Similar way, the potential energy by this. So, if you it, instead of understanding or deriving along the streamlines, the same concept we can visualize it, if a virtual fluid balls is moving from one location to two locations, since it is a virtual fluid balls, again I am to talk about these, where we consider it is not a one fluid flow ball movements, we consider there are n number of fluid balls are there. They are having a pressure exiting one by others. Because of that, there will be a flow energy, which we quantify into pressure into area into delta x.

That is what by mg, that weight of the fluid, that is what will give is on this. So, we can say it, any fluid balls if you consider it, the flow energy per weight, the kinetic energy per weight, and the potential energy per weight, that is what is custom. So, this is the difference between a simple ball and the virtual fluid ball. So, what I am telling is that, whenever you apply the Bernoulli equation, you should draw the streamlines. You should visualize how the fluid moves.

If I consider a balls are moving, a virtual fluid balls are moving it. If I draw the streamlines, I can apply the Bernoulli equations. I should know, the pressure variability, the pressure at the two points or the pressure and velocity. If I know any of them, then you know I can solve the problems. That is the idea.

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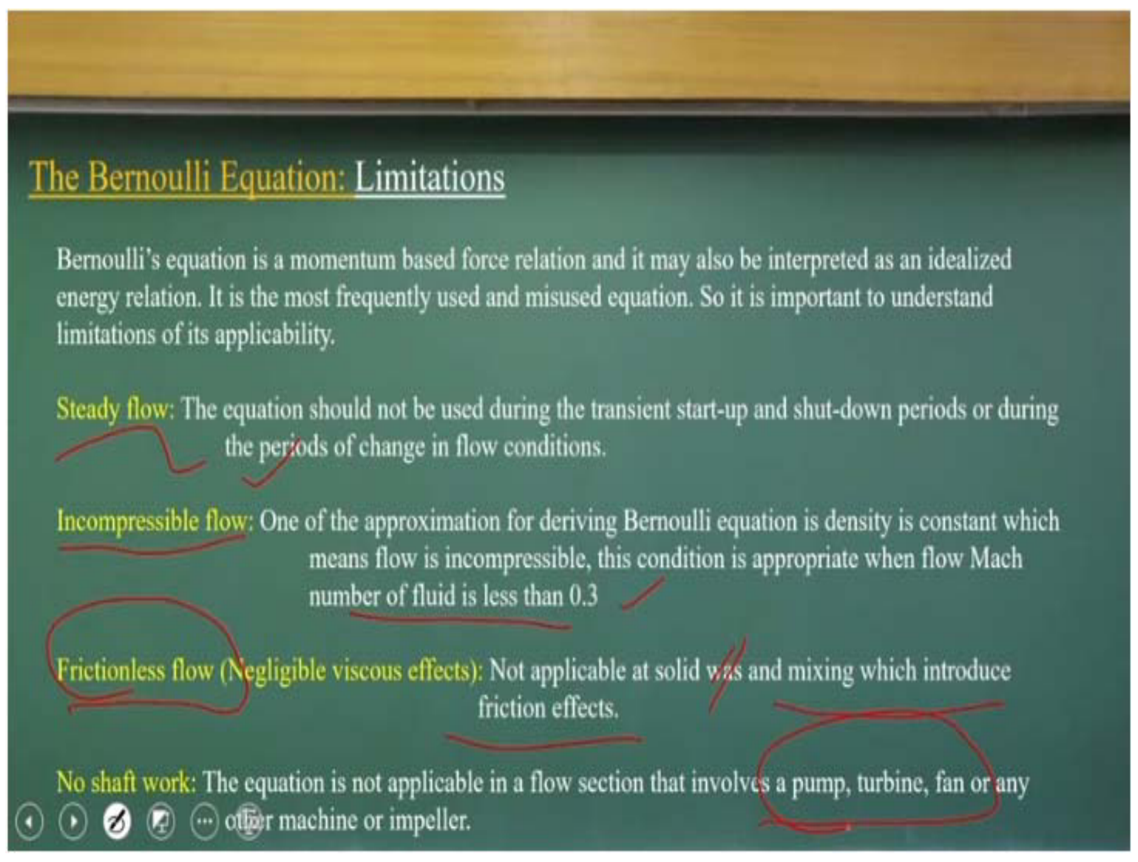

Let us have a very quick, what are the limitations of Bernoulli equations. Bernoulli equations can be applied for unsteady flow, but the simplified derivations what you use it, those are for per steady flow. That means, there is no time component is there. And remember it, this equation is most frequently used, also misused equations, okay. There is two solutions are available for us, I can say it is one mass conservations and energy conservations.

