**Mining Machinery**
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**Module - 07**
**Lecture - 38**
**Basic Pumping Theory**

Welcome back to our discussions. We have been talking about the pumps; we just got the introductions of different types of pumps and which are used in mines.

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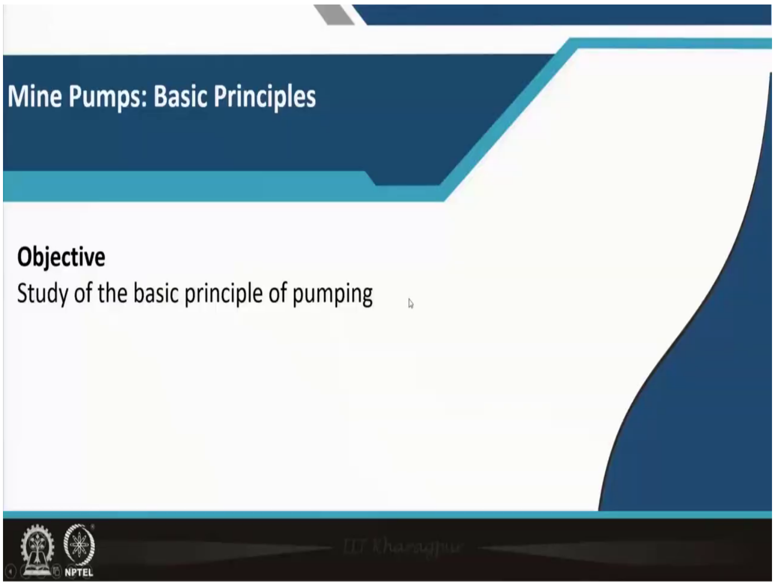


So, today, we will be discussing some of the basic principle of pumps, so that you can understand that how a pump work. So far, we have studied that we are having this centrifugal pump, we are having our reciprocating pump, we have also talked about that how are we have got submersible pumps, we have got mono pump, different type of pumps in the mines.

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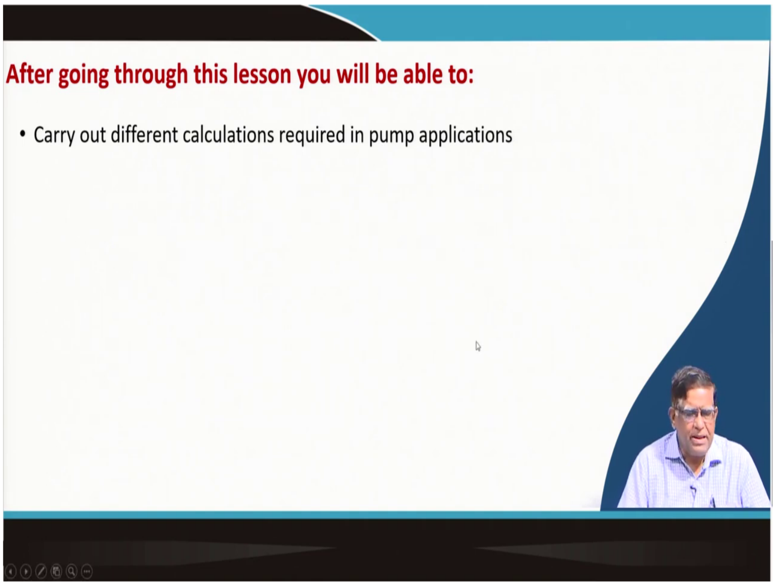


Now, this say today, we will be discussing about some very basic calculations regarding pumping. What normally you need to know? You need to know that what should be the motor power required to drive a pump, sometimes you need to know exactly under what conditions that a centrifugal pump may go for cavitations or you need to know what are the characteristics of the pump that means how it will behave.

It is a head, your capacity, its efficiency, what is the critical speed of a pump, what is the net positive suction head, this type of things are very much essential for selecting a pump for a particular dewatering projects in a mines.

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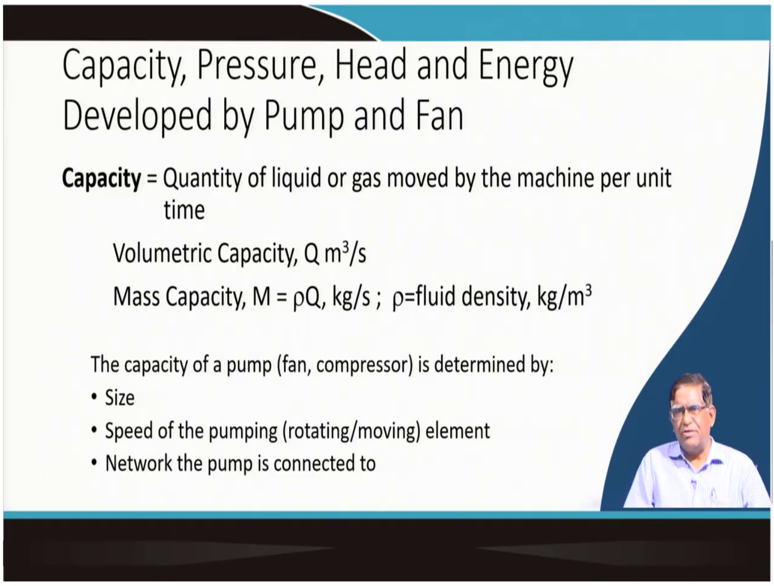


So, first thing is let us know what is understood by capacity, pressure, head and energy develop by a pump and fan. This is exactly we will be discussing about fan and compressors also in our next class. But this capacity it is that whatever the quantity or whatever the amount of that volume of fluid which will be passing through per second that is what is your capacity.

Now, one thing is there in case of pump sometimes, we need to know about the mass capacity also that is because the pumping can be done for slurry, sometimes for mud, sometimes for even paste.

So, that is why there the mass capacity is also important and that will be just when you multiply your capacity that is a volume rate that is you say sometimes it is a Q sec that is your cubic meter per second that is called Q sec. If you multiply that Q sec with the density, then it gives your mass capacity.

Now, this capacity of a any turbo machinery that is your fan or compressor or a pump, it is a mainly it depends on the what is the size and that what is the speed of pumping that is at what rate it is moving and then, what is your total network of the pump, how it is connected and also sometimes, it is with the type of pump that is at what how many stages or what stages you are doing, those are the things which determine the capacity.

