Upstream LNG Technology
Prof. Pavitra Sandilya
Department of Cryogenic Engineering Centre
Indian Institute of Technology, Kharagpur

Lecture – 65
Pumps in natural gas systems – II

Welcome after learning the basics about the pumps and their different types. Today we shall be going on to learn some fundamentals about the analysis of the various types of pumps.

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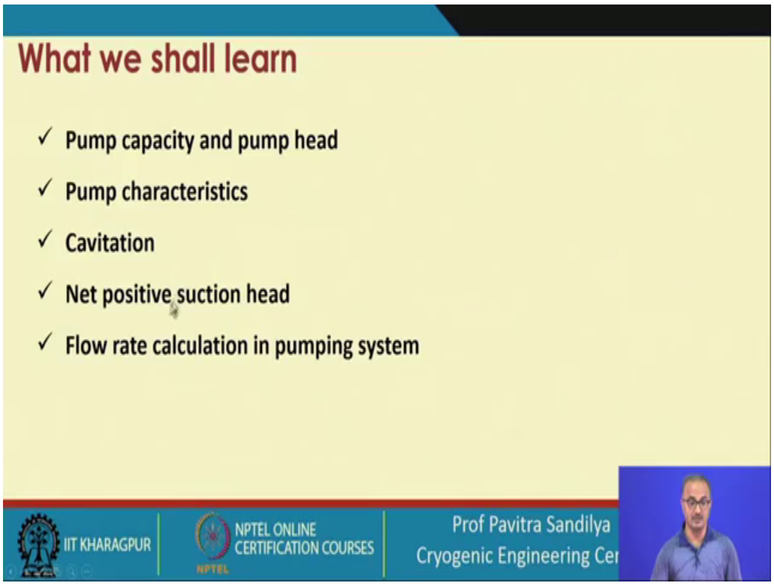

So, in this particular lecture series we shall be learning about the pump capacity and the pump head. What are the pump characteristics and Cavitation, the net positive suction head and how to calculate the flow rate in a pumping system.

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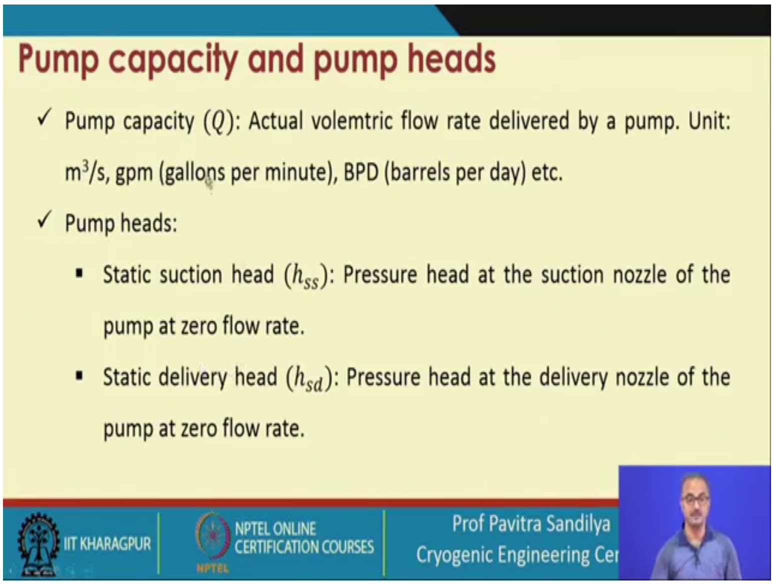

So, in this first we come to the pump capacity by it we mean that the actual volumetric flow rate that is delivered by a pump. And it is generally given in various types of unit like cubic metre per second or gallons per minute or barrels per day etcetera. And what is pump head? It is there can be various types of pump heads now we shall be looking at them one by one.

First we come to the static suction head what it means it is represented by h ss and it is the pressure head at the suction nozzle of the pump at zero flow rate; that is when the pump is not operating what is the head because we all need this kind of heads because the pump is basically as we learnt it is trying to push the liquid against some heights may be against some pressure. So, we need to know the what are the kinds of pressures available at the suction and at the delivery and that will help us to design the pumps. So, next we come to the static delivery head, it is represented by h s d and it is the pressure head at the delivery nozzle of the pump at zero flow rate.

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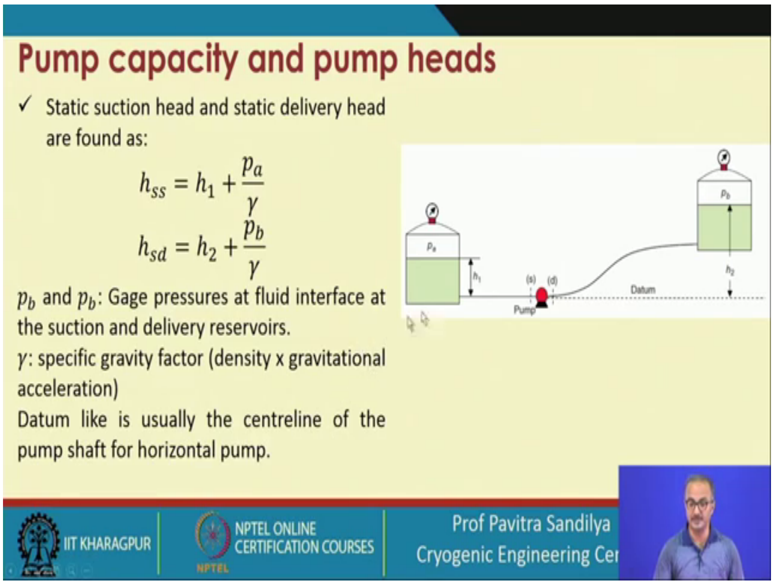

