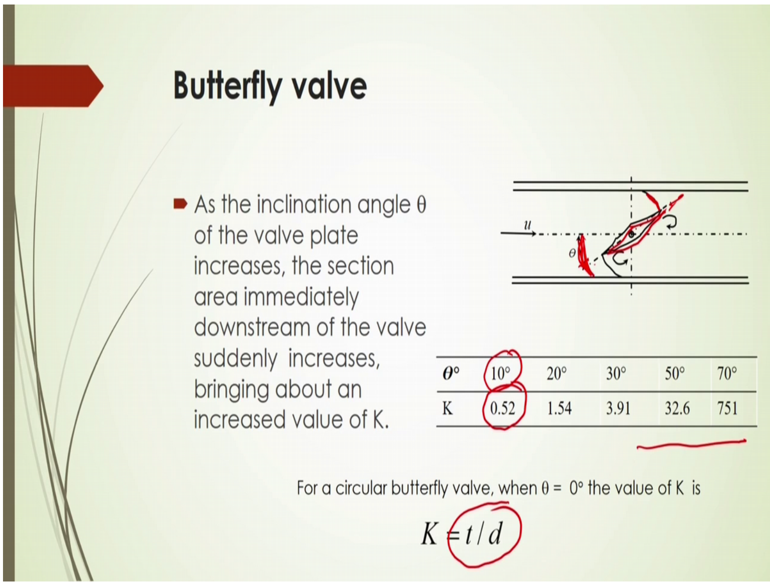

Similarly, if we consider a butterfly valve so, how this fluid is controlled by just movement of this valve here it is given. So, in this case if we consider at a certain position this theta of this butterfly valve as shown in figure here. So, as the inclination angle theta of the valve plate increases the section area immediately downstream of the valve suddenly increases that bring about an increased value of K here.

So, this minor loss depends on this inclination angle theta. This inclination angle theta if it is 10 degree then this minor loss coefficient will be 52; 0.52. Similarly, if we increase this theta the minor loss coefficient will increase accordingly. Now, for a circular butterfly valve when theta is equal to 0, the value of K; the value of K will be is equal to only t by d; t is the thickness and d is the diameter of the pipe.

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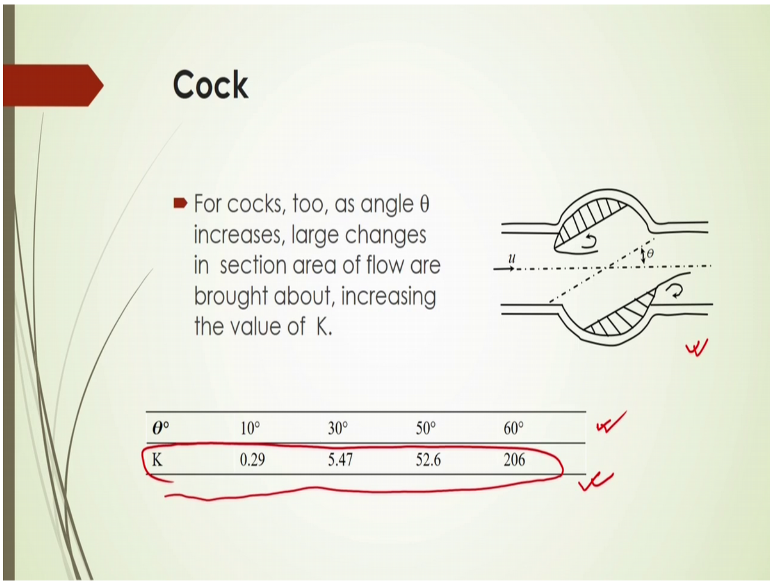

Now, similarly for cocks, in this case as shown in figure here, for cocks as angle theta again increases the then large changes in section area of the flow are brought about increasing the value of K. So, if we increase the theta here the respective value of K are shown in table here accordingly.

So, you can consider this what should be the minor loss coefficient for cock you have to consider. So, whenever you are using any cock, valve, butterfly or global so, whenever fluid will be flowing through that valves or cock there will be a energy loss; that energy loss to be considered for the conservation of energy equation and for simulation of the fluid.