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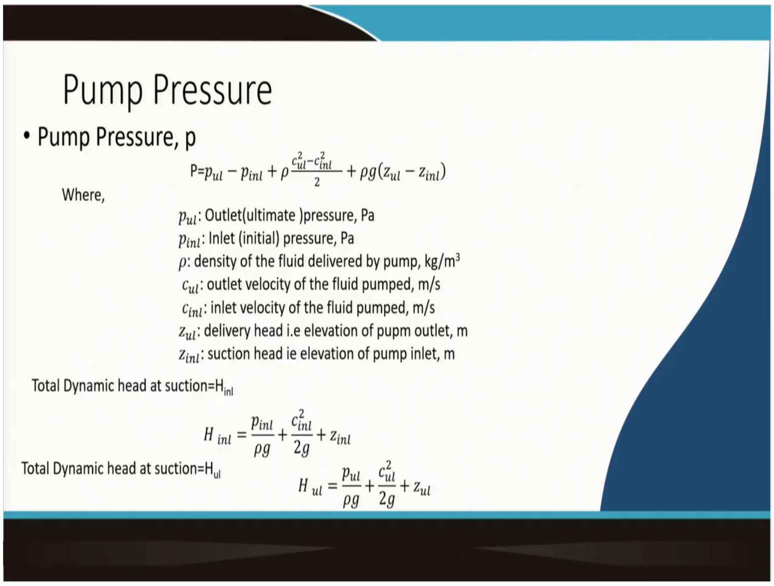


Then, another thing very important thing is to know that is your pump pressure. As we know that the definitions of it exactly for that liquid flow from high pressure to the low pressure so that how exactly pump create that it is taking out the water and then, your any fluid how it is pressing.

So, here the pump pressure it depends on what is exactly at the outlet pressure and then, what is at your inlet pressure, their difference is your the pump pressure. But within that it also generates depending on its density, your what is at what velocity is going that is your the when a fluid enters into the pump, there is at inlet velocity and when it is going out, there is an outlet velocity.

So, that pressure depends on that is exactly what is these differences of this velocity and depending on its density, a component is there. And then also, there is a what is that delivery head? That is where we say what the vertical that elevation difference at that delivery end and at that main eye or the pump level and that as a suction head that is which is elevation up to the inlet.

So, this from the basic principles of your hydraulics, you get this pump pressure is given by this equations which is difference of this your pressures at your ultimate pressure that means, at the outlet pressure and the inlet pressures that is your square that is depending on this the difference of the square of the velocities and that is your the head at the outlet and inlet. So, this is a basic equation for pump pressure.

Then, there is also one thing called dynamic head that dynamic head at the suction at a suction which is at the inlet of the pump, it is coming on that your whatever the inlet pressures and with the density, its velocity, these are the things which we get from the Bernoulli's equations and same things, we can find out what is at the outlet. So, this pump pressure calculation is the basic things.

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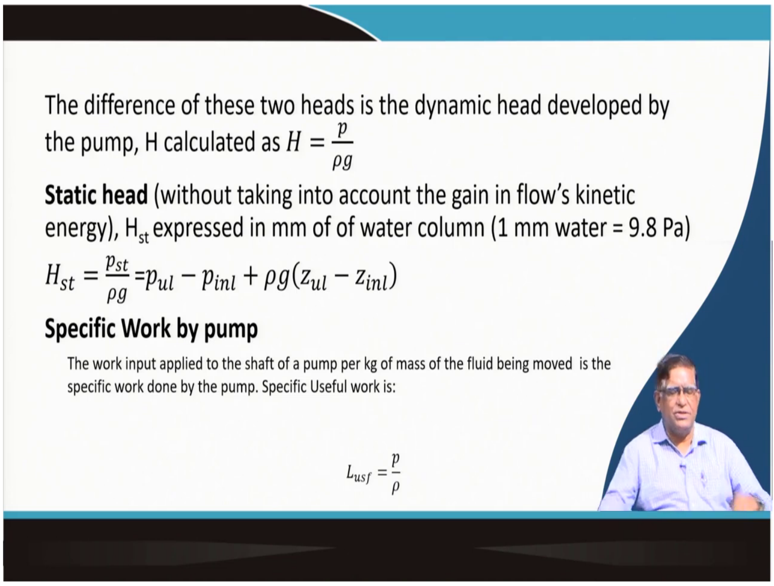


Now, this your outlet and inlet, there this dynamic head that is develop by this differences is your rho that is your the total pressure difference by rho intensity. So, this from here, this head is known and there is a static head, that static head exactly when we do not consider the velocity component as in the first equation, we have seen that it is a the difference of the square of the velocities if you do not take into consideration, then whatever head is there that is the static head.

So, difference of the static head and that your main dynamic head is your these component that velocity difference component is not coming over here. And then, exactly every pump is doing some work, exact that they are how much volume of water or fluid is being put that is depending on that how much work is being done by the pump.

And that is what is your useful work and that useful work is a normal expression is your that pressure raised by density. So, this is what a as a very preliminary things you need to know.

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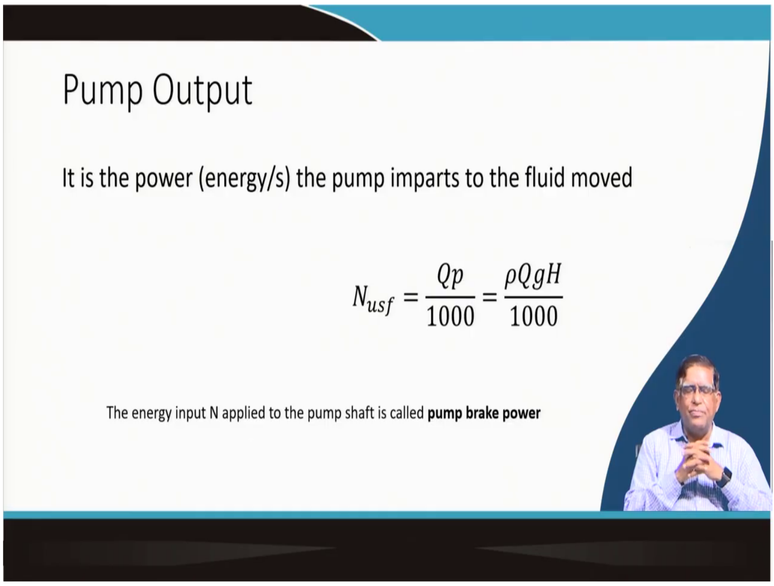


And from there, we get that main equations that your this useful work is exactly that is your what is your energy output per second that when you say as there how much exactly work is done, this basic equations is this quantity pressures by that is for conversion of the unit, you get this rho QgH by 1000 that is your what is exactly the output power in kilo Watt. We are dividing by 1000, we are getting it kilo Watt just taking care of the unit.

And now, this N which is applied to the pump shaft that is your that shaft will have to be rotated so, this much power will have to be. Now, to get the motor power, if your this one if you are whatever the efficiency mechanical efficiency is there, whatever the energy loss by dividing that you can get calculate the motor power so, that is.

