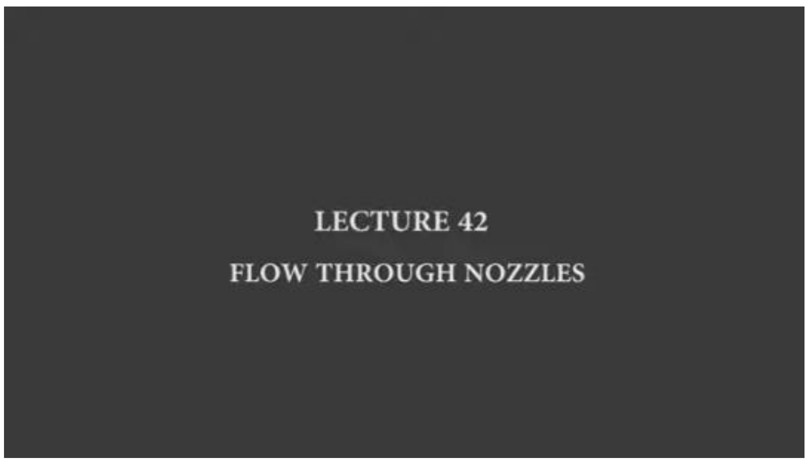
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

Lecture42

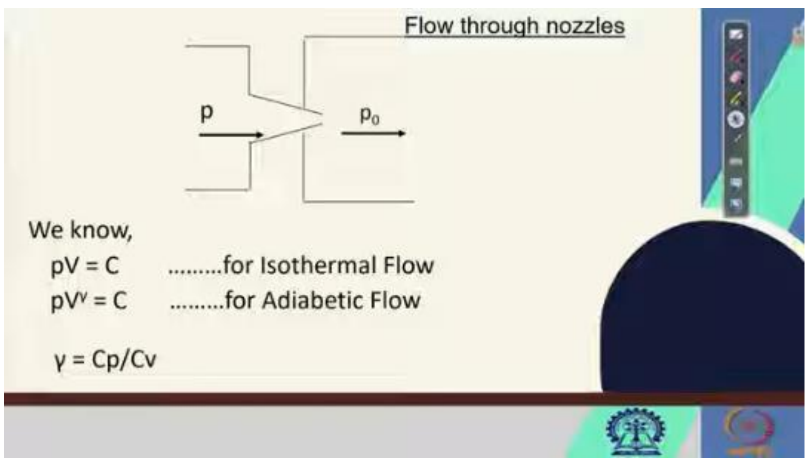
LECTURE 42 : FLOW THROUGH NOZZLES

Good morning, my dear students, boys and girls, and friends. We are almost reaching the end. Only a few weeks are left for the portion of my part assigned by, of course, both of us. My co-partner is Professor Bhuiya, and he is Kanishka Bhuiya.



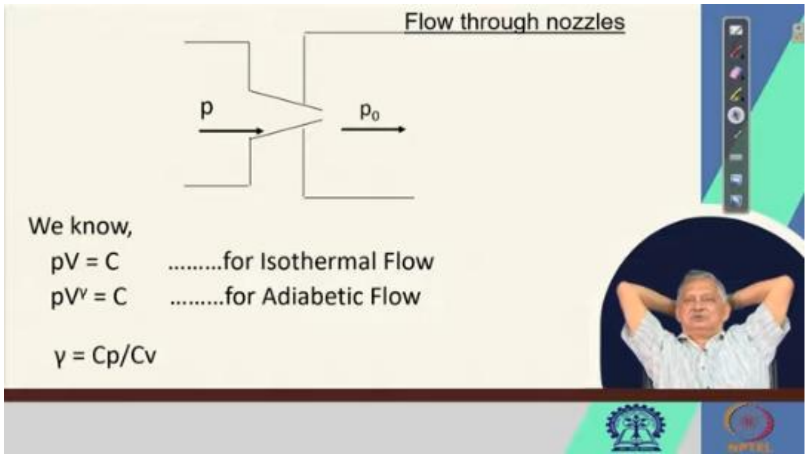
He will take care of the flow through, rather flow of this non-Newtonian fluid, which I have not covered. Non-Newtonian fluid you will cover, and also along with that, some other things like flow through filter media, things like that, okay. So, we now start with another very important one. It is the nozzle flow, right?

I hope you have all heard from your home that mummy or some other seniors are preparing some good dishes in the kitchen, and they are using a pressure cooker for some reason. Then, I do not think at this age or in the present condition, there will be very limited houses where pressure cookers are not available. So, all of you have seen. So, that pressure cooker is making some sound.



Isn't it? So, it is being heated, and after some time, when the pressure reaches a definite level, that valve on the top opens up, some pressure is released, and some sound is produced, right? And that sound we can hear here also. Obviously, not in the class, but we can visualize how it is happening through our development of the course, right?