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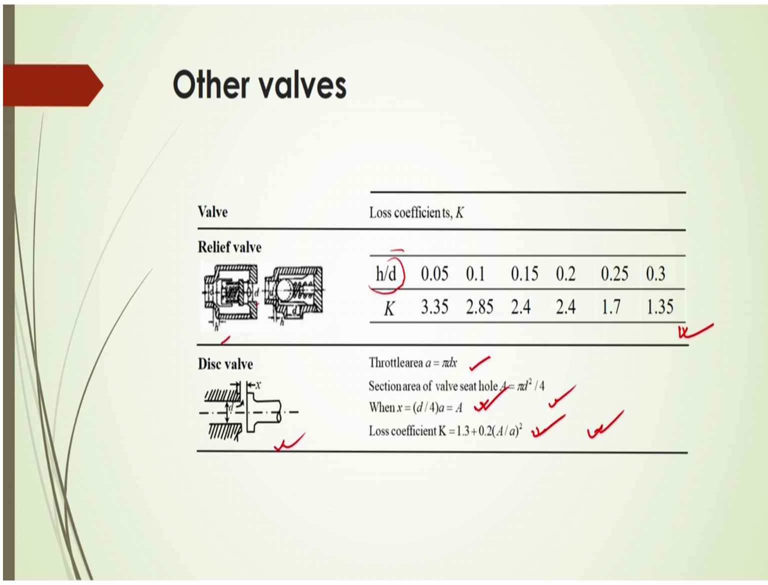

Other valves also will have the energy loss here it is given as shown in figure here for relief valves, for this valve and I will suggest you read this more details of the valves in different textbooks. So, this is not the scope for this lecture here, but I have given here for this short just consideration of just understanding the loss coefficient whenever fluid will be flowing through this valve and how this loss coefficient will be there and what should be the loss coefficient to be considered.

So, for this relief valve this again this h by d here as shown here as shown in figure this is h, this is d; this K how it will be changing. Similarly for disc valve the total area if it is a, that will be is equal to pi dx and section area of the valve seat hole that will be pi d square by 4 and when x is equal to d by 4 into A that will be is equal to capital A; then loss coefficient should be is equal to 1.3 plus 0.2 into A by a whole square.

So, for disc valve you can calculate what should be the loss coefficient if you know that A and small a capital A and small a; that means, total area and the cross sectional area of the seat hole then you can easily calculate what would be the minor loss coefficient.

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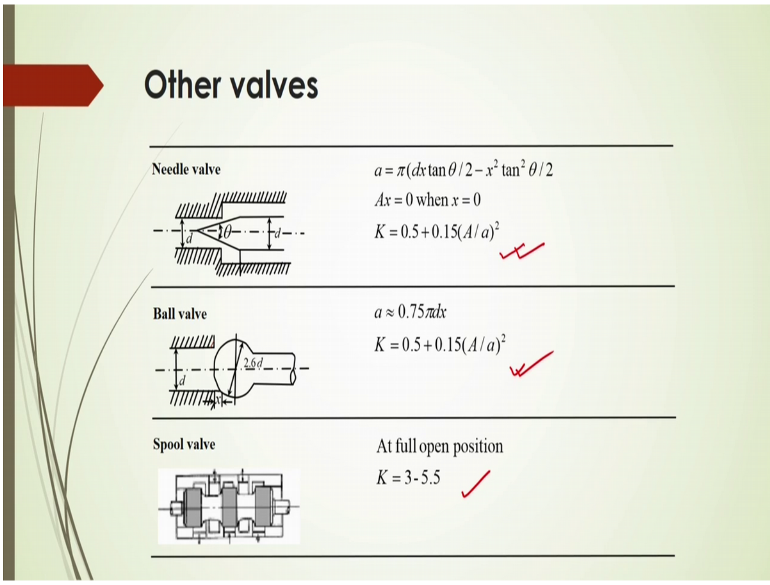

Similarly, for needle valve also the relationship to calculate this loss coefficient given here and for ball valve this K will be is equal to 0.5 plus 0.15 into again A by a whole square. Similarly, for spool valve this will be only changing within the range of 3 to 5.5. So, you have to take it suitably whenever you are going to design this spool valve.