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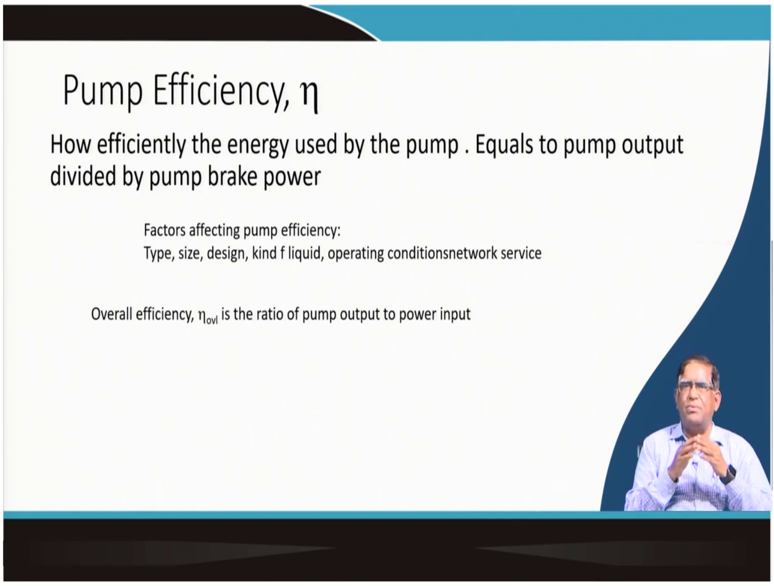


Then, you have now learnt that what is the capacity, what is the pressures and what is the power at the shaft of the pump and then, if you know the power at the shaft of the pump, you can find out what will be the motor power required.

Then, another factor which is coming that is your what is the efficiency of the pump? Efficiency of the pump will be exactly the pump is giving what output and then, what is that pump behave, but that is a ratio of this output by input is the your efficiency.

Now, that pump efficiency, this is a very very important thing while manufacturing pump and then while selecting pump and this vary with the type of pump different type of pump will be having different efficiency, their size, their design that kind of liquid for which it is being used and then, operational conditions and even the ambient conditions, those things will be affecting the efficiency.

And then, the main when we talk about the overall efficiency is the your pump output that is exactly what is the rate of work being done by the pump which we have just gave that equations and then, what is exactly your power input if you are that is how much electricity has been given to the motor to drive that is a power input, these two ratio it gives the overall efficiency of the pumping stations.

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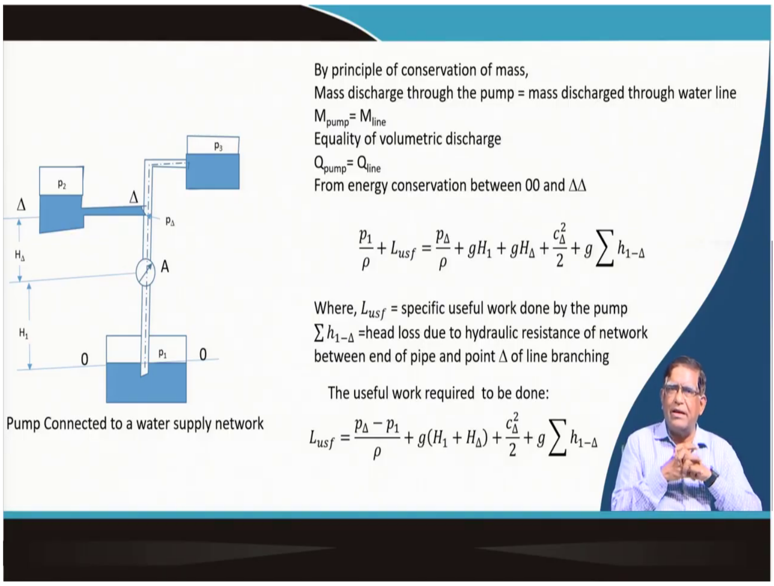


Now, there is your what exactly you get in a installations. If you see here, if any pump is there, we have got a suction side, we have got a head here suction head, we have got a discharge head over here and then, see from here the pump is if it is given to two different areas, it is being sent.

So, under such type of conditions, then if we see that we can apply two things, one is the conservation of mass that means, whatever the mass is just being taken over, it is that discharge there is no accumulation of any mass over here so, that is your whatever that output and whatever this incoming that will be giving you the total that is your that whatever the pump is going up towards a volumetric discharge.

So, from there, you can find out that a equations even for the energy conservation is another one, no energy is stored over in the pump. These two things that means, whatever that our useful work has been done by the pump, it is exactly related to the total useful work which has been done.

So, that means, that your by balancing the energy, you can calculate out how much is the useful work carried out and this gives that exactly the pressure differences and their head differences, velocity differences this leads to the total useful work in a pumping stations.

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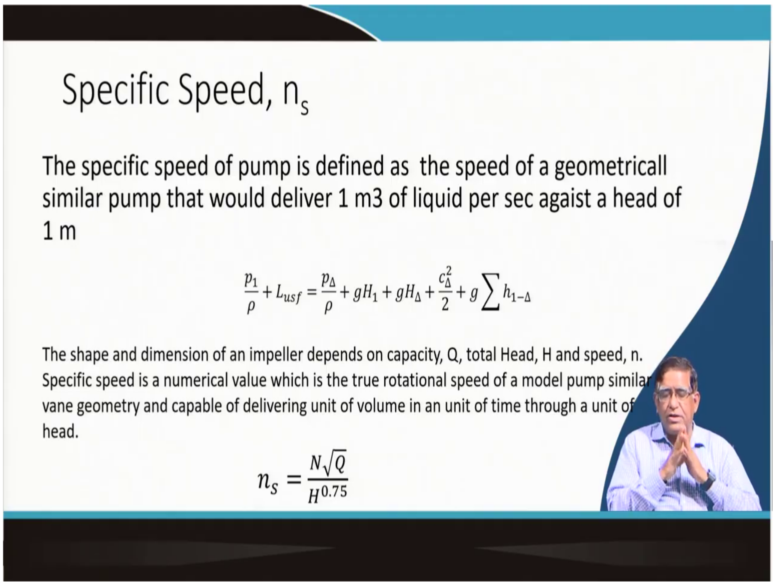


Now, sometimes when you are working in your mines that you need to find out that, what is the total scheme of your water collections and then, delivery and from there, you can find out that how much work will have to be done by pump. So, that is when in your mining methods you study, then how much water accumulated you are you require a dewatering scheme for that you will have to do the individual exercise while applying it.

Then, one very important thing as a concept is required that is your specific speed. Now, this specific speed is exactly is a for designing of the pump it is used. This number which were which is derived by an equations which is given here that specific speed is a square root of the capacity and then that is a H to the power 3 by 4 that multiplied by the that your pump speed that we get a specific speed, it is exactly if there be a similar pump, the pump differences are with the impeller.

You might have you remember last class; we were telling about that is what is the backward curve, radial or the forward curve, different impeller is there, the impeller can be designed in a different way. If our pump is defined in such a way that it is delivering 1 meter cube liquid per second against a head of 1 meter so, when you put distinct over there, this equation is derived and that is called a critical speed.

Now, this critical that is a specific, this speed this that specific speed exactly it is a it depends on this parameter only that is the capacity, total head and that your that total that at what speed it was that exactly the pump when impeller is rotating, you have got a particular rpm it is working.

Now, this the motor shaft speed is not that this critical speed. Critical speed is a number depending on that we know about what will be the characteristics of the pump that is whether it is a this normally, it will vary from 60 to 400 different type of specific speed can be there depending on your type of pump.

