Principles and Practices of Process Equipment and Plant Design

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Module - 04
Lecture - 55
Plant Hydraulics (Contd.)

Hello and good day to you all. So, today we are going to have our 2nd lecture on the Plant Hydraulics.

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We already have done a little bit of plant hydraulics. We have been talking about piping and the pipe fittings in the last class. Today what I intend to do is to cover pumps, then we will talk about the compressors.

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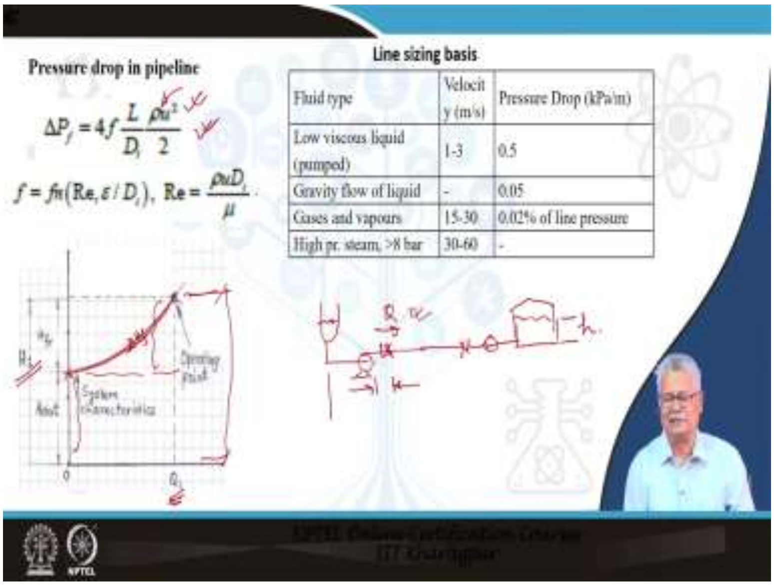

Regarding piping what we have said is, we know basically how to estimate a pressure drop in a pipe. Whenever there is a flow which leads to a velocity of u, that is a velocity u multiplied by the cross section - π by 4 into D square gives you the flow rate.

And this part of it is done already because we also know how to use that Moody's friction factor chart or Moody's chart whatever you may call and you can find out. For example, let us have a look here if I have a column, having a particular amount or liquid level in it.

We have a pump which takes suction from the column bottom and it is located at little bit ground level which is lower than this, then ultimately there are you have a valve here possibly a non-return valve here possibly a flow control. Sorry a heat exchanger and finally, it goes to a tank.

The tank has got some particular level of liquid which is h. So, even when my flow rate through this is Q, there is a differential pressure across this. This basically is an initial differential pressure and the corresponding head is this. It is due to the static head difference between these two.

Now, the moment the flow starts, there will be frictional losses which can be estimated by this equation and you know the procedure already. The additional amount of frictional head has to be overcome by additional head generated in your pump. So, I definitely will have corresponding to every Q or flow rate Q some total difference in the head between this point and this point.

So, what I have here is with Q, my head increases and since this Q is due to the frictional head and we have a u square term which means my delta P will be more or less proportional to the Q square, we have a very quickly increasing additional head due to this.

So, when there is no flow, this is only the static head and when I have a flow, this additional amount of head is due to friction. This is delta H due to friction and my total head or total pressure drop or head drop across the system is this. So, this plot of the head required to make the flow corresponding to a flow rate of Q, this relationship is called as system characteristics or system hydraulic characteristics.