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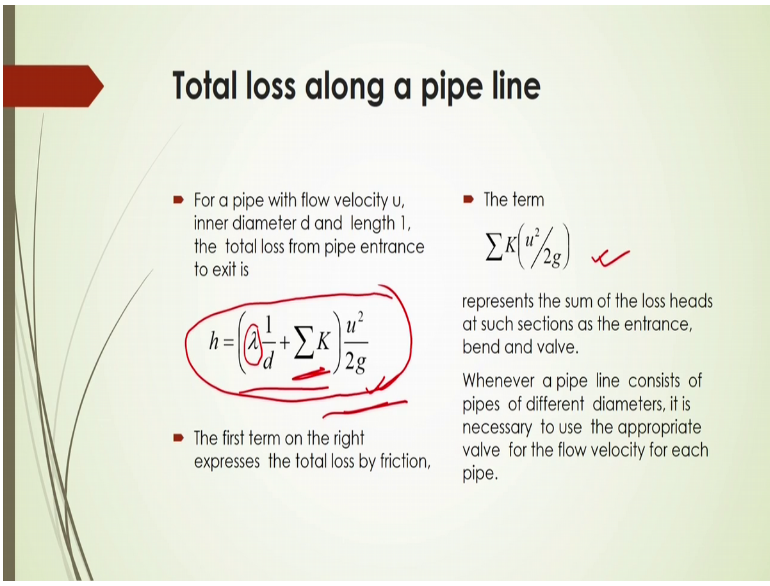

Now, what should be the total loss along a pipe line? If we are considering that a flow through a pipe with a velocity u of inner diameter d and the length l then total loss from the pipe entrance to exit entrance to exit that will be calculated by this in this case you have to consider both the loss major loss and minor loss. Now, if the pipe line is connected by valve, joint, bend or some other geometric change then you have to consider all those minor energy losses and also major losses based on this pipe geometry.

So, you have to sum up this minor loss and major loss then what should be the total energy loss whenever fluid will be flowing through the total pipeline. So, that pipeline maybe that is 2 meters, 5 meters even kilometers even 500 kilometers long also whenever oil is supplied from one location to another location through pipe line there you will see how this loss is calculated there you will see at different places a different locations the valve and also joints and the bend sometimes as per direction of the flow are considered.

So, first of all you have to based on the length and diameter, you have to calculate the loss coefficient for major loss and that will be calculated by lambda into l by d or lambda is called Darcy Weisbach friction factor or you can say it will be a f d only does f d that is denoted by f d that Darcy Weisbach friction factor and also all the minor losses that is sum up of all Ks here. So, this will be your total loss along a pipeline.

Now, the first term here on the right side expression the total loss by the friction and the term this one, represent the sum of the loss heads at such sections where there will be entrance bend or valve. So, whenever a pipeline consists of pipes of different diameters it is necessary to use the appropriate valve for flow velocity for its pipe and accordingly you have to calculate the minor loss coefficient and major loss coefficient and totally what should be the total loss whenever liquid is flowing through the pipeline.

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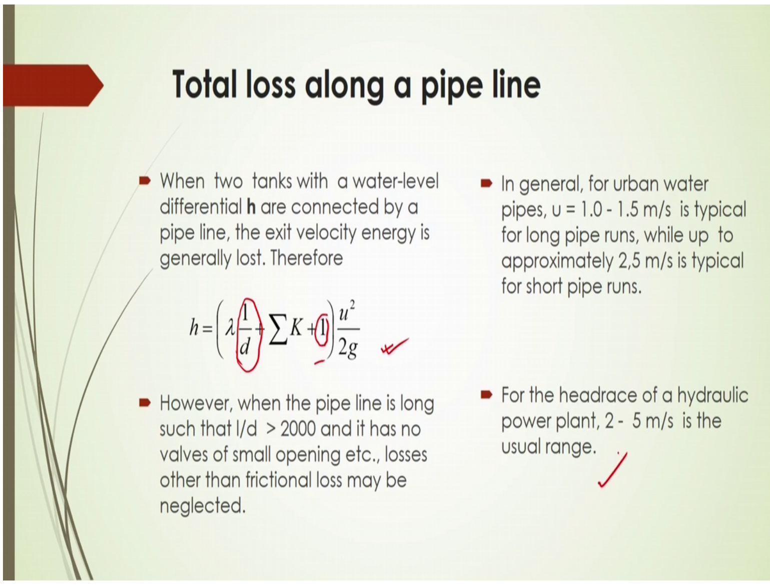

When two tanks with a water-level different height of h are connected by a pipeline, then the exit velocity energy of course, will be lost. So, therefore, in that case you have to consider that exit loss coefficient also in this case. So, it will be lambda into l by d plus summation of K plus 1 into u square by 2g.