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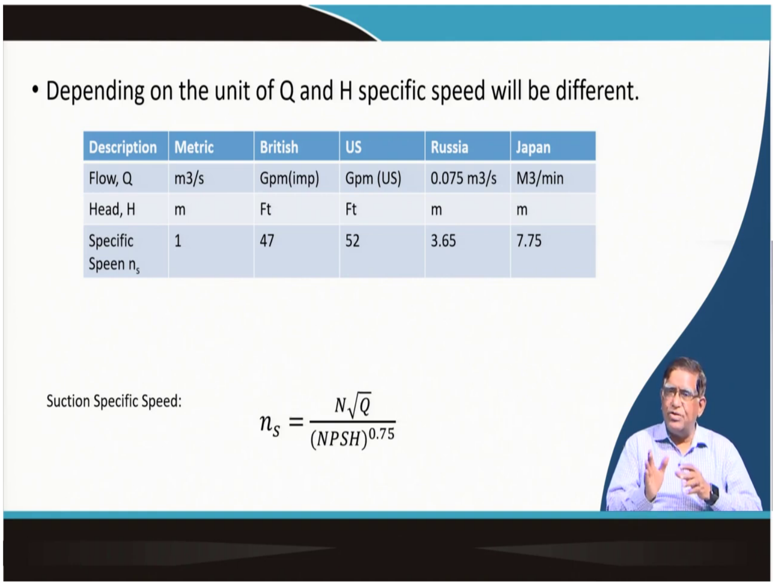


Say for example, in a centrifugal pump, you are having this your critical speed range, it is if your it will be varying depending on the unit. Normally, this if you are putting it your flow in meter cube per second, then your head is measured in meter that one that critical speed in metric system will be a 47 critical speed in British system, your 52 critical speed at Gpm and in Russia that every country has got different. So, this is exactly followed and required in designing of the pump.

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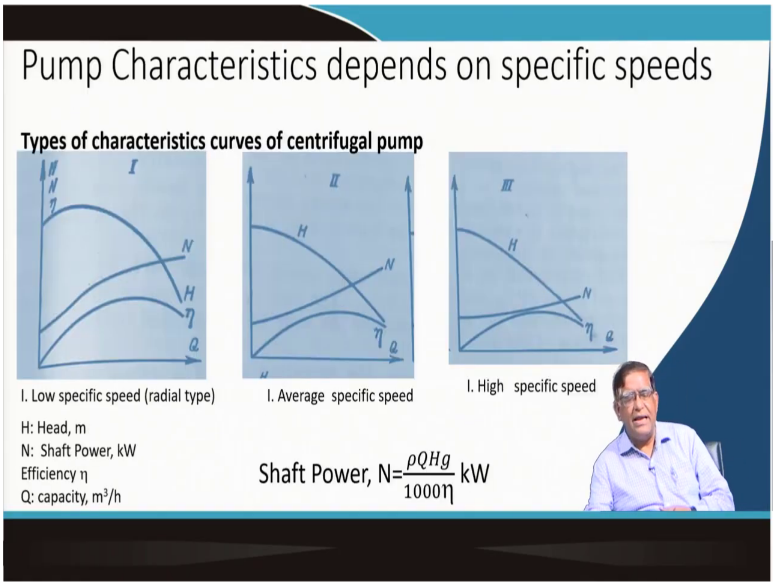


Now, what is exactly with that critical speed, how it exactly affect? Now, this specific speed; specific speed and critical speed is also different. Now, in that specific speed which you have just calculated out by that formula of your N square root of the capacity divided by your H to the power that 0.75 that your specific speed determines exactly how the characteristics of the pump is.

If it is a low critical speed within say 50, 60 like that a low value that normally in a radial type of pump impeller we get you see here that the power is increasing with your capacity, it is exactly if we say and is a power, head, efficiency, when you see the behavior of power, head and efficiency with the quantity that is your volume rate or output of the pump, we see here that efficiency is decreasing, but the power is increasing and then, your total head is decreasing.

This is a characteristics of a low specific speed pump. But if in average specific feed you can see here that is it is your this drooping that your head is going down and then, this efficiency is less than whatever inner low specific speed and in a high specific speed, you see a difference behavior, it is going down and then, it is going up and this is very fast falling down.

So, that is what exactly for the critical speed and you know that is power relationship you know now this power, it is exactly depending on Q and H and this when you see individually that your a pump characteristic curves, it shows that what will be that specific speed and that exactly in designing the pump, determining the impeller type it is used.

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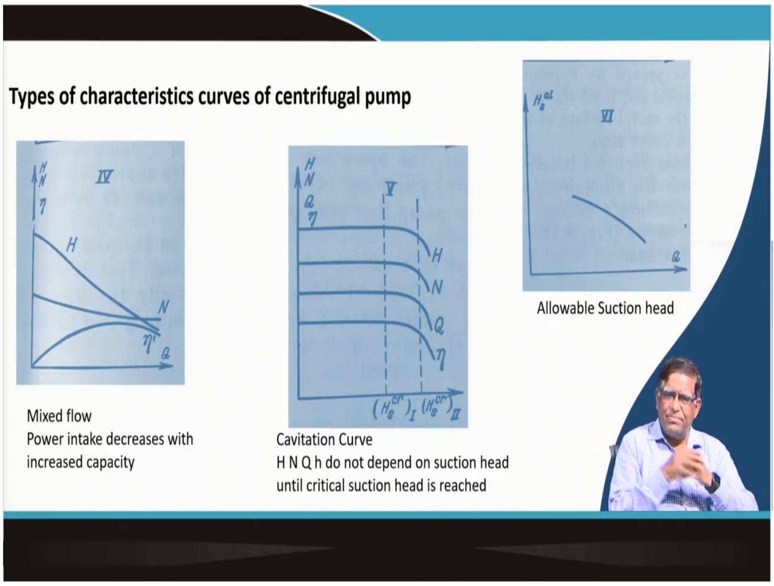


Sometime, there is another thing is where we are getting a mixed flow type of things. Exactly, here the power intake increases with the increase in the capacities, that power intake it is going over here and then, again it is slightly increasing over here, but then there is a that critical speed which comes under when it will be talking about your cavitation's, when it is started taking place that is your pressures and vapor pressure relationships, you will find that there are two level of critical speed.

And then, in any that is your the suction head, if you are pressing this your total head, your power and quantity and efficiency, if we see their behavior with the suction head. When the suction head has got one critical level after that particular one it starts following down and then at a point, it is exactly the vapor pressure will be playing over here and you get.

So, this is a characteristics of there and then, normally a allowable suction head is another characteristics which is drawn over here and these things you normally do a practical on a pump characteristics these things are studied. So, when in any mine, you may be finding that is a they do a lot of testing with the pumping stations and this characteristics need to be determined.