Applications of Bernoulli equations is too easy, people do so often it is misused. Another is that the incompressible flow, we discussed a lot of times. It is just we have to most of the fluid flow problems in civil engineering and mechanical engineering and others place where flow Mach number is less than 0.3, we can consider is a incompressible flow because the density variation will be less than 5%, which is we can neglect it.

The most important assumption is that the frictionless flow, that means it cannot be applied near to the solid. Because as you know it, whenever the fluid goes through near the solid, if there is a solid fixed surface, there will be the velocity gradient, there will be the shear stress acting on that. Viscous effect will come to pictures. So, those reasons we cannot apply it. Similar way, the mixing zones also we cannot apply it. There is no shaft work because of presence of either pumping.

That means is getting extra energy from the outside or the turbine, taking energy from this or pump or the other machineries. So, where we cannot apply it, I will tell it later on that we can use this also in applying the Bernoulli equations. That is what the advantage of Bernoulli equation because we can easily incorporate the energy loss or energy gain in the Bernoulli equation as compared to the other equations what is available to us. So that's the reasons Bernoulli equations has a lot of advantages.

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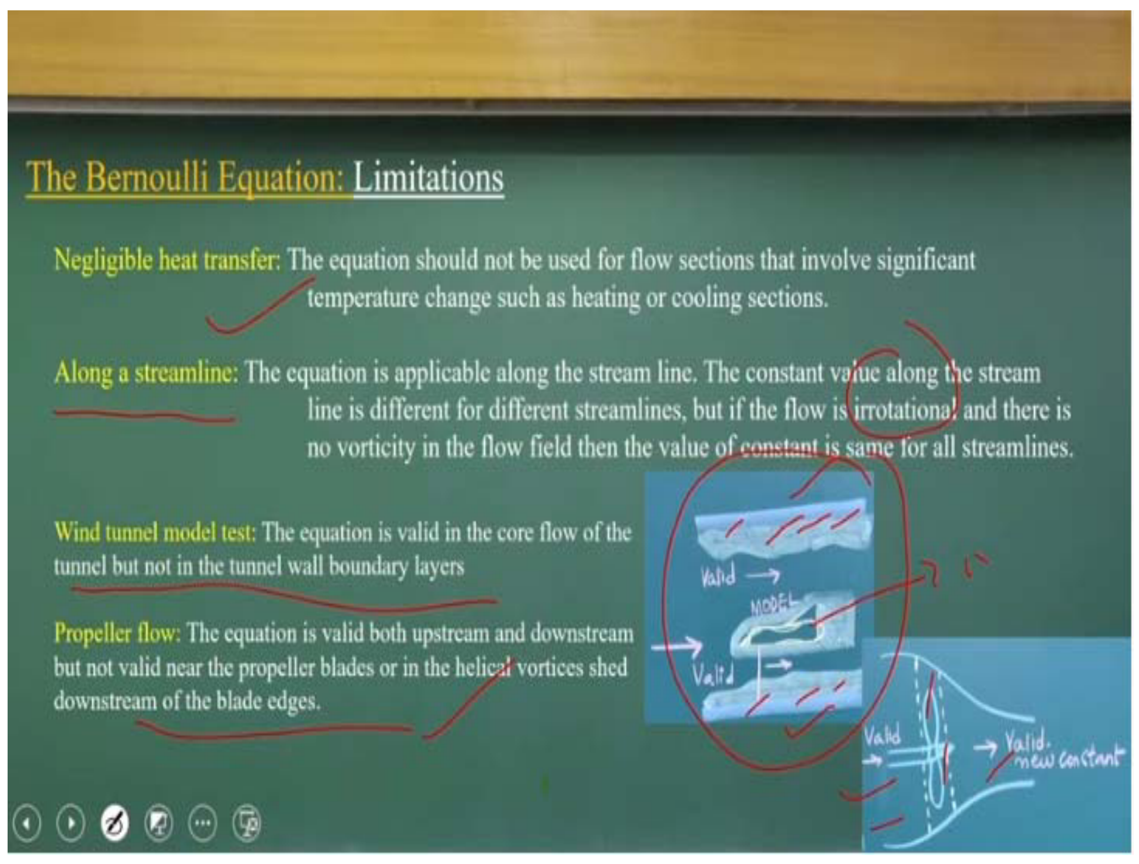