Now, here in this particular figure what we see that how to find out the static suction and static delivery heads. So, here you will see that we have two tanks and in this tanks this shows the pressure gauge fix two tanks to know the pressure inside the tanks and this is the pressure at the exerted on this tank and p a and this is the p b pressure.

And here we have the s represents the suction side and d represents the delivery side of the pump and here we take some kind of datum and this datum is usually the centreline of the pump shaft for horizontal pump. So, with the horizontal pump at the shaft centre we are taking the datum because whichever energy we are going to represent they will be respect to some kind of datum. So, this a datum we are fixing for the pump.

And now we find that how we find out this h as a suction line that this equal to h 1 plus p a by gamma; that means, this particular height elevation from the datum and the pressure head. And pressure head as we know this is divided by gamma this is the specific gravity factor which is the product of the density and the gravitational acceleration that is rho into g.

So, that is how we are finding the static suction head and then on the delivery side also we are finding it by h 2 that is this much head does this that means, the pump is getting this total head at the suction and against and it has to push the liquid against this particular head which is due to the height plus the pressure. So, this is how we are finding this static suction and static dynamic head.

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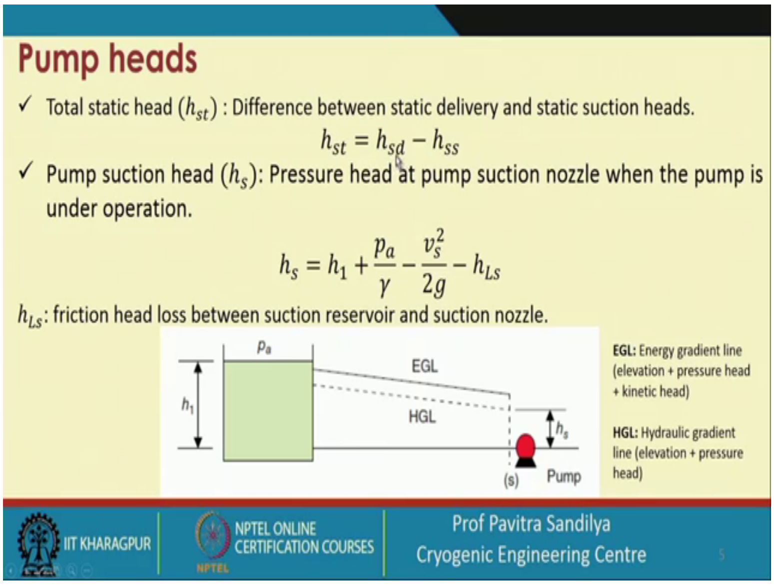

Now, the total static head is given by the difference between the static delivery and the static suction heads. So, this is how we are finding the total static head; that was the pump has to push against this particular head.

Now then we have the pump suction head that is given now again we see this particular figure this in this thing we are finding the pressure head at the pump suction nozzle when the pump is under operation. The difference is this when the pump is not under operation there is no kinetic head and when there is no flow of the liquid. So, there is no pressure loss due to the friction.

So, what we find here now when the pump is under operation we find this is the one which is the kinetic head and this is the one which is coming due to the frictional loss of inside the pipelines. So, that is how we are defining the pump suction head under operation and here we have the h l s which is coming here this is a fiction head loss between the suction reservoir and the suction nozzle. So, this is a reservoir and this is nozzle. So, between these two what is the frictional loss and here in this thing we have two things EGL and HGL these are known is energy gradient line which is the summation of the elevation the pressure head and the kinetic head and the hydraulic gradient line which is the elevation plus the pressure head.