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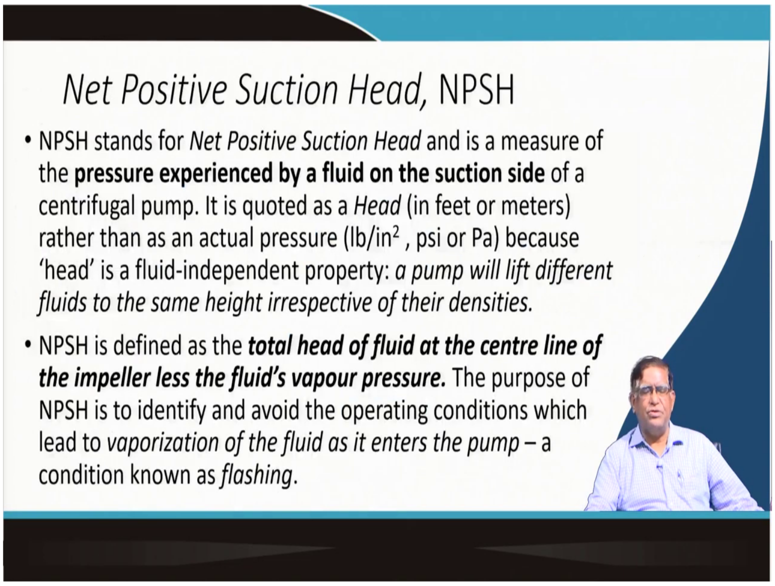


So, you have got a rough general idea about what is the pump capacity, power and then, this specific speed. Now, let us talk little bit about what is a net positive suction head, another concept which is very very important. It is a measure of the pressure experienced by a fluid on the suction side of a centrifugal pump that means, from the where it is suck that is your lifting the fluid, there that head is the suction head.

Now, this head is expressed in your actual pressure that is and then, the head is a fluid independent property. A pump will lift different fluids to the same height irrespective of their densities that is why it is called as a head; it is a property of the pump. And the net positive suction head is the total head of fluid at the center line of the impeller less the fluid vapor pressure.

Now, this vapor pressure is again a concept you know that is exactly and where you might be remembering that how things boil, your bubble formation takes place and at that time that depending on the what is the vapor pressures on it.

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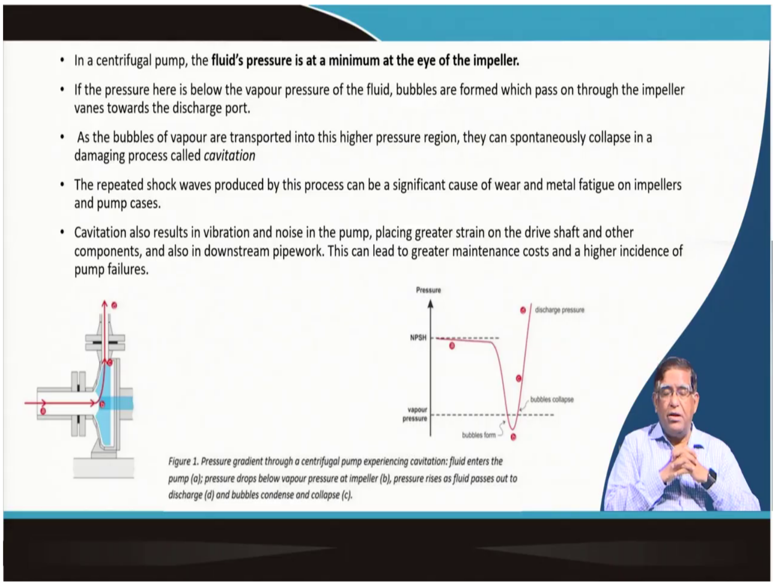


Now, exactly this net positive suction head when it comes over here, you can see here one thing that your after sometimes, this your when is vapor pressure level near that it starts bubbling that is your bubble formation starts and then, when that it goes below again the pressure raises, here bubble will be collapsing. Now, that when the bubble formations and then bubble bursting at that time energy is released on the impeller and there the pitch comes on the impeller and that phenomena is called your cavitations.

So, that means, that net positive suction head, it is a very important property of the pump and then, the relationship with the vapor pressures, this is very very important for the pump maintenance. If the pressure is below the vapor pressure of the fluid, then the bubbles are formed which pass on through the impeller vanes towards the discharge port and wherever it will be collapsing at that time, this your the this phenomena is called your cavitations.

So, now whenever there will be this bubble collapsing, there will be lot of shock waves will be produced and then, it can cause a significant wear and the metal fatigue and that a pump failure in centrifugal pumps failure, a many a times it is with the this formation of this cavitation’s. You can see this diagram where your this fluid is entering, this is the eye of the your centrifugal pump where you can see this is the impeller and which is there inside that your volute casings.

Now, when this is coming over here at this place, if that vapor pressure if it is go below this vapor pressure, then the bubble formations will take place and then, there is a when it is it will be coming over here, that bubble will be collapsing. So, this phenomena inside the pump is very very important things.

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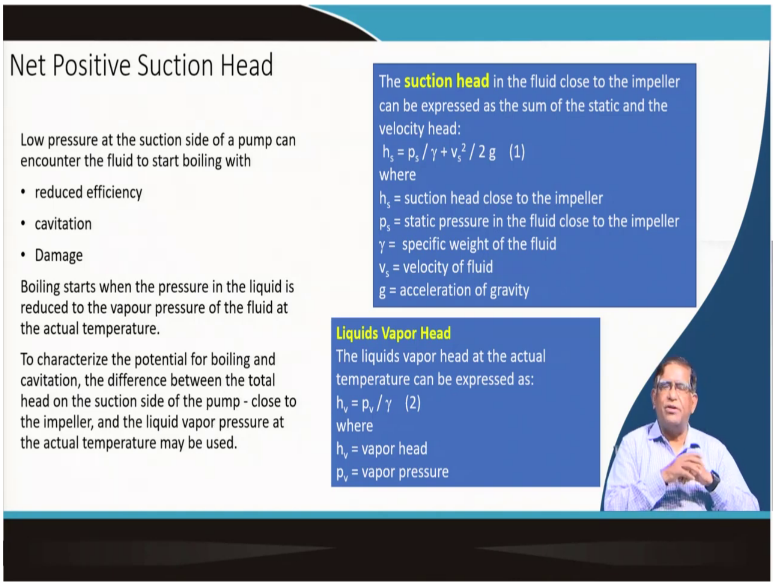


So, now, that means, the net positive suction head is important, and it is exactly that what is the; what is the temperature, what is the vapor pressure and then, how, what is the density of the fluid all these things will play. But one thing is there, the low pressure at the suction side of the pump can encounter the fluid to start boiling that is if in a if your net positive suction head is above this vapor pressure.

Then there will not be any cavitations. So, we need to say that it does not go below this then only the pump will be running properly. Now, here the suction head of the fluid close to the impeller can be expressed as a sum of the static and the velocity head. So, we have discussed earlier, you know the suction head will be having one your velocity component once they are static component.

And then, the liquid vapor head, it is exactly on the basic on the basis of the vapor pressure and specific weight of the fluid. Now, these two values if you know, then you can find out whatever there will be a condition for that your cavitations will be coming or not.