That is what is there, if you look at this wind tunnel test, if you are doing it, we know very well, there are the wall in both side. This is the model. And this wall and model side there will be viscosity effects, so we cannot apply the Bernoulli equations this reasons. Only you can apply the Bernoulli equations the reasons where valid is written. So, whenever you apply the Bernoulli equations, you have to first look it whether frictional effect is significant or not significant.

And it is applied along a streamline. That means, before applying that, we should draw a streamline, then we apply the Bernoulli equation at the two points, or you should justify the flow is irrotational, okay. That means flow is not rotational. There is no vorticity. Then constant is same for all the streams. But I encourage you to draw the streamlines and apply Bernoulli equation. Without sketching the streamlines, you apply the Bernoulli equation, it shows that you do not have a confidence or do not have an understanding how you use the Bernoulli equation.

Because casing of the fluid flow problems, any fluid flow velocity diagram, pressure diagrams, it indicates that what knowledge we have. So, considering that part, I encourage you to, whenever you have a fluid mechanics problems, first let us gauge the streamlines, find out what are the pressure, what are the velocity at different points, what is the height from a distance. All you know it, then equate it, then you solve the problems, okay.

Without drawing the streamlines, if you are solving the problems, either you do not want to understand how the flow process happens or you just want to mechanically apply Bernoulli equations. That I feel we should not do it when you want to have these things. So these are all assumptions and we should have a careful, whenever we apply the Bernoulli equations and here if you have the wind tunnels, okay, you can see that the regions, the control volumes where you have the pumps are rooting it.

That is the reasons you cannot have it is valid from one side to others, but you have new constant will come it, the constant value will change because of additional energy we are putting through this fan system.

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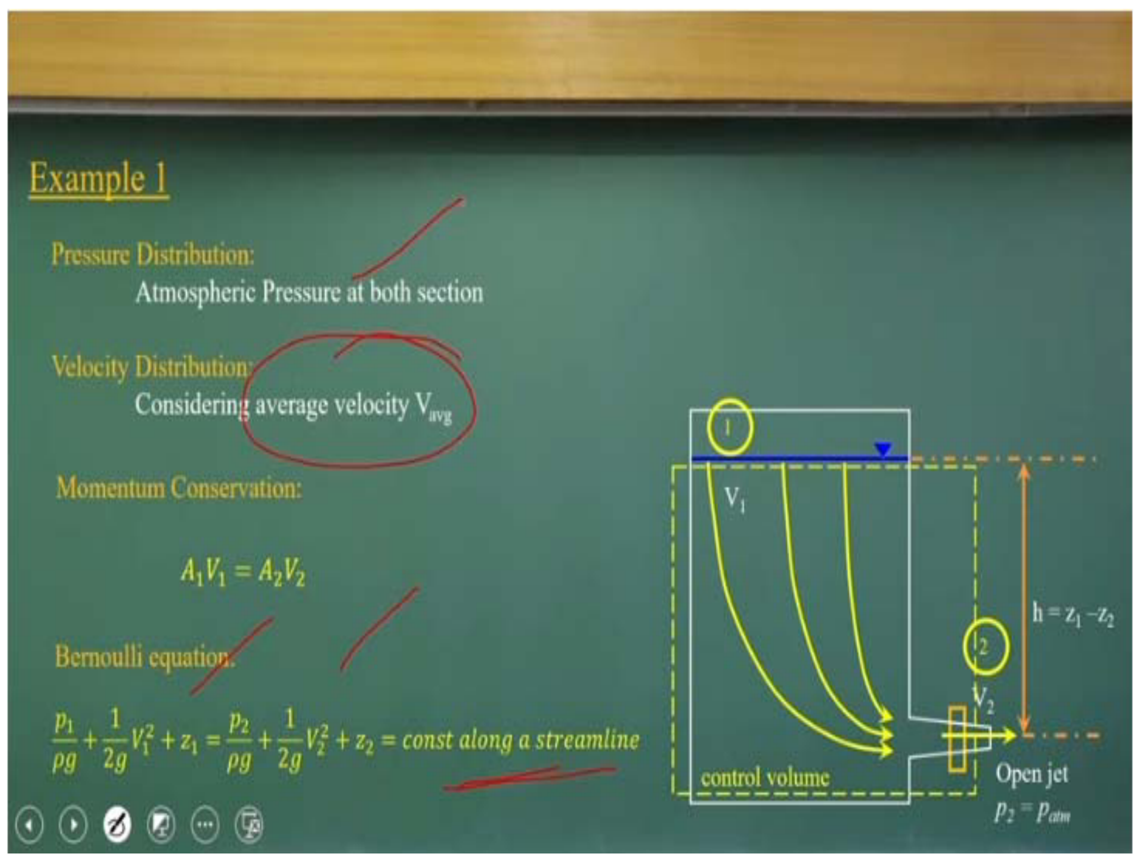