However, when the pipeline is long such that this l by d that is ratio of length to diameter of the pipe is greater than 2000s, in that case it is suggested not to consider the losses that is given by a what is that loss other than the frictional losses that may be neglected. And in general for urban water pipes u will be equals to 1 to 1.5 meter per second, is typical for long pipe runs and while up to approximately to 0.5 meter per second is typical for the short pipe runs. And for the address of a hydraulic power plant generally the velocity is considered as 2 to 5 meter per second as usual range.

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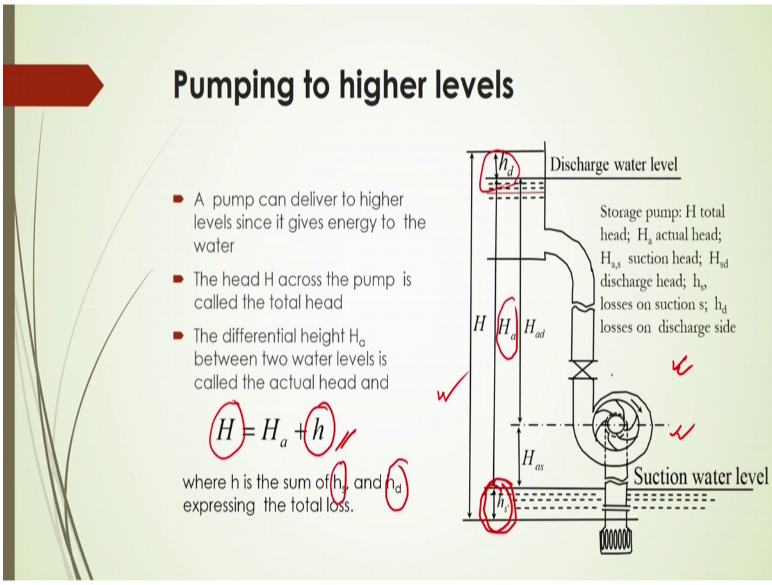

Now, if we consider a pumping a fluid to higher levels. So, in that case a pump can deliver the liquids to higher levels and it gives some energy to the water for which it will be flowing up to a certain location. The head H across the pump then it will be called as total head as shown in figure here. The differential height H a this height between two water levels is called the actual head here and H will be equals to total height will be equals to this H a plus h.

This is your h and this is your actual height of this water level. So, the sum is this H will be equals to this h is nothing, but the sum of h s and h d. What is this h s? This is your h s and this is your h d. So, this was water head loss and the suction water head loss. This h small h will be equals to summation of this two head loss. So, total head then H will be equals to this H a plus this H d plus h s.

And in this case storage pump if we consider then this storage pump will be suction in this water from the reservoir and it will be delivered to a certain height of that water reservoir. And this h s is the losses on suction s and h d is the losses on discharge side it is the given in figure. So, based on this figure you can calculate what should be the total head loss.

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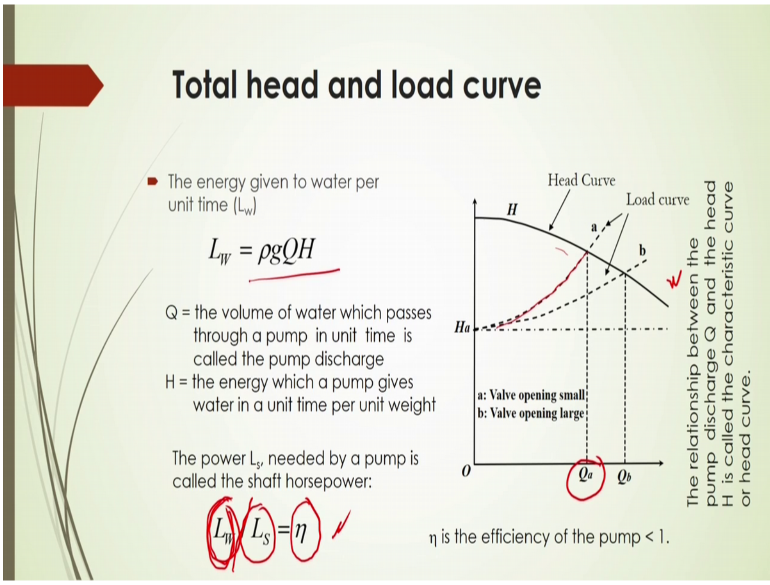

