Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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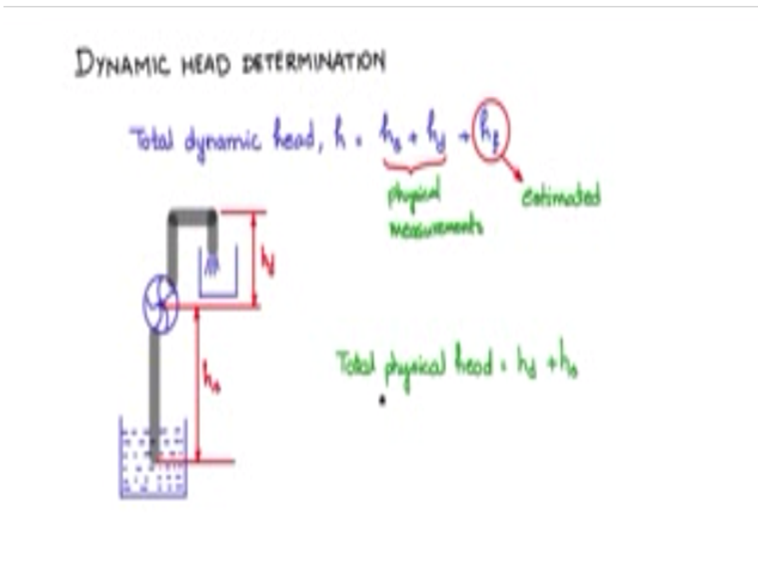

Let us now discuss on how to determine the dynamic head for a water pumping application. We know that the total dynamic head H is given by the suction head hs, plus the discharge head hd, plus another component or virtual component of the head which is due to friction loss. Now these two components hs+hd are determinable from physical measurements, direct physical measurements.

However, hf is not physically measurable, because this is a virtu7al quantity it represents a friction loss you need to estimate it. So this needs to be estimated. So how do we obtain these quantities. Now let us see the hs and hd part, this is the easier part and then later we will see how we go about estimating the friction loss component of the head also.

Now consider a water tank at a lower level, so it is filled with water and we need to lift water out of this tank and put it over a tank. Now let us have a pipe and that is called the suction pipe, it is reaching the centrifugal pump, so this is the centrifugal pump, this is the suction pipe, and then from the other side of the centrifugal pump where in other pipe which is called the discharge pipe and it discharges into over a tank in this fashion.

Now what are the hides in this case, now the pressure required to overcome the height from the bottom of the suction pipe up to the central axis of the pump is called the suction head. So let us mark that, so all the water that is within the suction pipe up to the edge of the suction pipe and the potential needed to lift that water from the edge to the suction pipe up to the axis of the pump is called the suction head hs.

Now above the pump from the center axis of the pump up to the maximum height with the water is lifted up is called the discharge head hd. Now in this case the total lift, the water has to be lifted to a total height of hs+hd, and the total physical head is hd+hs.

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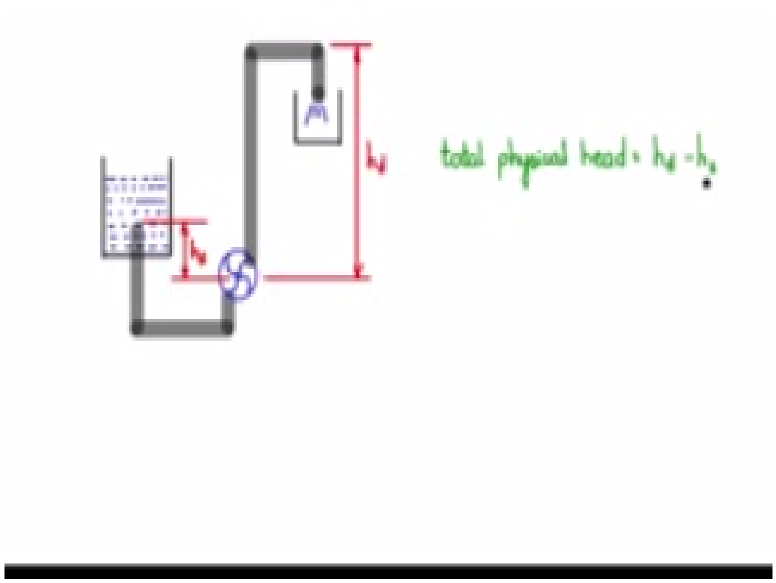

Now consider another scenario where you have water in the tank has shown like this, so this water tank containing water is having a pipe connected like this in this fashion. And it is placed at a height above common ground reference and the water flows from this out let of this tank into pump like this so the inlet to the pump is in this fashion where the pump may be aware the water which is being sucked in through the section pipe is at a higher level than the pump itself part the pump needs to pump the water to a much greater height located in this fashion where the delivery tank is at a much higher level than the source tank.