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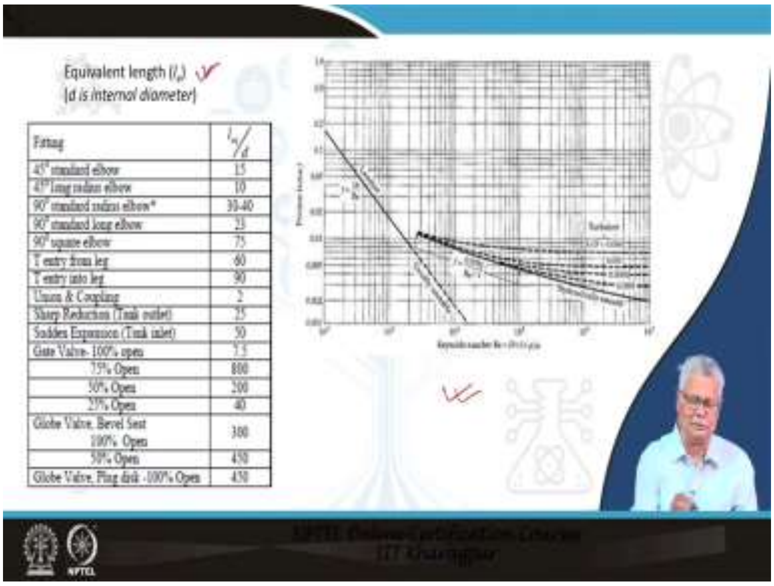

Here is a list of here is a basically the phoenix friction, phoenix friction factor chart that you have used and in order to account for the fittings, we have already known that we use the equivalent length concept.

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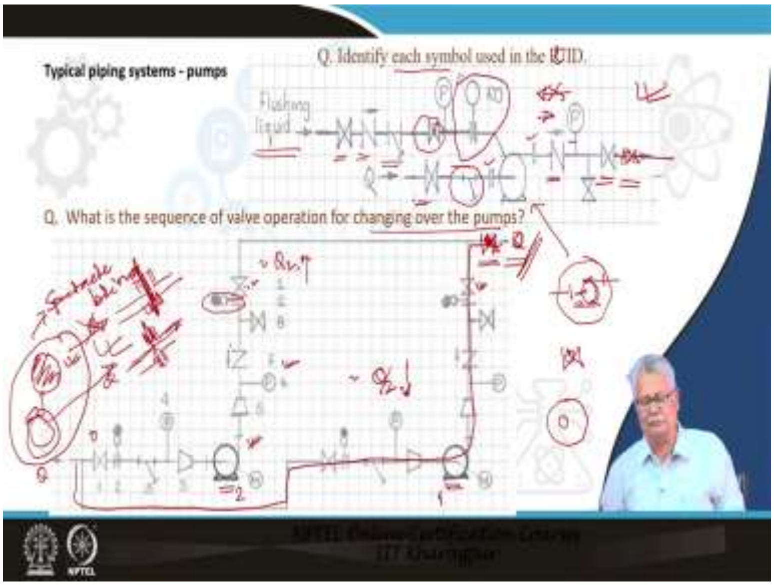

Now, what we do is we need to know about the pumps or rather first let us have an idea. Let us have an idea that what is the arrangement around a pump? What we have here is a symbol which stands for the centrifugal pump. Naturally, the centrifugal pump has got it is inlet at the centre, the discharge is from the periphery and normally it will have a pedestal.

So, this is the system and this is the symbol for a centrifugal pump which you have here. If you have a symbol like this, it is a gate valve and if you have a shuttle here, it represents a flow regulation globe valve. Now, if you see here what you have is the pump will have a flange. It has a flange which matches with the flange of the piping.

At the discharge, we have this symbol which is a non-return valve. That means, it does not allow any back flow. It is stopped and the direction of flow all the time can be this. So, there is either flow or flow in this direction only. Quite naturally you would like to know what is the pressure developed by air pump. So, we are expected to have a pressure gauge here.

Now, you usually will be having a bleeder valve also to see if your line is full or if you would like to drain something from there, then you have at the discharge another valve which is isolating this discharge side from here and possibly you will have your globe valve somewhere here.

If you look at the suction, the suction has got a similar gate valve for isolation and this one is a strainer. This is a typical Y type strainer which filters out. If any particles come, it does not allow that particle to go to the pump and damage that pump. So, you will always find wherever required a strainer which could be Y type or there are other types of strainers also.

The arrangement shown here is for pumping something pretty heavy and highly viscous material. So, what is done in such cases of these pumps is after the pumping is over. When you stop your pump, you keep it filled with something quite light. For example, if it is a pump for a vacuum gas oil or heavy vacuum gas oil, it will be filled up with diesel. So, you have a connection of diesel filling up for your casing.

The supply of this flushing liquid which is diesel which could be diesel in this case will naturally come from an isolation valve and you never want a back flow in this. You never want that from the casing. The material should go to your flushing liquid supply.