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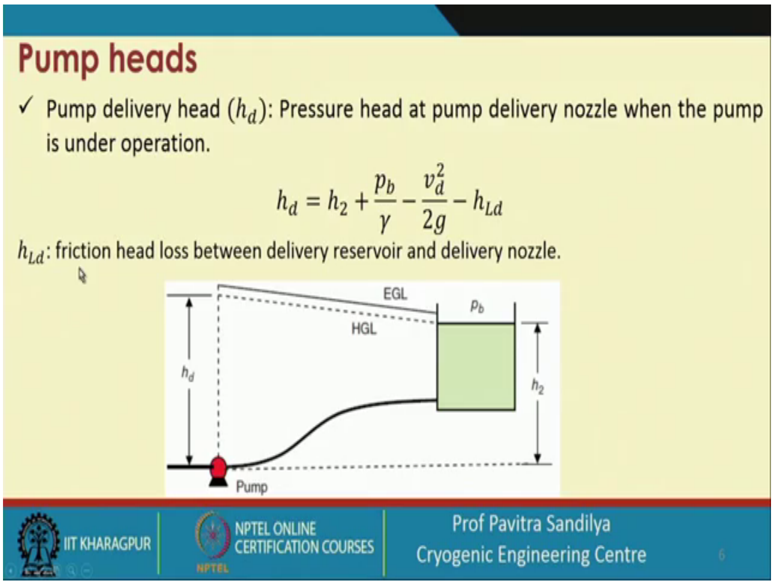

Now, here we have, next the pump delivery head. So, once we learn the pump suction head this is the delivery side that when the pump is under operation what is the pressure head generated at the delivery side. And again similar to the pump suction head we have the h 2 this is the potential energy then this is the pressure energy pressure head over here and this is the kinetic head in the in this pipeline between the pump and the delivery reservoir and this is the frictional loss in this particular line. So, this is how we are finding the pump delivery head.

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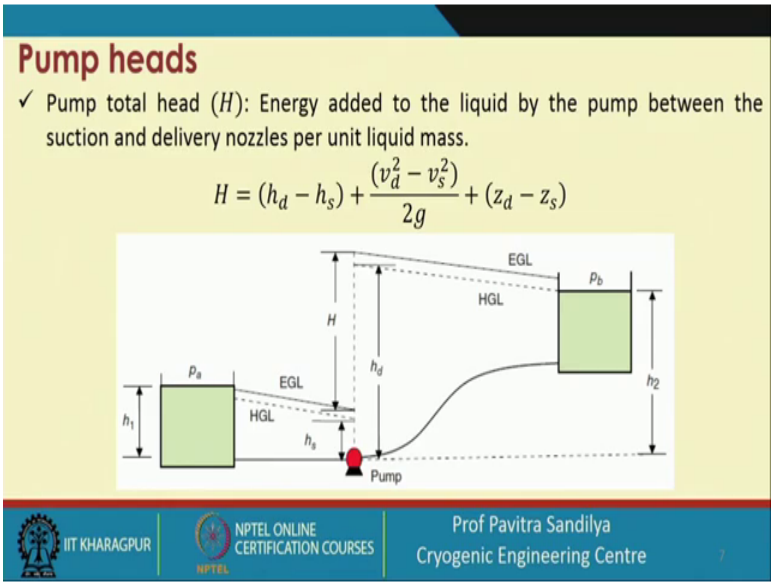

Now when we talk about the total head that means, energy is added to the liquid by the pump between the suction and the delivery nozzles per unit liquid mass. So, this is the total pump that is to need the liquid flow from a one pressure to the other how much energy needs to be added that is what is given by the total head of the pump. And here you can easily figure out that this is the way, this is the potential head difference this is the kinetic head difference and this is the elevation head difference. So, this is how we are finding this things only thing is this one has to know one thing one has to be careful about is that here we are kind of neglecting the frictional head.

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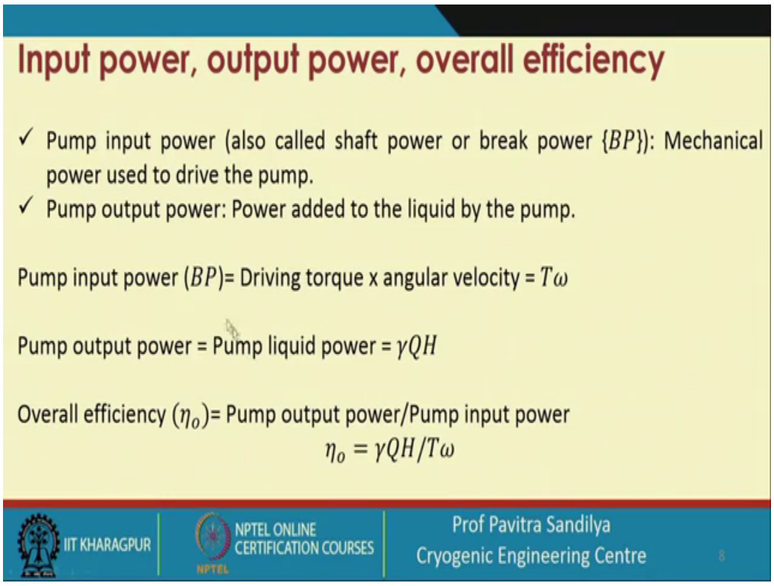

Because we are assuming that as if they are same on the both the sides, where can neglecting that. And now to calculate the pump power pump input power pump output power and the overall efficiency because we need the power dictates the cost of the operation. So, we need to know the power. So, power input power is given by also called shaft power or the break power given by BP sometimes we also use just P to denote the input power and it is the mechanical power used to drag the pump.