And again what should be the total head and load curve for this pump. Now, the energy given to the water per unit time L W that will be is equal to rho g into Q into H; where Q is the volume of water which passes through a pump in unit time that will be called as pump discharge and H that is denoted for the energy which a pump gives water in a unit time per unit weight. And the power denoted by L S needed by a pump to deliver this fluid that will be called the shaft horsepower.

And actually since there is a energy loss so, pump cannot be given the 100 percent efficiency so there will be a certain efficiency of the pump based on the loss of this energy. So, what will be that efficiency; that efficiency can be calculated that energy given to the water per unit time L W divided by L S that is power that required by a pump.

And this two will be equal if this energy given by water per unit time will be equals to that is L S and their 100 percent efficiency of the pump will be there, but really no pump will give you the 100 percent efficiency, no pump is 100 percent efficient. So, in that case there may be the efficiency 80 percent – 90 percent. So, heater should be here 0.90, what does it mean that whatever power is needed by a pump the all and all power cannot be utilized for delivering that total water to deliver to a certain location because of the loss of energy for the pipe junction for the friction or for the other geometrical condition inside the pump also and valve and also there will be a loss because of this impeller of the pump.

So, if we consider the efficiency curves of this pump or we can say that load curve or head curve of the pump that is denoted or represented by this figure here this H is see this is your H curve here shown that is total head curve. So, as the load of the pump is increases, then you will see that the head loss or head curve would be decreasing and in your that is the volume of water increases a per unit time that you will see for load curve here for a and b a for valve opening for small and for valve opening that is large. So, this two cases you will see for the small opening of the valve you will see the higher load compared to that large opening of the valve load.

So, the relationship between the pump sides or discharge Q and the head H is called the characteristic curve of a head curve characteristics phenomena of the head curve. So, from this head curve you can easily calculate if you know the discharge per unit time then what should be the head that is given by this pump you can calculate easily and what should be the efficiency of the pump from this you can also calculate.

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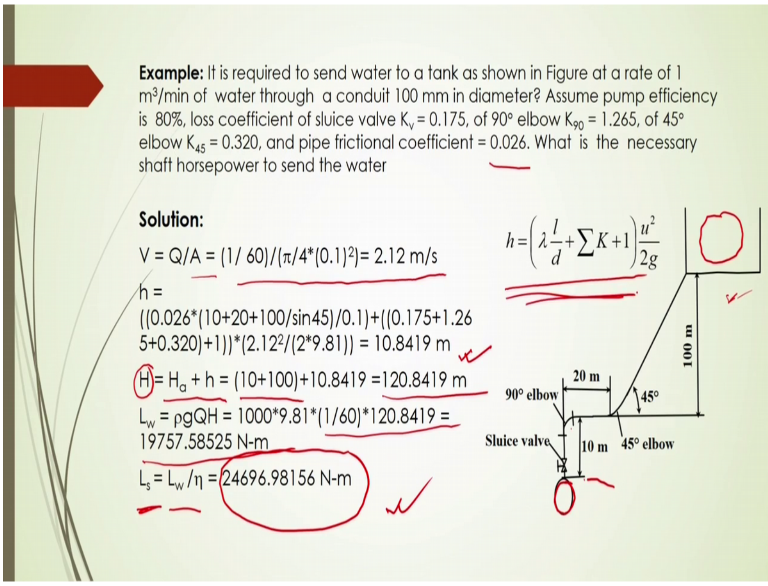

Let us do an example for this now it is required to send water to a tank as shown in figure at a rate of 1 meter cube per minute of water through a conduit of 100 millimeter in diameter. And in that case assume that a pump efficiency should be 80 percent loss coefficient of space valve is used and this coefficient is that K v will be is equal to 0.175

of 90 degree elbow and K 90 is equal to 1.265 of 45 degree and elbow K 45 that will be is equal to 0.320 and pipe frictional coefficient is 0.026 then what is the necessary shaft horsepower to send the water here.