So, you have a non-return valve, also you have you must have in fact another strainer here and to regulate the flow, you have a globe valve here followed by a pressure gauge and a restriction orifice and a restriction orifice. What it does? A restriction orifice is nothing but a flange. It is a disc with a hole inside, it is a disc with a hole inside.

The purpose of the restriction orifice here is to provide pressure drop. That means, it will provide a certain amount of delta P across this and it will limit the flow of the flushing liquid to this. The flushing liquid normally will not be used. The flushing liquid will be mostly used during shutdown to fill up the system and possibly in some case to fill out the downstream piping as well.

Now, this is a single pump and it is a single centrifugal pump and in case of centrifugal pumps, the capacity control is directly by throttling the discharge which is done by this particular globe valve. And I believe that you have been now prepared to identify each symbol in this particular drawing.

We will find all of these are present, we will find that all of these are present in this drawing also, but you have one additional extra symbol. This simply means a spectacle blind, this is called a spectacle blind. What you have is something like this. You have the pipe, you have the flange, you have the other end of the pipe with a flange.

And it is possible for you to have a disc making disclosure. It is also possible for you instead of having this disclosure, what you could also have is something like this a disc with a hole inside which is something like your restriction orifice, but in this case the purpose is not to have any resistance, but you have a disc whose inside diameter is almost the same as your pipe.

So, what happens is when I have this particular hollow disc inside or the disc with a hole inside, there will be flow and when this is instead of this particular disc you have something which is a just a blind disc or it does not have a hole. There is no flow there. When you have this disc which is a solid disc something like this attached to the other one with a hole which looks like this, this is called a spectacle blind.

So, what you will have inserted inside is either this side. So, it will be the case of no flow and this side the spectacle side when you have flow through this. So, this is the case when you have the blind inserted and when you have this particular orifice inserted.

Now, what you have here is if you look there are two parts and this arrangement allows changeover from pump 1 to pump 2 without any change or without interrupting the supply of Q in discharge line. So, your Q comes in and goes here when you have pump 1 in operation, what happens is something like this.

This is your path. All valves in this line has to remain open and the pump runs. So, you have a discharge flow of Q. At the same time when this valve, these valves are on the second pump is shut, it does not it is not in operation. All valves in this line are shut. So, if I have to change over from here to here without any interruption in supply, what I have to do is basically the first thing I have to do is to start my pump here.

What do I do next? I supply before I start my pump I have to open this valve, so that my liquid reaches here. My blind should be off. That means, this orifice should be in the orifice should be in. Now, what happens now is once I have done it, you will have your casing filled up with the liquid. Now what you do is, you start your pump. Once your pump has started, you can see whether it is developing pressure or not from P, you have a non-return valve downstream.

If required you can open the bleeder valve very bit little bit and see if there is pressure developed and the liquid has come up to this point or not, then what you do is, you open this. Normally these two pumps are identical.So, if you have this and this circuit both on, simultaneously the flow through this ideally will be nearly Q by 2.

This will also be nearly Q by 2, then what you do is, you simply start closing your valve here. Do not close a suction valve. What happens is from Q by 2, it starts coming down and you start opening this valve more or rather you have your flow regulation. So, this would keep on going up.

So, this is what is the procedure for changing over from one pump to the other, from number 1 to the number 2 pump without any interruption in the flow from your system. Normally, the flow regulation will be done with a valve, possibly a globe valve or a control valve which is common to both. I believe with this you have some idea and if you are really requiring P and I to be developed around a pump which is required almost in all plants, you can have this as a model in your system.