And what is pump output power? This is the power added to the liquid by the pump that means, you are inputting some power to run the pump and the pump itself is adding some kind of energy to the liquid to make it flow.

So, the pump input power is given by the product of the driving torque and the angular velocity, the torque is given by T and omega is the angular velocity then pump output power is given as the density factor into the flow rate into the head total head. And this is the overall efficiency factor which is nothing, but the ratio of the output power and input power of the pump and this is given by this particular expression.

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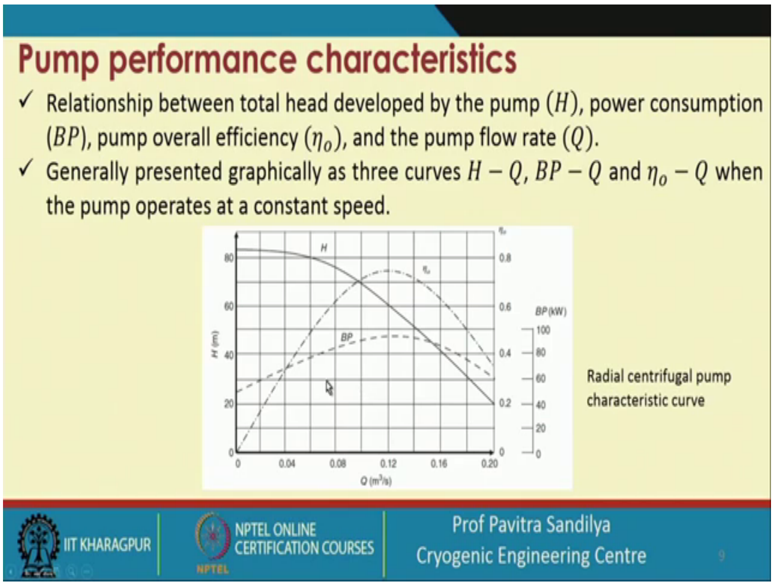

Now, here we have to know the pump performance characteristics and what it means is that it basically is the relationship between the total head developed by the pump that is H, the power consumption the power, the pump overall efficiency and the pump flow rate.

That means, when we are correlating the energy given to the pump with the head developed the efficiency of the pump and the flow rate given by the pump these things are the called this the pump characteristics. And it is generally given in a graphical form where we plot the head versus the flow rate then power versus the flow rate and the efficiency versus the flow rate when the pump operates at a constant speed.

Now, here we have a typical characteristic curve here you see on the x axis we have the volumetric flow rate given by metre cube per second on this side we have the head that is given in metres and on this side we have the efficiency, overall efficiency and here another scale is there which is giving the input power. And all these things we are plotting with these three curves we find that the as the flow rate is increasing the head is decreasing.

So, this head we shall find from any flow rate we can find out from this left hand axis and next is the overall efficiency, we find the overall efficiency first increases and reaches a maximum and then again start decreasing with the increase in the flow rate and this we can read out from this right hand side axis. And lastly we have the power input to the pump which also increases with the flow rate initially and start decreasing at a higher flow rate and this is can read from this particular axis. So, this is a typical pump performance characteristic curve and this is for the radial centrifugal pump. So, different types of pumps will give us different types of characteristic curves.

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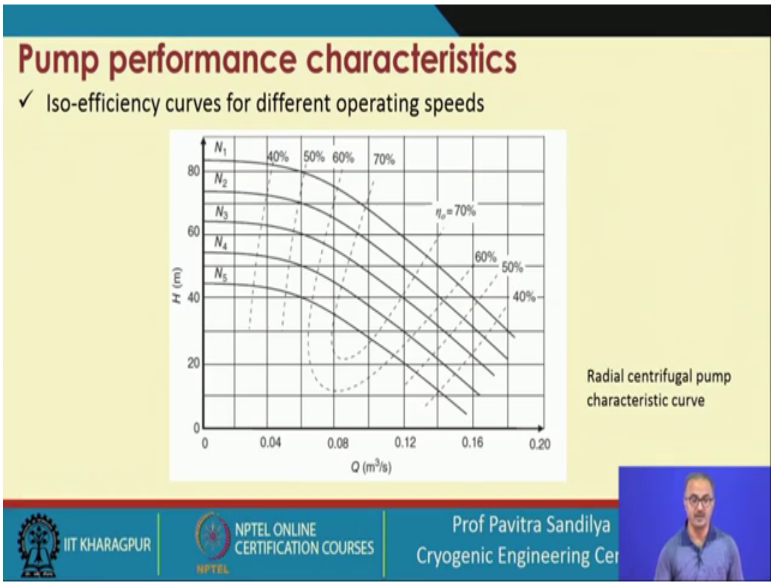

Now here we another set they another presentation here we are having the Iso-efficiency curves for different operating speeds iso means same; that means, we are drawing in this one again we are drawing the head versus the flow rate. But now what we are doing that we have different types of operating speeds here and the for different operating speeds and all these things 40 percent, 50 percent they show the efficiency Iso efficiency means these are some contours of the same efficiency. And we are drawing it for the different types of flow rate and this is also for a centrifugal pump.