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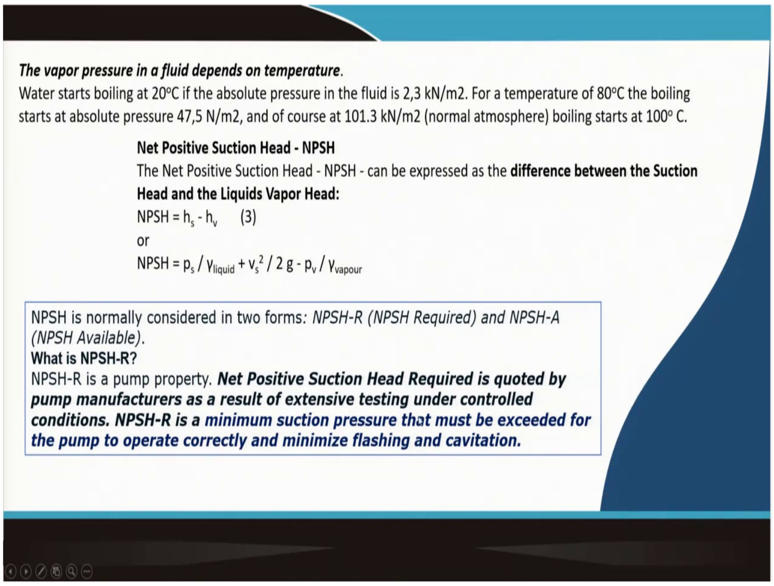


Now, the vapor pressure of a fluid depends on the temperature that is water starts boiling at 20 degree centigrade if absolute pressures in the fluid is your 2.3 kilo Newton per meter square or it will be for temperature 80 degree centigrade, it will be 47.5 that means, that when we say that is our at 100 degree centigrade when we see our water boils at that time exactly this is our it will having a pressure of 101.3 like that.

So, this net positive suction head, it is exactly can be expressed between the suction head and the liquid vapor head, their differences is the net positive suction head. This one you need to remember so that and then, you can calculate out what is the net positive suction head. So, it is normally considered, there are two term s of there, one is called your NPSH is required.

And NPSH is available for when it is coming to a pump that is your NPSH is required, it is the pump manufacturers they give that, that is exactly they do a lot of testing and after the testing, they specify the conditions that under these conditions, this pump will be running such a way that so that if they do not do this test, their NPSH is if it is less than vapor pressure, there will be more bubble formations and there will be cavitations and (Refer Time: 25:50) will be damaged.

So, there is a the required one that is NPSH is required is the minimum suction pressure that must be exceeded for the pump to operate correctly and minimize flashing and cavitation this is what there.

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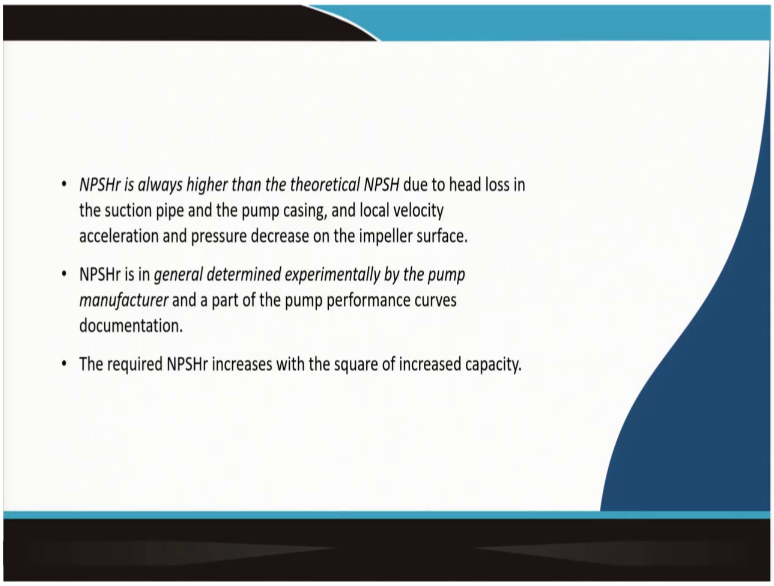

So, this NPSH is required is always higher than the theoretical NPSH due to the head loss the suction pipe and the pump casing and local velocity acceleration and pressure decrease on the impeller surface.

Now, it is the as I said this manufacturers, they do these things experimentally and they find out from the determining those curves that is your from the performance curves ok. So, now, normally it is that NPSHr that is Net Positive Suction Head required increases with the square of the increased capacity.

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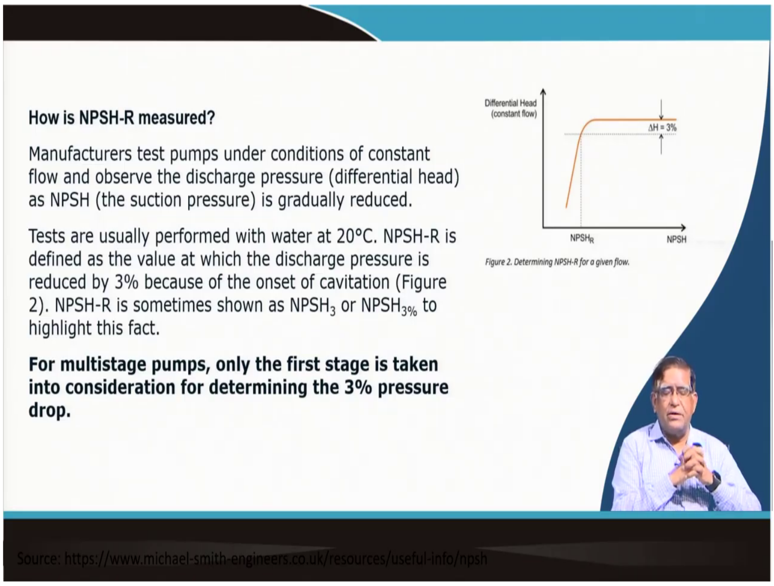


Now, that in a manufacturers test pumps under conditions of constant flow and observed the discharge pressures and they plot it and from there, they find out. So, the tests normally, they are performing and then, they determine that is your where it will be there if the pressure difference is 3 percent that pressure, they will be starting cavitations, this part is taken.

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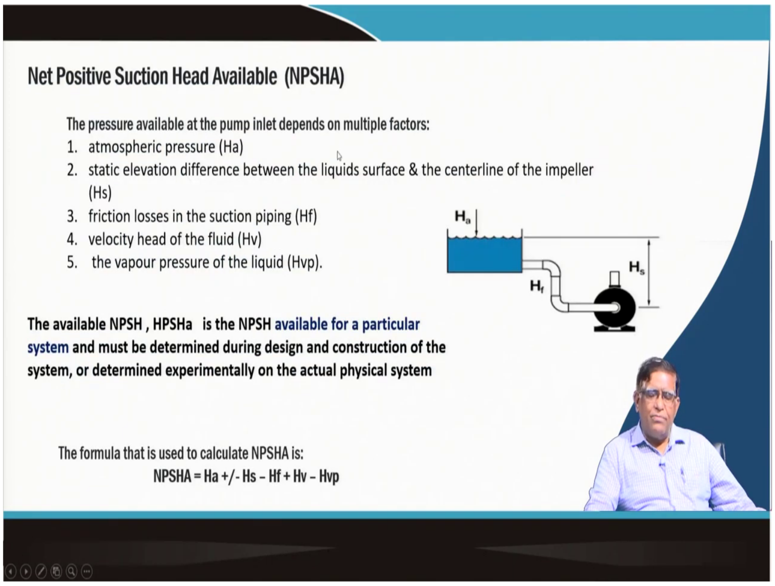


Now, these are done for separately for single stage pump, multi-stage pump, different will be having a different and this comes with the pump manufacturers they developed over there. Now, this net positive suction head available, this concept is the pressure available at the pump inlet depends on these factors mainly that atmospheric pressure.