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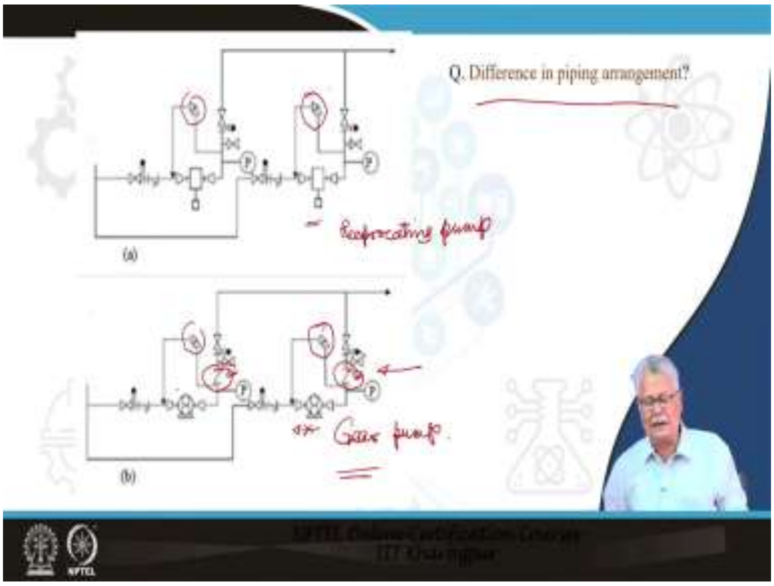

That was the case with a centrifugal pump. In case of centrifugal pump, we could open or we could shut that discharge valve and stop the flow without stopping the pump but I should not do it for a very long time. Why we cannot do? We can talk about it later on. You will find here, here what you have is a reciprocating pump and what you have here is a gear pump.

Now, you will find some subtle difference which I will not explain fully to you. There are some small differences in the piping arrangement. I would like you to find out and possibly question yourself and understand why the subtle differences is there between these two.

You will notice one thing that each of these, each of these, they have for the protection of the downstream a safety valve mounted that means and the safety valve if the discharge pressure goes high discharges back to the suction itself. Now what is the difference here? You will find here a non-return valve, a non-return valve which is missing in the other one.

So, my question here is you definitely have required or installed this non-return valve, so that there is no back flow. It is true, your gear pump is a rotary pump. So, there is a chance that it may rotate under very high pressure downstream. If your downstream pressure is high, your gears may rotate in the other direction and have a backward flow which is prevented by this particular non-return valve here and here.

So, I understand that yes both are basically positive displacement pumps, but there is some difference in the piping arrangement when you are using a reciprocating pump or another type of pump, which may have a back flow of liquid which has to be prevented with a non-return valve.

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I have two more examples of piping arrangement here. Here is the typical arrangement what you have with a control valve. Let us look at the fittings. In most of the installation, what you will be finding is the size of the control valve will be at least one size, often two sizes smaller than the main piping.

Here the main piping is 4 inch and you see it is a 3 inch nominal size control valve which is provided quite naturally you have a contraction in the cross section and you have an expansion in the cross section here. So, you have a reducer here and an expanded here as a pipe fittings. You normally will be required to drain your arms when you send your control valve for maintenance. So, you have two bleeder drain valves here which are typically half in size in industry.

You require naturally if you have to send this for maintenance, all equipment will require maintenance and if that bit is so you have to isolate it. So, you have a gate valve here and a gate valve here. If you shut this drain, this you are at liberty to take off your control valve.

When this happens, that means this is shut, this is shut. Naturally there is no flow here, there is absolutely no flow. So, during this period you can still continue to have a flow of Q by regulating the opening of the globe valve which is in the bypass line. It is the bypass to the control valve which is manipulated in order to keep this Q same.

This arrangement allows you to maintenance or service your control valve including calibration your own online, calibration of your control valve without affecting or without interrupting your flow through your circuit. The left one that you see here is basically a blending arrangement.

You have a stream A which is coming from the left and a stream B which is also coming from the left. B mixes into A. The flow rate of A is governed by the flow controller and a control valve here. The flow rate of B is regulated by exactly a similar arrangement which is a controller and a control valve.

Now, here what happens is a non-return valve has been provided. That means, in case the pressure here exceeds the pressure at this point, there is a chance of back flow, there is a chance of back flow which is Q. So, that is prevented due to the presence of this.

So, quite naturally what you expect to happen, you expect to happen what you expect is you will provide this non-return valve on the line which is really badly affected. If the other liquid has a back flow if this goes into this particular stream really, does not, it does not matter much.

But in this specific case if A gets mixed with B, the you have a problem and that is why you have install your non-return valve here in the root of B joining A and generating the blend A plus B. Just go through and try to identify these components of the piping system and realize why every component of the piping has been provided.