But the pipe connection may be in this fashion so let us see what are the section heads and the delivery heads here so take the tip of the pipe and the center of the pump for the source side or the suction side and we will call that one has HS the taking the tip of the pipe has the worst case and the center of the pump we get has the suction head now considering the highest point to which the water is pumped to the center of the pump.

So this is for delivery you will have the delivery head so now here actually in actuality water is pumped from this level to this level so if you take the highest point so the water is pumped from the minimum level this one to the maximum level this one so the difference in this height is where the water body has been lifted, so energy needs to be given only to achieve a transfer of the water body to a height of this difference HD – HS so in this case the total physical heat is not actually HD + HS it is HD – HS.

Because the suction side of the source and the peeping is such that it is above the pump central access and therefore there is some positive pressure which is aiding the pump to push water this is a positive pressure which is aiding the pump to push further into the delivery head so therefore in this kind of a scenario you will see that the total physical head is HD – HS.

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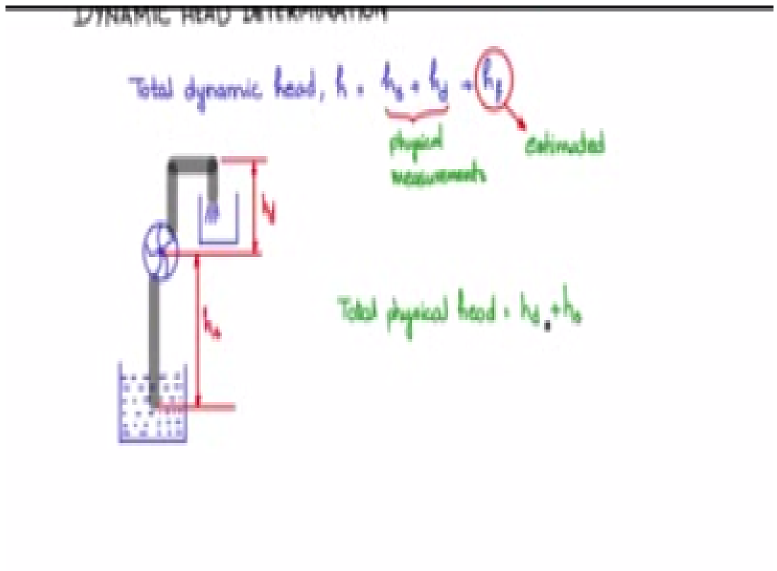

However for the case of pump if there is a sum which is down below the ground for the case of bore well where the water source is below the ground this is the total head that will come into picture the delivery head + the suction head and the delivery head will always add up.

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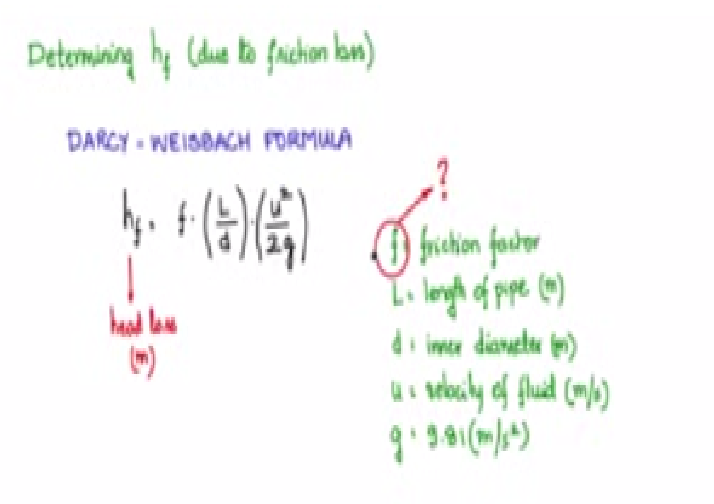

We saw the we could determine the suction head HS and delivery head HD from physical measurements and depending up on how the source tank and the delivery tank are placed for a given application now we need to find HF the equivalent head representing the friction loss we will use for this an emphatically relationship that was proposed by wise back it is popularly called the DARCY WEISBACH formula it is given in this fraction h_f which is the head that you do the friction loss component f friction factor into L the length of the pipe and total length of the pipe by d the inner diameter of the pipe then we have u^2 /2g where u is nothing but the velocity of the fluid flow m/s g is the gravitational acceleration $9.81m/s^2$, so this is the DARCY WEISBARC formula so let me list down the various variables hf is the head loss and meters.

f is the friction factor it is a unit less quantity L is the length of pipe the meters d is the inner diameter of the pipe again and meters u is the velocity of the fluid flow in m/s g is the acceleration due to gravity in m/s^2 now among all these parameters g u d L they are easily measurable L is L and d are measurable u also is measurable the fluid flow velocity f is the friction factor and this is something which is not so easy to obtain in fact it was not easy to obtained till.