You can see here this atmospheric pressure whatever it will be there and that difference between these two heads at the your eye level and also that whatever is the friction losses in the pump and all that pipe there will be friction losses. So, this then, your total when you know the different heads, then by simple balancing, you can find out that is your net positive suction head available is calculated by considering all these different heads.

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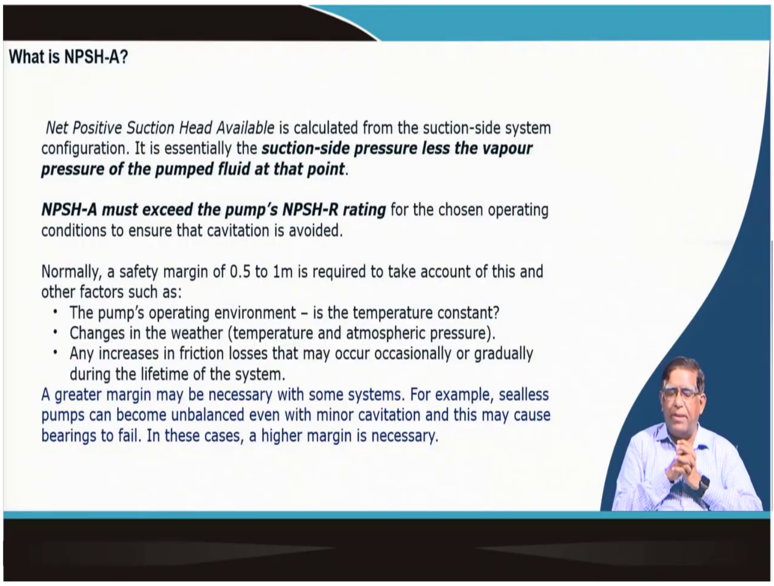


Now, from here, you can tell that what is that net positive suction head available, it is calculated from the suction side of the system configuration. It is that suction side pressure list the vapor pressures of the pump fluid at that point will be giving you the net positive suction at available and then, normally, for your operations, it should be more than the required rating whatever given by the pump.

Normally, for a safety margin, we can keep that 0.5 to 1 meter is required for this differences between these two particular net positive suction heads ok. So, now, the other thing which is important for you the greater the margin may be necessary for the some systems.

For example, a sealless pump, if you are to use it that it can become unbalanced if you need the minor cavitations and this may cause bearing to fail in that cases, a higher margin is necessary. That means your net positive suction head which is required and which is available, their differences may be required more.

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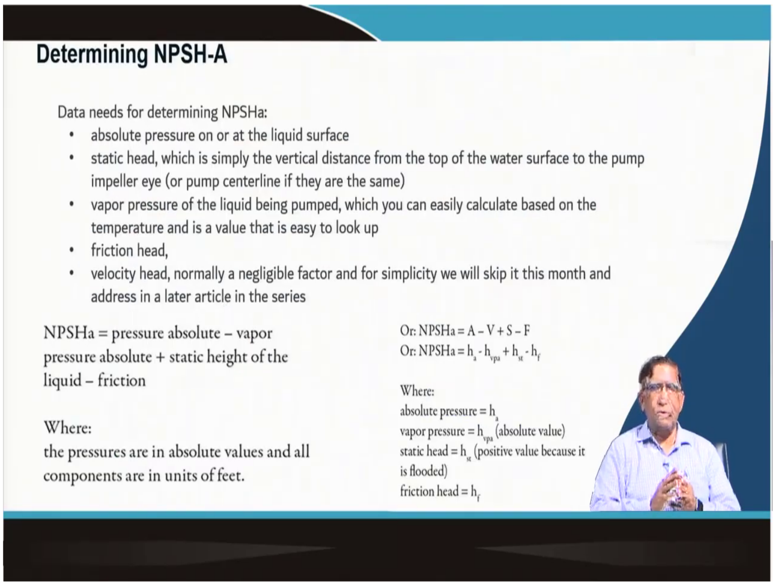


So, these issues are seen whenever you are going to select a pump for a particular applications you will have to calculate these things. So, basically you can remember this net positive suction head, your pressure absolute what is there its required, then vapor pressure absolute what is required, static height of the liquid and the frictional loss if you subtract, there you will find out what is your net positive suction head available, you can get from a pump.

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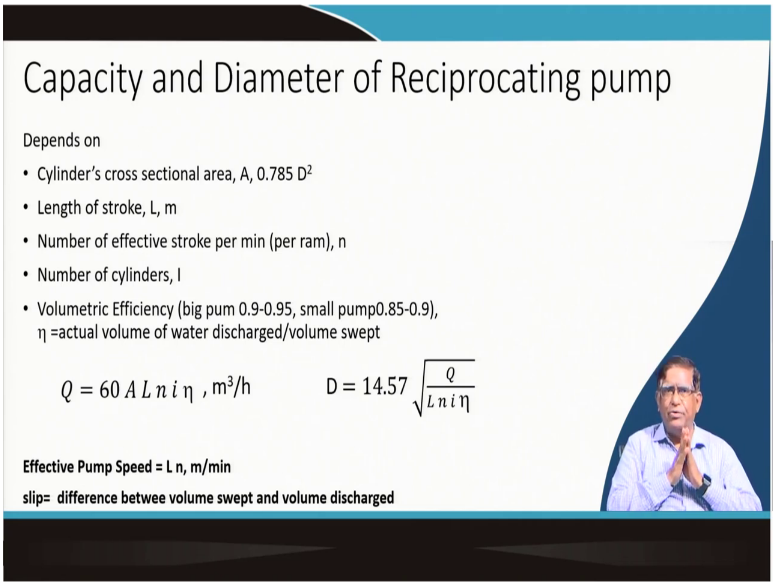


Now, the another thing is there that we have said so, for centrifugal pump in case of your reciprocating pump, their capacity how do you determine? The capacity of a your reciprocating pump depends on the your that what is the cylinder cross sectional area, then what is the length of the stroke, what is the number of that is your strokes per minute and what is exactly you are having this your number of cylinder, how many number of cylinders that is your this i and that your efficiency these gives the capacity.

And then, the diameter which is there that can be calculated from this formula. So, you can get that the capacity and diameter of the reciprocating pump can be calculated out.