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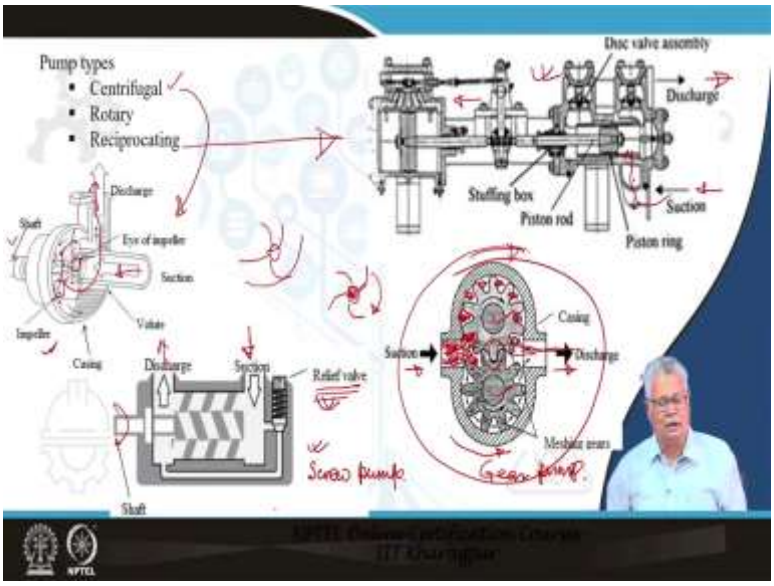

We have talked about piping, we have talked sufficiently enough. In the way we have also mentioned about the centrifugal pump. We are I am not going to talk about the basic principle, but I will talk about the components of the centrifugal pump which is shown here. You definitely have a casing in which there is an impeller. The impeller if I look at it is going to look something like this and it is rotating in which direction.

It is rotating in sorry I made a mistake. I will put it like this and draw it in the proper way. The direction of rotation is this. The liquid enters in the eye of the impeller, travels along and gets thrown tangentially. So, you can see the movement of the liquid particles which are shown here with small small arrows. These are the ones. And this happens within a casing and the impeller is driven by a shaft. The eye of the impeller is this. The suction comes and terminates here supplying the liquid to the impeller eye.

The casing is here and you have it is also known as a volute because it is not just a cylinder, it ends with a discharge arrangement as well. So, liquid comes in this way, gets thrown of tangentially and goes out this way. I have already mentioned that you can have say a centrifugal pump. It is capacity can be controlled by simply discharge throttling.

Here what you have? This is the centrifugal pump and here what you have is the reciprocating pump. If you see here what will you find? You will find let us say it is an arrangement in which what you have is a row is a reciprocating piston. What it does is, it takes suction from here and discharges it here.

When it moves to the left when this moves to the left, what it does is the suction the material gets sucked in and with it reciprocating back to its original position. In that case, there will be a valve which will shut here and it will come out through the discharge. This is very common there are plenty any basic hydraulics book. You have a look that will explain you the working of a reciprocating pump.

And there are various types. You can have a dual acting, single acting and different variations are there and it could be driven by an electrical motor, it could be driven by a steam engine anything. Sometimes with air compressors also, compressed air also. Here what we have is a gear pump. What you normally have is two machine gears; gear 1 and gear 2 which are meshing here in this range.

So, naturally it is within a casing and the suction is from here and the discharge is from here. The liquid comes in and fills it up. Naturally this will be all filled up with the liquid which is coming from the flooded suction, then what happens the gear rotates this way and if it rotates this way, this also has to rotate this way.

So, naturally the liquid which is trapped here, the liquid which is trapped here will be travelling to the discharge end. One thing is true that means, it is as if a packet of liquid is picked up from here and finally, discharged at this particular point and it goes out, it happens with both the gears meshed together and since they are meshed, there is no direct connection between the suction and the discharge.

You will also understand one thing that this is a positive displacement pump and it can it is supposed to handle more viscous liquids. There is another pump which is shown here. What is this? This is basically a screw pump. What you have is a helical screw. Now, if you have a helical screw and you have a suction and a helical, this screw itself the grooves are quite deep.