Let us solve the first problems. Find a relationship between nozzle discharge velocity, tank free surface, assume the steady frictionless flow. Okay, this assumptions really simplified our problems okay. It does not happen. There is anywhere whatever the flow happens is, there is a frictional effect. But sometimes that frictional effect may not have a that significant error, which may not generate that much of error in the velocity. But anyway, for the academy point of view, we consider as a frictionless.

That means the friction effect are very, very less, we can neglect. Here when you have these problems, if you look it, you will have a tank, you have open jet. And there is a height h from this. Now, I will apply the concept of virtual balls, okay. Like I have a one ball is here, it will move like this, move like this and come out like this. There will be another ball, will come like, there is another ball will come like this. So, all these yellow lines, whatever is given is that the path, representing path of virtual balls.

So, ball starts from here, goes out as a pre-jet here. Now, if you look it, what is the advantage for me, that at this point where is a free surface, the ball is at the rest condition, the velocity is 0, the pressure is atmospheric pressure. And when you have a water jet, you have a sub velocity V_2, that is what you have to relationship that and you have the pressure become for a open jet will be the atmospheric pressure. So, you know the pressure velocity and the air locations from the data.

So, you apply basic equations is the Bernoulli equations. So, you just visualize that I have virtual fluid balls and these are ruling it, okay. And they will follow like this and go out from this. So, at first position, they are at the free surface, and they will move it and they will go as open jet. If that is the conditions, so we can find out to apply the Bernoulli equations along the streamlines, which is visualizations of the streamlines as the path of virtual fluid balls.

$$\frac{p_1}{\rho g} + \frac{1}{2g}V_1^2 + z_1 = \frac{p_2}{\rho g} + \frac{1}{2g}V_2^2 + z_2 = const\ along\ a\ streamline$$

Then I apply at 2 point 1 and 2 of Bernoulli equations. If I do it, I will get a relationship between the velocity and the height. Now is very basic concept, that you can apply the Bernoulli equations between these two along the streamlines. Here, we are considering the average velocity distributions and both the sides we have the atmospheric pressure.