We had an another empirical relationship called the coal group white formula using that the friction factor was establish, so this is the one which is more difficult to estimate but today with computer and coal group wise whole group white formula we will be able to find the friction factor use that friction factors of substitute here in the DARCY WEISBACH formula and we will get the head loss and use this head loss and substitute into the total dynamic head formula you will get the total dynamic at.

And use that total dynamic had to obtain the power required the hydraulic power required for the application, so now let us see how we get this friction factor.

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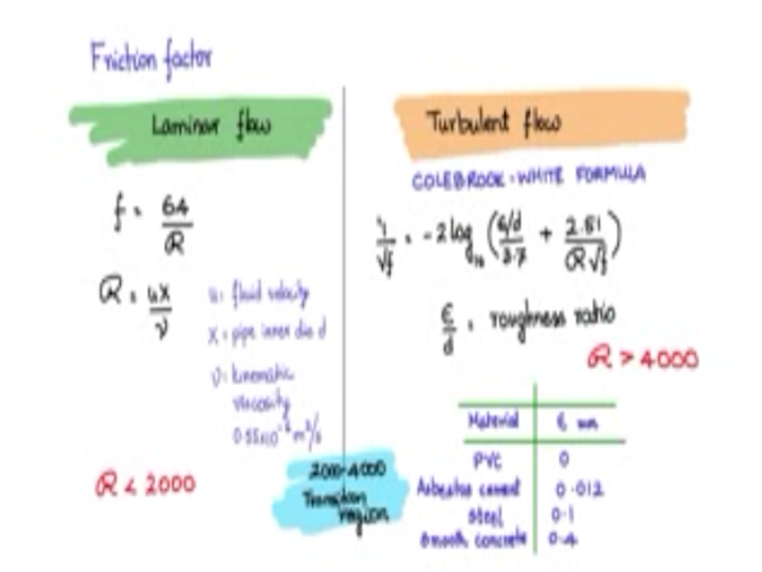

The friction factor is depended on the type of fluid flow see the fluid is incompressible most of the time what we are talking about is water pumping and therefore it is incompressible it is flowing through a pipe that are cylindrical the diameter is fixed therefore we can consider these two types we can consider these two types of flow that is the laminar flow, and the turbulent flow so the Reynolds number will indicate whether the laminar or turbulent, so let us say if the flow of a laminar.

So then the friction factor f is given by 64 by Reynolds number the simple equation where Reynolds number is ux/ n the kinematics viscosity, so here u is the velocity of the fluid x use the velocity of the fluid x is inner diameter of the pipe and that is d nosslet's is the kinematic viscosity and for water it is $0.55x10^{-6}m^2/sec$ so we can use this and find out the Reynolds number substitute it into the laminar flow equation and obtain the friction factor.

Now if it was turbulent the flow where turbulent then we will use another empirical relationship Colebrook white formula after Colebrook white formula was proposed by Colebrook white it became it became quite popular especially after the computer came into being and computers were used for finding out the solutions of equations.

See the Colebrook white formula is something like this let me first write it down, see this is a transient the equation you cannot have an analytic solution for this, $1/\sqrt{f}$, f is the friction factor is equal to $-2\log_{10} \varepsilon/d/3.7+2.51/R\sqrt{f}$ so you will not have an analytical solution so you have to get obtained the value of $\bar{f}$ through an iterative means so you will have to put them in a loop and then iteratively obtain the value of f.

I will show that shortly how to do that, so because of that computers are needed so only after computer and design came into being this formula became popular and then started and it got being used into the Darcy–Weisbach formula to determine hs, so Darcy–Weisbach formula became quite popular after this became popular. Now let us see this new variable which have introduced here what is that ε, so ε/d is a ratio and that is called as the roughness ratio, this has come into being because it depends the friction depends up on the smoothness of the inner walls of the pipe through which the water is flowing.