So, what happens is something like this. The liquid gets trapped between the grooves, it gets trapped in the grooves and as it rotates. It is pushed from the suction to the discharge and finally, it comes out So, you have a rotating shaft here, here normally in this as well as in this type you will have integrated safety relief valves. I believe you now have an idea about that centrifugal and rotary and reciprocating pumps and we move forward.

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Quite naturally whenever you are to select what type of pump you require, there is a guideline which is normally referred to. Here it is a flow rate and here you have a pressure. This is a typical industry guideline graph which is only a guideline. It is not a sacrosanct thing. For example, you can very well see there is a limit to the pressure when you are talking of the centrifugal pump.

There is a limit of the maximum flow rate which is this beyond which you normally go for reciprocating pumps. In case of rotary, the total head to be that can be developed there is a limit and quite naturally the capacity is in between the centrifugal limit and the rotary limit.

So, if you know your service that you required, if you know your flow rate, if you know your pressure that is required for your flow, what you do is sorry you simply locate your point and see which type of pump can serve you. This particular location is somewhere which could be served by all three types. If it is here possibly in that case you are going to go for a centrifugal pump. If it is here, everyone can make it say clearly that you require a reciprocating pump because the pressure developed compared to the flow rate is much higher.

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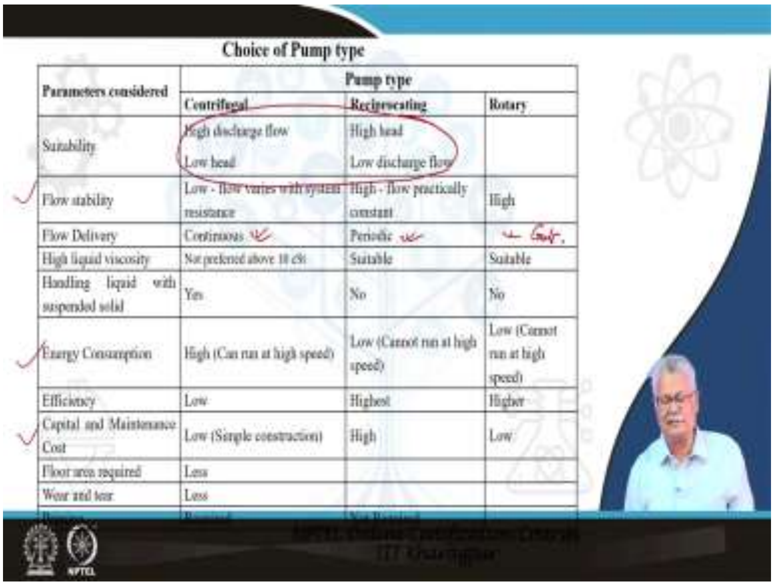

So, what we do is, we bring a few other characteristics of parameter that you normally consider and these are regarding the capacity and the head we already have said in the last chart. Regarding flow stability that means your rotary pumps and the centrifugal pumps, they provide you a continuous flow. In case of a reciprocating pump, it is fluctuating, it is basically periodic. So, this is continuous, this will also be continuous.

Now, regarding flow stability it is like this. We already have mentioned that in case of centrifugal pump what you could do is, you could throttle your discharge and reduce your capacity. So, if due to some reason in your process, the discharge pressure varies the flow would also vary and it has to be taken care of when you select your pump.

Whereas this will never happen in case of reciprocating. I will not say it will never happen, but it will rarely happen because every pump has got a limit and some small amount of leakage takes place and with a higher discharge pressure, possibly there will be one percent leakage in even in reciprocating pumps. So, these are the other points here regarding efficiency capital maintenance cost floor area which you must consider or which you may consider in order to decide, what type of pump you really require.