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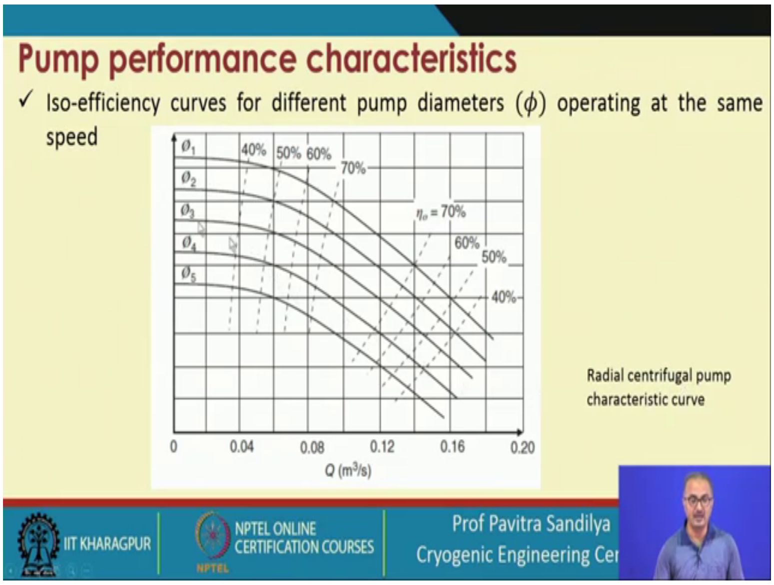

Next we have Iso efficiency curves for different pump diameters operating at the same speed. So, here we find again we have h versus Q here and again we have the various contour plots for different efficiency and here we are plotting the different types of the diameter. And we shall see later on how we make use of this characteristic curves in determining the performance of a pump.

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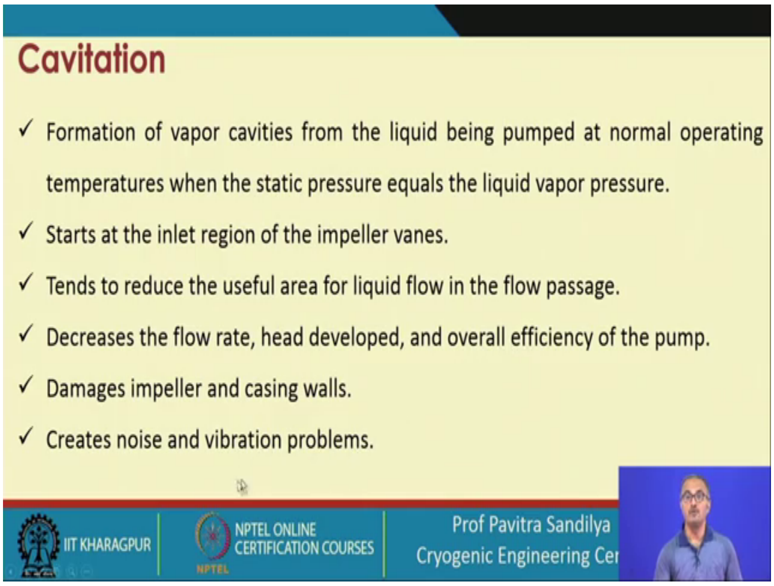

Now we come to a very important phenomenon that dictates the pump operation and that is called the cavitation. And what is the meaning of cavitation? The cavitation means the formation of some vapour cavities from the liquid being pumped at some normal operating temperatures when the static pressure is equal to the liquid vapour pressure. That means, when you know that any liquid would vaporize when its vapour pressure becomes equal to the surrounding pressure.

So, if this is the same case that if the pressure, the static pressure becomes equal to the liquid vapour pressure then what will happen this liquid will start boiling off and when the liquid boils what happens it will form some kind of bubbles and this bubble cavities, this formation of the bubble cavities is called the cavitation phenomenon. So, and it starts at the inlet region of the impeller vanes.

So, it when we have to make sure that the at the inlet whatever pressure is available on the suction side should be much more then the vapour pressure of the liquid. Because if the pressure is more then there is no chance of any kind of boiling and so, that we can avoid cavitation and why we need to avoid cavitation we shall just see.

Now, what happens when cavitation occurs? It tells to reduce the useful area for liquid flow in the flow passage because now some of the area is being occupied by the vapour cavities. So, we will find that there is a drop in the liquid flow rate. And as we know the pumps are used to drive liquid and not the gases we are using compressors, blowers, fans etcetera to drive the gases or vapours.

So, we do not want the formation of any kind of gases in the pumps that is why we need to avoid the cavitation also the cavitation decreases the flow rate the head developed by the pump and the overall efficiency of the pump. And not only that we also find this kind of cavitation damages the impeller and the casing walls and they create noise and vibration problems why?