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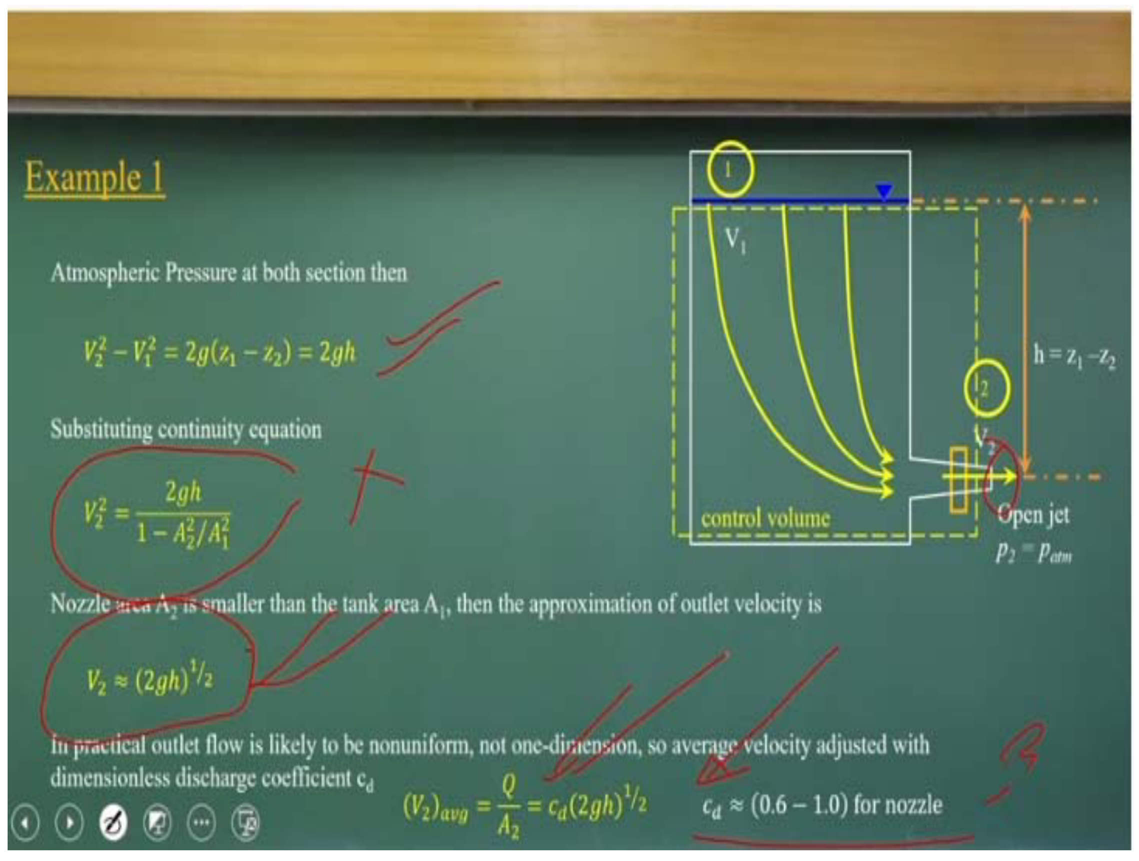

And if this is the case, what we get it, the velocity difference between these two will be 2gh, okay. And they had a considering of area, but let us not have a require for continuity equations, but as you know

$$V_2^2 - V_1^2 = 2g(z_1 - z_2) = 2gh$$

This is a very simple things as you know it, whenever you have a ball, height of h, it falls from a height of h, the velocity at the ground will be the same equations what we have. How do we have that?

But in this cases is not a ball, these are virtual fluid balls, that means fluids are moving it. Because in both the points, we have the presser is equal to atmospheric pressure. The flow energy at the point A and point B are the same. Because of that, it looks like that, is virtual fluid balls are the balls only, solid balls are only. So which is just representing us the velocity, which is the velocity of free fall of a ball from a height h, which will be the,

Substituting continuity equation

$$V_2^2 = \frac{2gh}{1 - A_2^2/A_1^2}$$

But in this case, have neglect the friction part. We have considered the jet, the open jet will have atmospheric pressure. The jet will not have a pressure difference, and because of there is no pressure difference between section and section 2, the flow energy becomes the same and the velocity is only have the V1 = 0, so we get it these equations. But in case of, real case of the nozzle case, we do not have the flow theoretically. It will not be non-uniform, will not one dimensional.

Nozzle area A_2 is smaller than the tank area A_1, then the approximation of outlet velocity is

$$V_2 \approx (2gh)^{1/2}$$

In that case, we have to introduce a coefficient of the discharge, cd value, which value is from 0.6 to 1.0. Theoretically there is no energy losses, but whenever have a fluid flow and there will be energy losses and there is a change of the flow areas, or if you consider it, your cd value will comes out, the coefficient of discharge, which is a correction factor, because we have not considered the energy losses, not considered the change of uniform pressure distributions and flow velocity.