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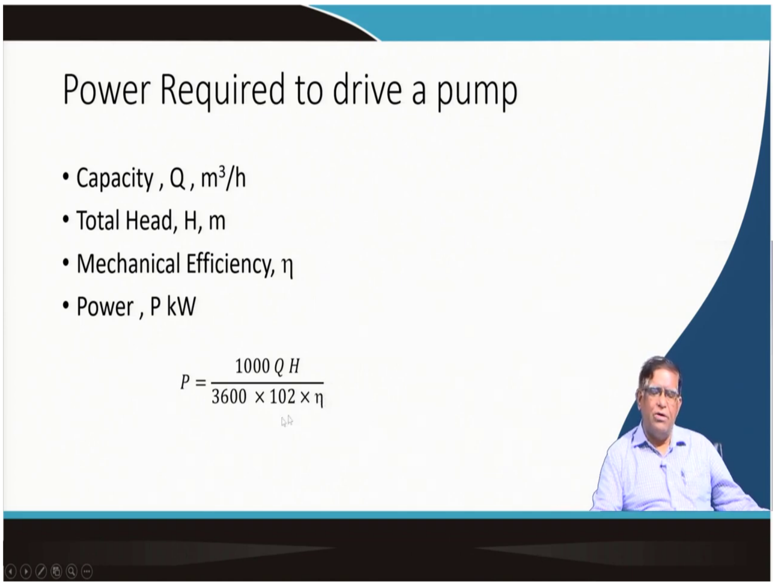


And then, you can find out that what will be the power required to drive a pump? It is just if you know the capacity, if you know the that pressure head, then you can find out the power required in this form and then, the motor; motor rating will be divided your this much kilowatt motor can be available over here

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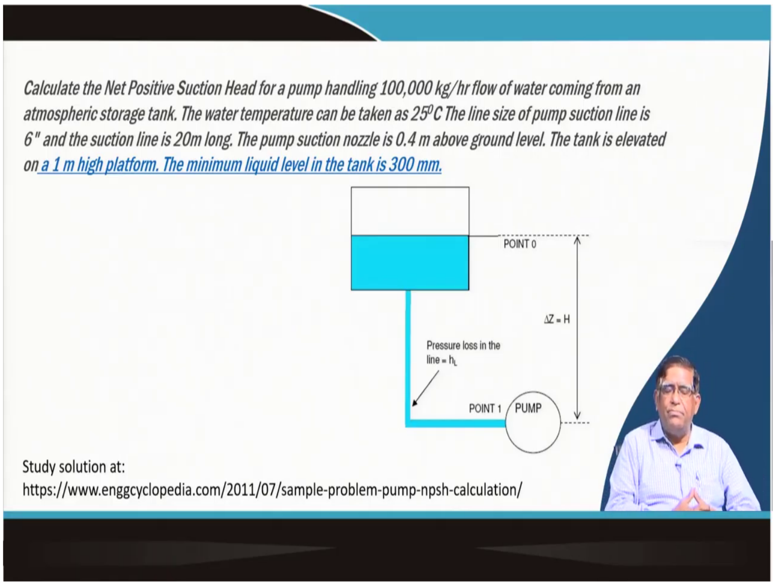


So, you can do this problem. Calculate the net positive suction head for a pump handling 100000 kg per hour flow of water coming from an atmospheric storage tank. The water temperatures can be taken 25 degree centigrade. The line size of the pump suction line is 6 inches, and the suction is 20 meter long.

The pump suction nozzle is 0.04 meter above the ground level. The tank is elevated on a 1-meter height platform. The minimum liquid level of the tank is 300 millimeter. Such type of situations can be created; you can study the solutions at this particular instant given, so that similar type of problem in the minds you can easily find out.

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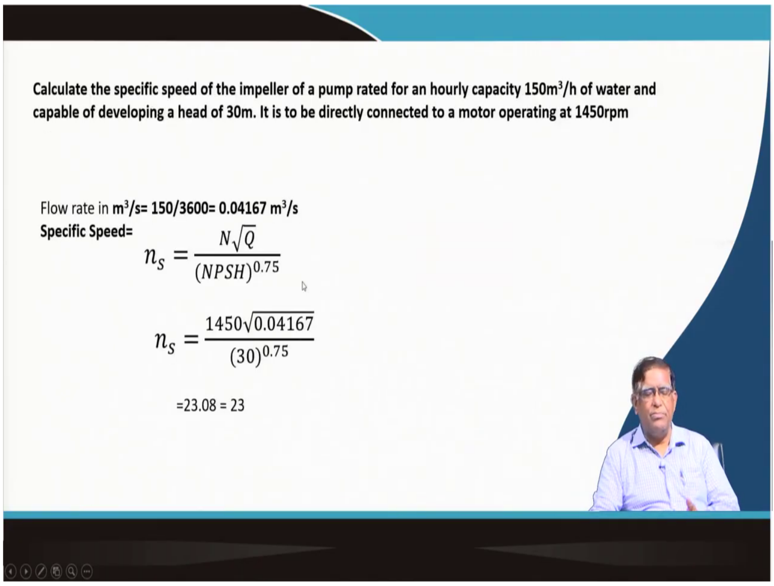


Similarly, we have said that your some calculations you can find out from the specific speed, you use this formula from the specific speed at net positive suction head given, then you can find out and once you find out this number, you can find out that means, what will be the characteristics, it is a low specific speed. So, you refer to the diagrams and you can suggest that how the pump will be behaving.

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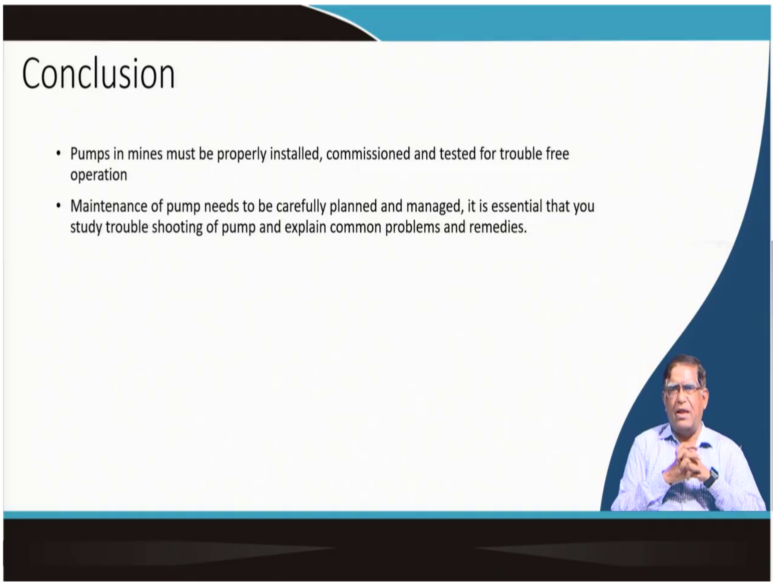


So, in a nutshell, we have just discussed today that what are the basic principle or basic calculations we made in a pump, but most important thing as a mining engineer, your in the mines that dewatering activities require a different type of pump selections. Most important is your how that pump will be maintained and how they will be managed for that we will have to study a little bit more with the applications-oriented thing.

I hope with this, you will be able to take up a simple dewatering plan for the mine and then you can select a pump for a given conditions. You will have to practice few numerical on this then you will be able to resolve the issues that are faced in the mines.

Thank you very much.