Because what happens when this cavities are formed and as they move out of the pump there is suddenly a pressure rise because of diffuser the volute section of the pump as we learnt earlier. And due to this increase in the pressure what happens? These cavities start collapsing and when they collapse what happens they will hit the casing wall or the impeller is such a high speed that it will start giving those pitting action. That means, some of the materials could be chiselled of from the impeller or the casing and this kind of bursting of the gases and the liquid ejection from the gas bubbles they will cause this very noise and the vibration and it can cause the erosion of the material. So, that is how we are going to damage the pump if there is cavity.

So, from all these angles from the operational point of view, from the maintenance point of view we always must make sure that we are not approaching any cavitation condition in the pumps.

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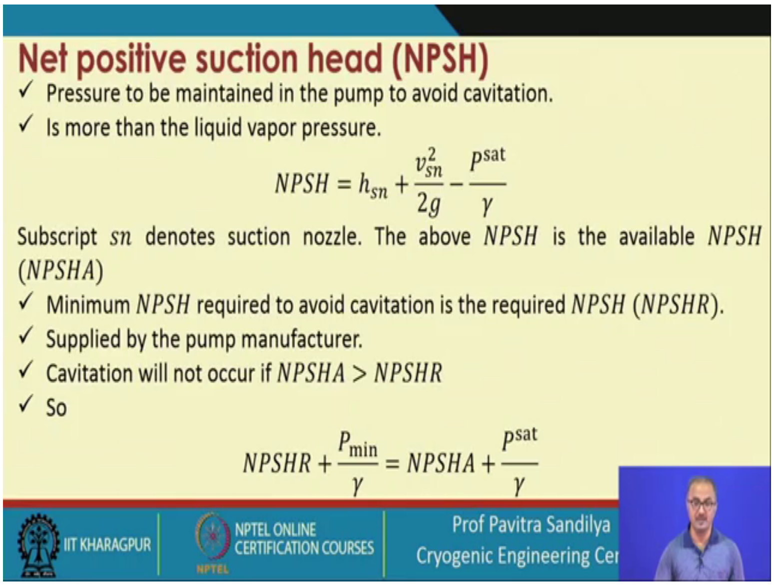

Next we come to the net positive suction head, this is given in short as NPSH and this is related to cavitation as we shall see now. This is the pressure to be maintained in the pump to avoid cavitation. So, we have to maintain this NPSH to avoid any kind of cavitation effect.

So, here we have the NPSH is more than the liquid vapour pressure, as I told you that if we maintain the pressure more than the liquid vapour pressure only then we can prevent the boil off of the liquid. And what it takes into account that this takes into account the head available at the suction side suction nozzle sn is suction nozzle then the kinetic head and this is from this we have this is the total head available from this we are subtracting the head due to the vapour pressure. So, this p sat is the vapour pressure of the liquid at the given temperature at the inlet.

And this minimum NPSH required to avoid cavitation is called the NPSH required. So, NPSHR is the minimum NPSH which we need to prevent the cavitation and we should see to it that the actual NPSH is more than the NPSHR.

So, generally this NPSHR value is given by the manufacturer and the available NPSH that is NPSHA should be more than the NPSHR, that is the required NPSH and here is the relationship between the two that NPSHR plus there is the P minimum that minimum pressure required this divided by gamma is equal to NPSHA plus S sat by gamma.

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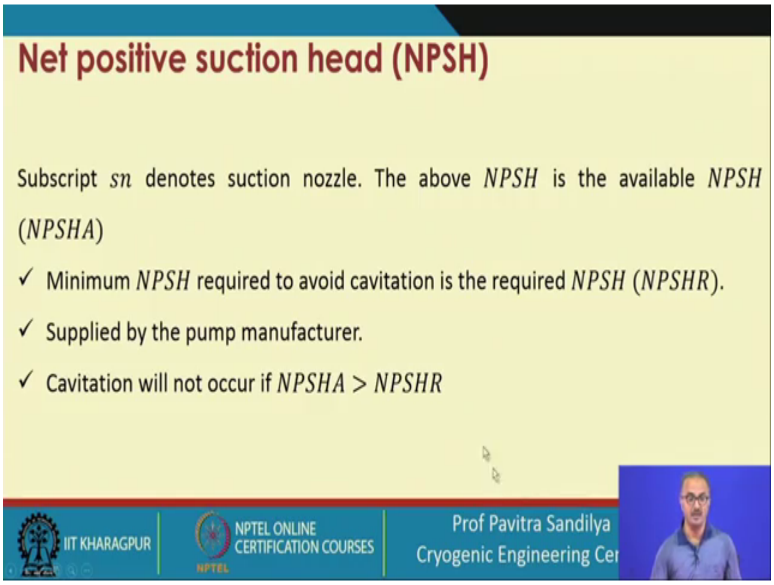

Now, this NPSH is available is this and minimum NPSH required to avoid cavitation is this.