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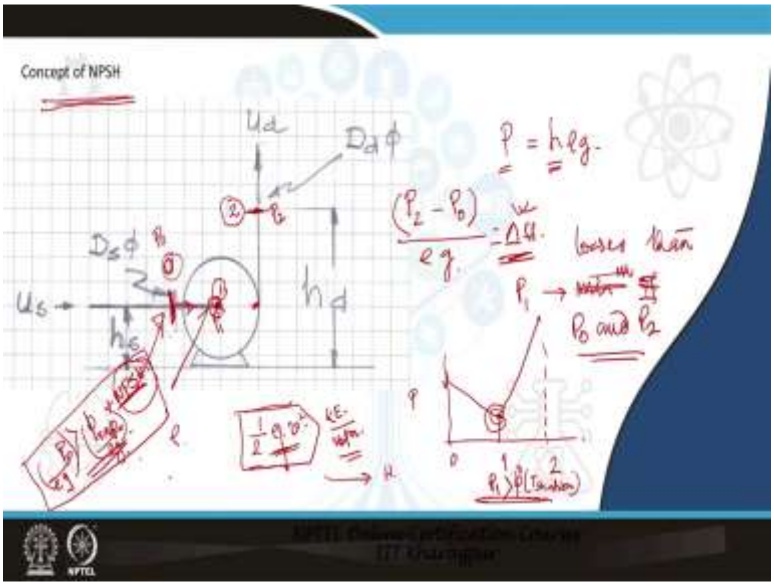

What I will do is, I will just give you the concept of net positive suction head today and stop. The net positive suction head I will just take the example of a centrifugal pump. This I say is my 0.1 rather I will say this is my 0.1 and this is my location 0 and this one is my location 2. That means, I am talking about the suction flange of the pump, the eye of the impeller and the discharge.

Now, you know very well that in a centrifugal pump what happens is you have a pressure here which is P 0, this pressure will be P 1 and the pressure here will be P 2. The difference between the pressure at this point and this point is practically it is a very short length. So, I will say that the P 2 pressure is here or here.

At the tip of the periphery, the pressure is P 2, the total head is P 2 and it is same. I could also relate instead of P, I could also talk in terms of h rho g and this is the head. So, I am going to use either h or P. Now, let us see a few things. If you have a supply pressure, there will be one particular pressure P 0 at the suction flange which is the expected minimum pressure here.

The expected minimum pressure is P 1 is minimum of P 0 rather I will not say minima, I should have said lower of lower not lower than and P 2. That means, from this point to this point it flows by pressure gradient. What happens inside, the impeller, the impeller imparts kinetic energy which gets converted into head. So, quite naturally you are adding energy here, you are adding head here. So, the pressure increases from P1 to P2.

So, if I have the locations here as 0 1 and 2 and if I plot either my P or my h whatever I would like to say, this would be the point. Now, let us see the head developed is because of the kinetic energy which is imparted by the impeller. What is the kinetic energy per unit volume half rho into v square if v be the velocity of the particle over there and it is a kinetic energy per unit volume of liquid.

Now, what I would like to say here is something like this. If your row comes down, this is what gets converted to head and I am going to say that I am really interested in the head developed by this particular pump which is basically P 2 minus P 0 and if I am talking of head, I must divide it with rho into g is equal to delta H.

So, I am really interested in my delta H to be developed by this higher, this value more will be my delta H. So, what I really have here is something like this if rho comes down my head developed by the pump comes down, when can row come down if I have vaporization inside, when, where exactly is a chance of vaporization maximum where I have minimum pressure. That means, at the eye of my impeller.

So, what I say here is something like this. I must ensure there is no vaporization at the eye of the impeller. That means, at this point my P 1 has to be higher than the pure component vapor pressure at the suction temperature. This is something which I have to ensure. That means, this pressure I cannot measure, but I have a way of knowing this particular pressure because it is a supply pressure to of the liquid to the pump itself because when I do my calculations, I can find out or estimate what this pressure P 0 will be.

Now, from here to here on what it depends, it depends on the impeller type and who can tell you the best way of estimating the difference between P 0 and P 1? The manufacturer. So, what the manufacturer tells you is, you must have at this point. The pressure here should be greater than P vapor pressure definitely plus sum which is which he calls NPSH.

Now, instead of since he said it is head or meters of the liquid, I am going to use divided with rho g. I am going to divide this with rho g, everything gets converted it to head and this is the condition which is imposed by the manufacturer that means, at the suction point the pressure of the liquid has to be higher than the vapor pressure of the liquid at the suction condition by an amount by an amount and this is called the net positive suction head.

It is specified by the manufacturer in the characteristics and it is a characteristics of the pump on what it depends. It depends on the construction. I think with this I will stop here. I suggest that you yourself also read about a little bit more about net positive suction head. We keep and continue further concept of net positive suction head after this.

Thank you.