So, very interesting that this is your pump by which water is sucking and through this valve of sluice valve and then it is discharging through this pipe line and the discharge amount will be collected here in this storage tank. Now, in between you are using this what is that sluice valve for 90 degree bend, 45 degree elbow like this. So, in that case you have to calculate that what will be the horsepower required for this pump?

So, if we use this equation first of all you have to calculate what should be the velocity. So, velocity will be equals to Q by A that will be equals to after substitution this is your it is given that 1 meter cube per minute that is 1 by 60 you have to divide then into cross sectional area you know the pipe diameter is there. So, it is coming 2.12 meter per second after substitution of those values and then what should be the h total head loss that will equals 2 lambda into l by d plus summation K plus 1 into u square by 2g.

Here lambda is the friction factor in to l by d. So, it will be coming as this after substitution of those values. This is given to you frictional coefficient is 0.026 into l by d; l is the total length of the pipe and d; d is the diameter and then other losses here summation of K for this sluice valve and then a 90 degree elbow and then 45 degree elbow after substitution of those values. And finally, we are getting this values of h as 10.8419 meter.

And, what will be the total head, this H? This H will be equal to H a plus h. This H a will be equal to what? This is to what water distance that is water level distance is 100 plus here 10. So, it would be 10 plus 100 that will be plus 10.84 19. So, this will be is equal to 120.8419 meter and then L W will be is equal to rho gQH. After substitution of those values we are getting here as 19757.58525 Newton meter.

And then what will be the efficiency? Efficiency is here it is given 80 percent. So, L S that is power required for the pump to deliver this fluid based on this equation here and then we are substituting those L W and theta value then we are getting this total power that is required for the pump to delivery to its reservoir here.

So, based on this example you will be able to calculate the total energy loss considering the major loss and minor losses and those minor losses are coming if you are using different valves, bends, elbows or different cross sections by changing this pipe and changing the directions then you have to use this equation for total energy loss calculation.

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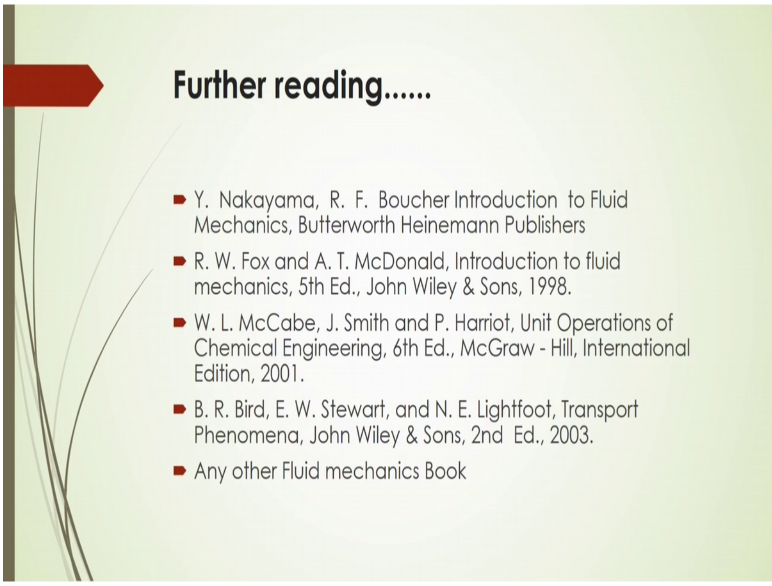

So, I think we can now understand that how to calculate the major loss and minor loss for the different geometry of the pipe, cross sections, expanding, contraction of the pipe, branching of the pipe, using valves and also what will be the major loss without using those valves. So, for calculation of the energy or considering the conservation of energy you have to consider those losses and you have to add up with those losses of energy to calculate the actual energy for that.

So, you can get more information regarding this major and minor losses of this pipe based on the geometry change from this text book given here. So, thank you for this today's lecture.