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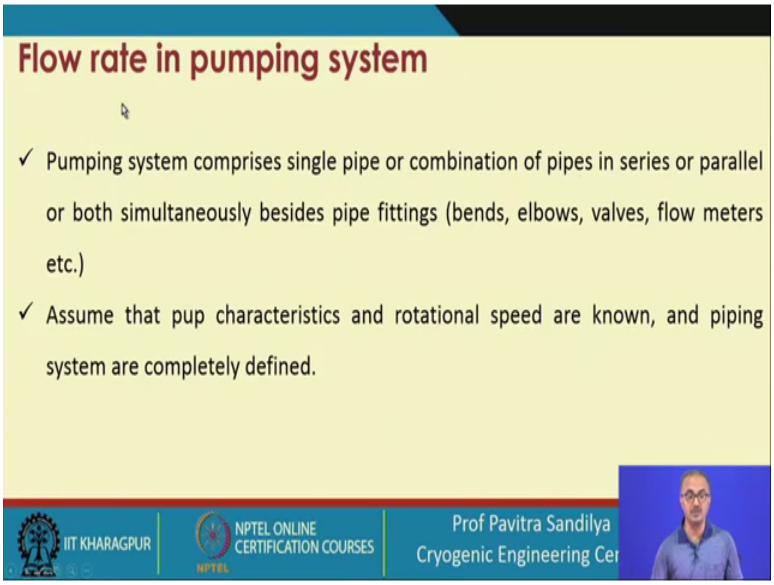

So, in this now we come to this flow rate in the pumping system. In this pumping system we find that the pumping system what it comprises of, it comprises the single pipe or a combination of different pipes which are laid in either series or in parallel or both.

And then we have with a pumping system various types of joints and fittings like bends elbows valves flow meters etcetera. And we assume that the pump characteristics and the rotational speed are known and the piping system are completely defined. So, this is the pump. So, if we have all this things defined characteristics and other operational things are defined then we can find out the flow rate in pumping system.

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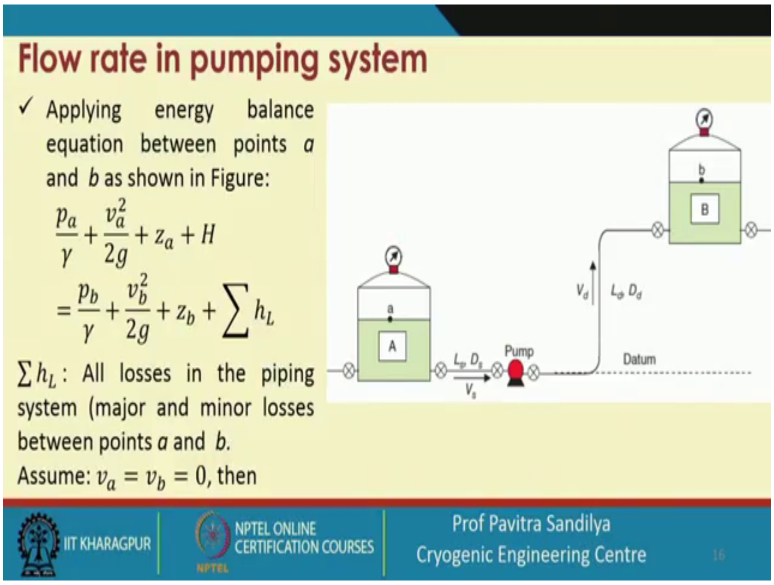

Now, here is a particular typical pumping system shown here. So, as we shown earlier this is one tank from which the liquid is taken through a pump and is to be delivered to another tank at an elevation.

And these are the various types of flow velocities and the L is the length the diameter of the pipe line on the suction side and this is on the delivery side and here we have the datum. So, this is tank A and this is tank B which are exerting this pressure at point a and at point b.

So, we are what we are doing we are writing just an energy balance and on the suction side we have the all these energies pressure energy kinetic energy the potential energy and the head of the pump plus on the delivery side we have this pressure energy kinetic energy potential energy and the head loss through the pipelines.

Now here we are assuming that because this cross section is very high we are assuming that the velocities inside the two tanks of the liquid that is that the velocity with which the liquid level is falling in the pump we are that in a tank we are assuming that these velocities are almost 0 and negligible in comparison to the velocity inside the pipelines because the tanks have a very high diameter.

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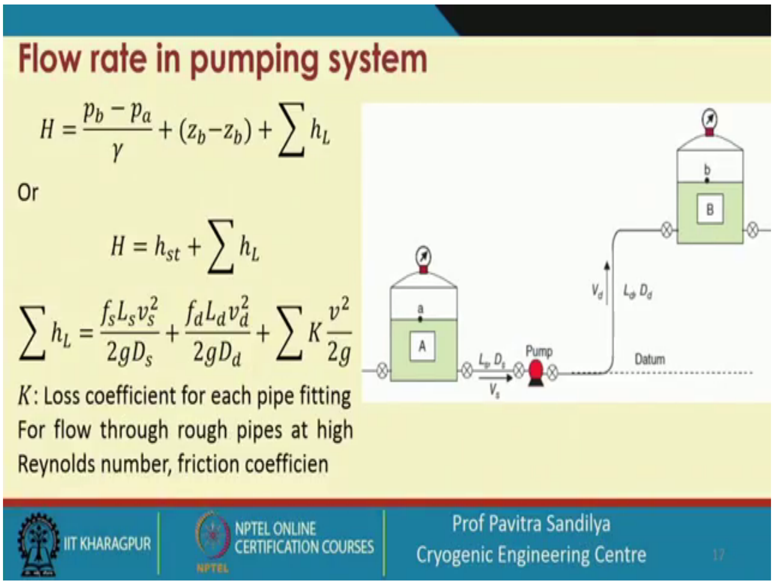

So, with this assumption what we do we now simplify the equations to find out the head and this is how we are writing from the thing that this will under we found this is the total head that is there to be a finding this head.