In practical outlet flow is likely to be nonuniform, not one-dimension, so average velocity adjusted with dimensionless discharge coefficient c_d

$$(V_2)_{avg} = \frac{Q}{A_2} = c_d(2gh)^{1/2}$$

$$c_d \approx (0.6 - 1.0) \text{ for nozzle}$$

All what contributed, there is a cd will be there, which will be the coefficient of discharge, which vary from 0.6 to 1 and 1 case is a theoretical case, which does not happen it, okay. Theoretically, we cannot have a no frictional surface, okay. Theoretically, it happens, but really there any surface if you consider it, you will have some energy losses, the velocity distributions cannot be uniform at this point. We will have a non-uniform pressure distribution, velocity distributions, that is what we will have a cd value will vary from 0.6 to 1 to compute average velocity.

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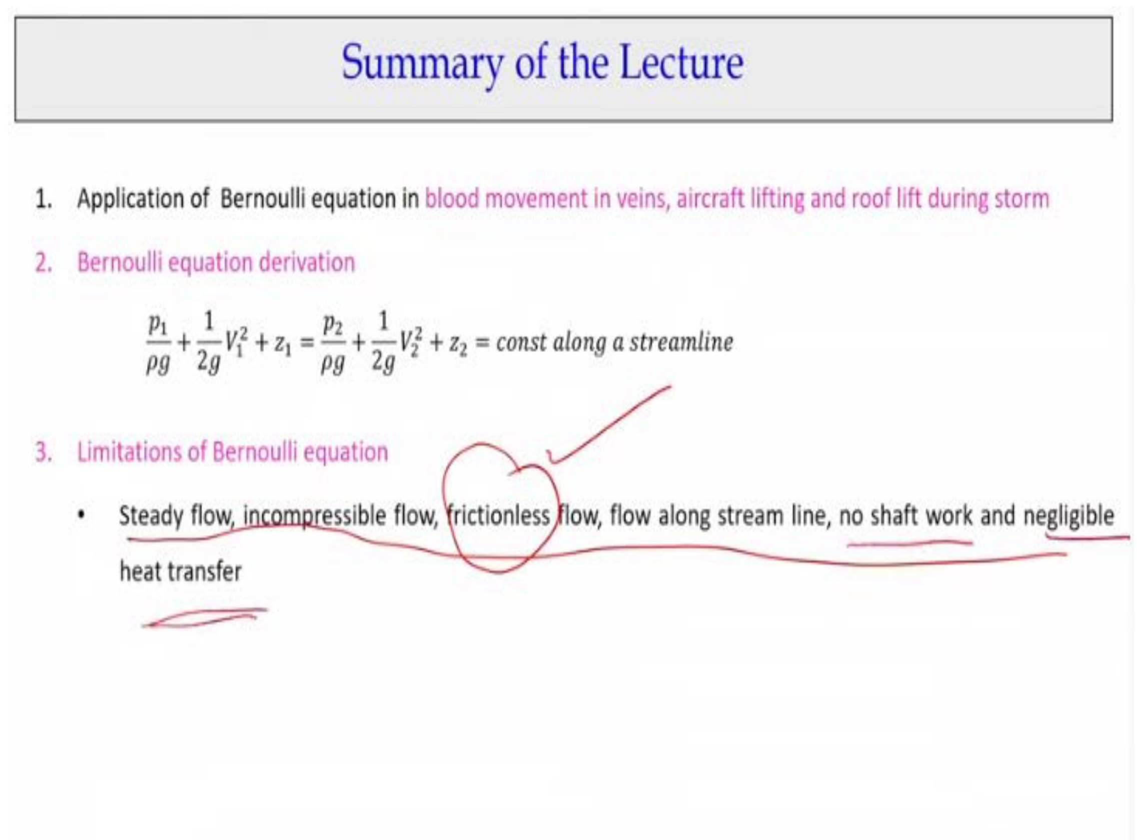

Now, let me take that again putting this Bernoulli equation, you know it, the basically when you apply along the constant lines you will have three energies; the flow energy, kinetic energy and potential energy per weight. And that is what is representing this, in terms of meters. Each terms will be the meter. And you should have the basic assumption is steady flow, incompressible flow, frictionless flow, okay. No shaft work, no heat transfer, okay. With this, I come load this lecture. The next class again we will discuss about Bernoulli equations.

$$\frac{p_1}{\rho g}+\frac{1}{2g}V_1^2+z_1=\frac{p_2}{\rho g}+\frac{1}{2g}V_2^2+z_2 = const\ along\ a\ streamline$$