And ε is actually the height of the pumps on the inner walls of the surface of the pipe divided by be the inner diameter so this gives you a measure of the roughness and it is called the roughness ratio, so you need to use that for the important materials ε in mm for PVC it is 0 so now a days in many of the applications PVC is used the inner wall is absolutely smooth can considered it as 0 asbestos cement was used quite some time and some places it is still used it is 0.012, steel 0.1, smooth concrete.

So concrete is used in large applications where large floors are there so it is around 0.4, so you would use these values of ε and substitute here to obtain the E value of the roughness ratio and substituted here Reynolds number calculate in this fashion and you can substitute for this value all the Reynolds number here the only unknown in this entire equation would be and you have to solve for it you will not be able to another obtain this value of here you will have to iteratively do that so probably you may how to use octave and find out this value of f how to know if the flow is laminar or turbulent so you calculate the value of R.

If the value of renounce number R is less than 2000 than it is safely laminar if the value of the renounce number is greater than 4000 than it is clearly turbulent flow in between 2000 and 4000 is the transition region the value the friction factor is not clearly defined so we can take the worst case maximum of these two formulas whenever it is in the transition region.

So between two renounce number of 2000 to 4000 we say that the transition region than we will calculate the friction factor by this formula and friction factor by this formula and then take the max value of worst ace value of the higher friction factor value so that then you would have rated it for under worst case conditions.

Next important exosite that we need to do is how to solve this Colebrook white formula and find the value of f for an given value of roughness ratio and renounce number before numerical solutions became popular for this there were no more graphs refer to as the mode charts let me show you that.

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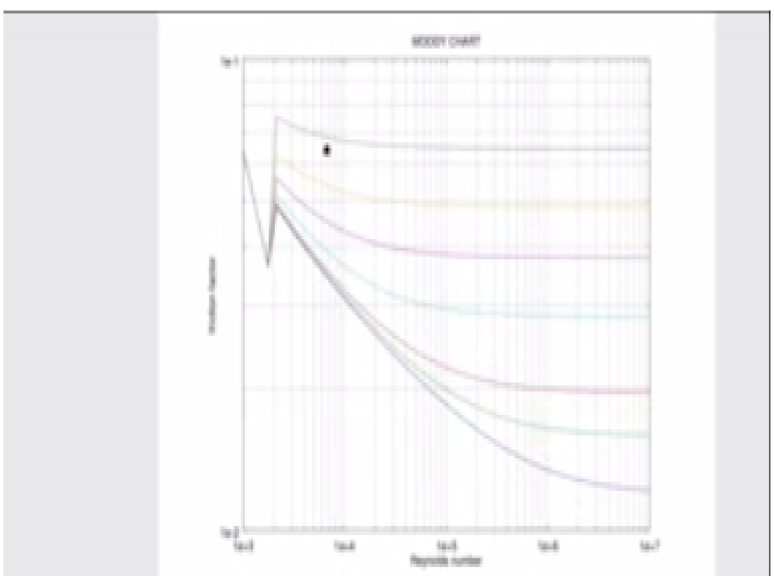

When you go on to the internet browser in Google you type moody chart then you will see the graphs similar to this, so these are the Nomo graphs basically there are graphical representation of the cold group white formula. So how do you read this? You see this is the family of curves each of these curves that you see is for different roughness ratio. So for given roughness ratio this is the friction factor. The profile as the Renaults number is changed, so the x axis here is the Renaults number.

And I have given the Renaults number to sweep from 1000 to end to the power of 7, so as you sweep the Renaults number you see that up to 1000 this is using the laminar flow equation once 2000 is crossed and some where here around 4000 the turbulent flow models comes into the picture and this is where the actually the cold brooks equation is used in between it is actually the maximum of the 2 models that has been used as the worst case.

So that is what we have done here and what the moody chart that we have obtained using optimum, so if you look at the moody chart which is their which you obtain in the literature it will be very simpler observe that this region is the lamina flow region this line here is number is equal to 2000 so this is the laminar flow region and this region is the turbulent flow region where we use that turbulent flow model and here is that transition region between 200 to 400 this is the 2000 number equal to 2000 line now each of these lines of our different ratio 0.001,0.004 0.02,0.04 so like this you have these no more graphs then let us say you calculate the number using $R=ud/\mu$ that is kinematic viscosity then based on the value.

And based on the roughness ratio you can select that specific curve and take out the vertical intercept and you will get your friction factor so this way people used to work use the moody chart obtain the fiction factors substitute it in the formula and obtain the fiction loss head but after the adventure of this computerization and the numerical algorithm started becoming popular mat lab type of environment became very popular with the students and the engineering we can easily solve the gold rope white formula using hydrativer methods and that is what I am going to now show you using environment .