And here we find the total energy loss due to friction this is given by the friction factor on the suction side and this is given by the friction factor on delivery side this plus whatever loss is happening in the various fittings and the walls etcetera. So, this is accounted for K. So, this k is the loss coefficient for each pipe fitting for flow through rough pipes at high Reynolds number.

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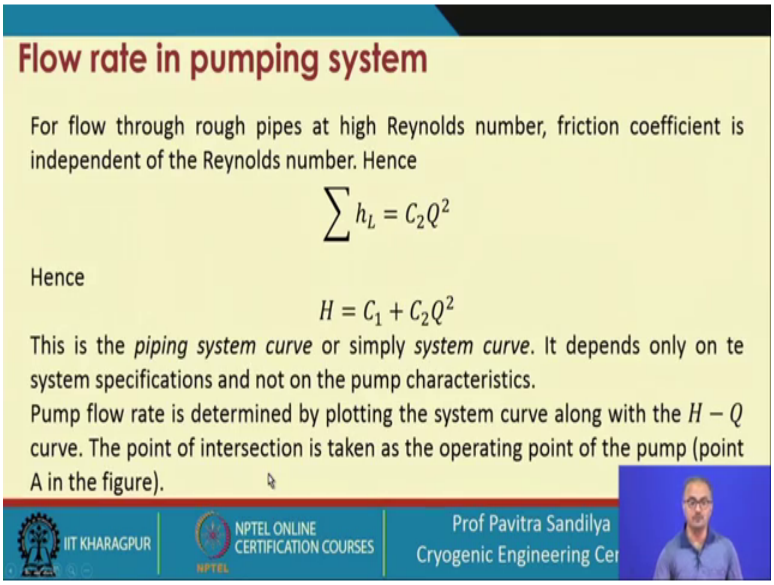

This friction coefficient is independent of Reynolds number. So, that we can find that we are taking it to be a function of the Q square and that is how we are finding this H is equal to C 1 plus C 2 Q square.

So, where this now this is what we are relating that we are relating the head with the flow rate. And this particular equation is called the piping system curve or the simply the system curve and it depends only on the system specifications and not on the pump characteristics and the pump flow rate is determined by knowing this H Q curve. So, we are plotting H and Q and we have to know that in this particular equation this C 1 C 2 are some constants which are specific for the given pumps.

So, what we shall do to find out the flow rate? We shall be first plotting this H Q curve and on this we shall which is given by the supplier, manufacturer and on this we shall be plotting this particular curve and wherever the point of intersection is that point of intersection will be the point at which we should be operating the pump.

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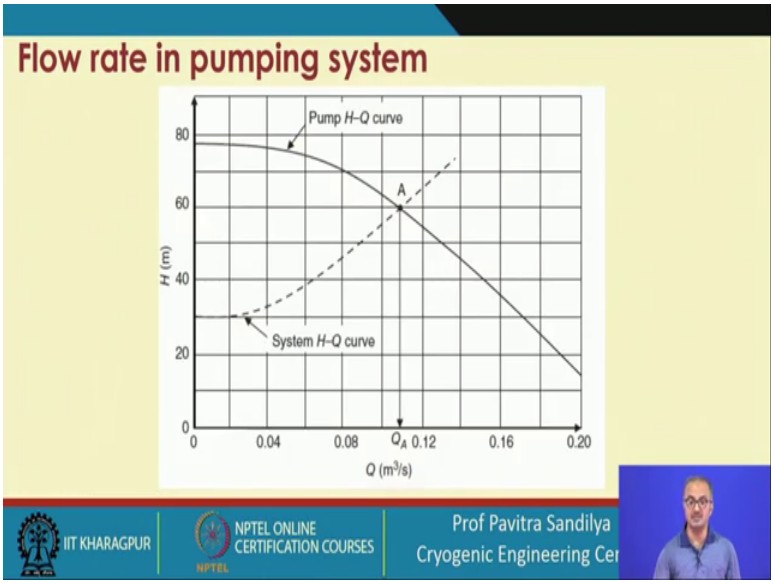

And here is the figure. We find that this is the pump characteristics which is given by the manufacturer and this is the curve we are generating from the energy balance and wherever these two curves are meeting this point A. So, what we do at this point A whatever flow rate is there we are getting that point of operation that is the flow rate for this particular pump.

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So, that is how we are determining the flow rate in a pumping system and these are the various books you can refer to for more detailing about the pump characteristics and other topics which I have covered.

Thank you.