Those who are in the urban or rural area, but there are some, what do you say, meals and many other big industries. There, for entering into the shift, maybe six o'clock in the morning, two o'clock in the afternoon, and again ten o'clock at night, because of the eight-hour shift. So, before that, five minutes before, there is a siren, there is a sound from that. Typical industry, right?



Whether it is production or any other, it is normal, right? If it is a big one, small ones may not be, but big ones it is there. Apart from that, I think I don't know how many of you have seen, no, none of you might have seen, because seventy were, you might not have been born at that time. So, during that period, there were very, very loud sirens all over the country.

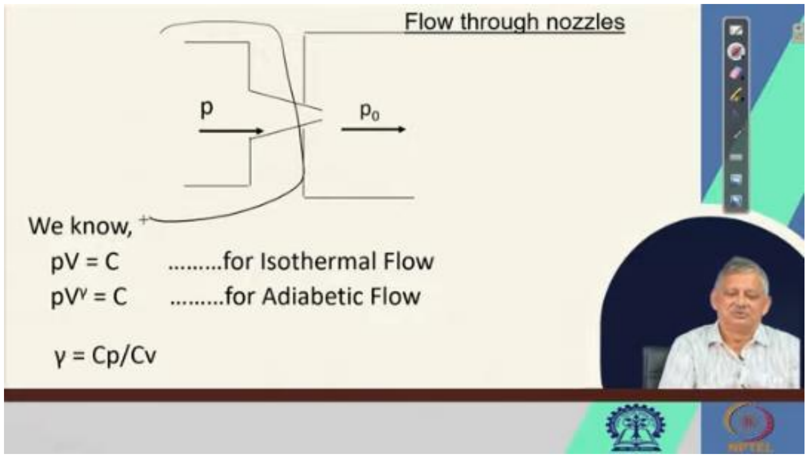
Typically, during the war, that siren is used to alert you, right? That also falls under this category, okay. Besides that, I am talking right now; this is also sound-producing. So, from inside, to outside, there is some sound, right? And that sound, somebody from inside, that is air, is coming and coming out from the mouth, giving the sound.

And obviously, this is the creation of nature, right? However, another thing you can also see and hear is sound. You do whistle. You make just like that mouth, it will not come. You have to make a definite shape, definite size of your mouth.

Then only if you blow, there may be some whistling. Right, this also falls under this, right. So, what we are showing you on the left side, you see there is a reservoir where the pressure P is much, much higher, right. Yeah, I do not say much, much higher compared to some. It is a, yeah, source of pressure, right?

Or reservoir, you can say. And there is a nozzle. You see, the nozzle is like this, okay? Better to take this. Yeah, this is the nozzle, right?

So, what is happening? Air is blowing, or any fluid is blowing, there is a narrow space, right. So, through this narrow space, that is called a nozzle, through this narrow space, air is coming out, right. So, at this At this tip, the pressure is very high, right? Sorry, at this tip, the pressure is very high, and that I will find out.

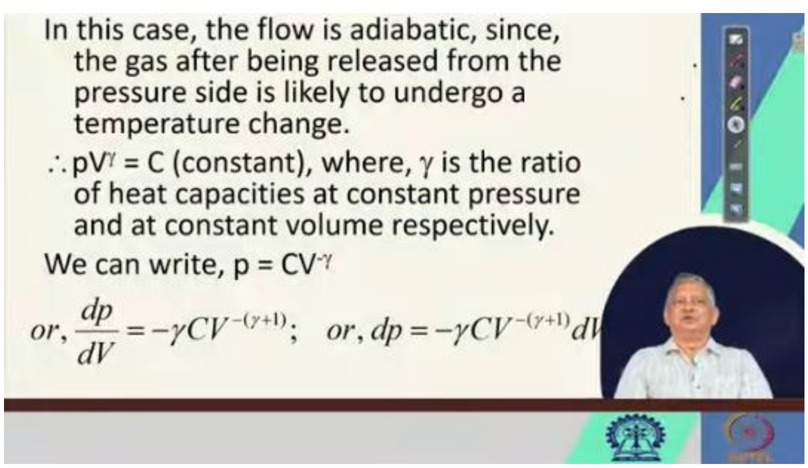


There is this, it is called the tip or nozzle speed pressure, that is P0, right. So, this may happen earlier also, in many cases, we have also said that for isothermal flow, We have said. So, isothermal, we have said that is where the temperature is constant, the flow temperature is constant, it is flowing from here to there, is isothermal, no temperature change. But for adiabatic flow, it is flowing from here to there, the temperature may change, but

There is no heat transfer, dq is 0, right. And for both cases, we have seen that the gas losses are available, right. For isothermal, PV is constant, and for adiabatic, PV gamma is constant. Where gamma is nothing but the ratio of C_p over C_v. Then what are C_p and C_v?

C_p is the specific heat under given pressure, and C_v is the heat capacity under given volume. So, C_p over C_v is gamma, right. This is dimensionless because C_p and C_v both have the same dimension. So, gamma is also a constant and is also dimensionless. Is that?

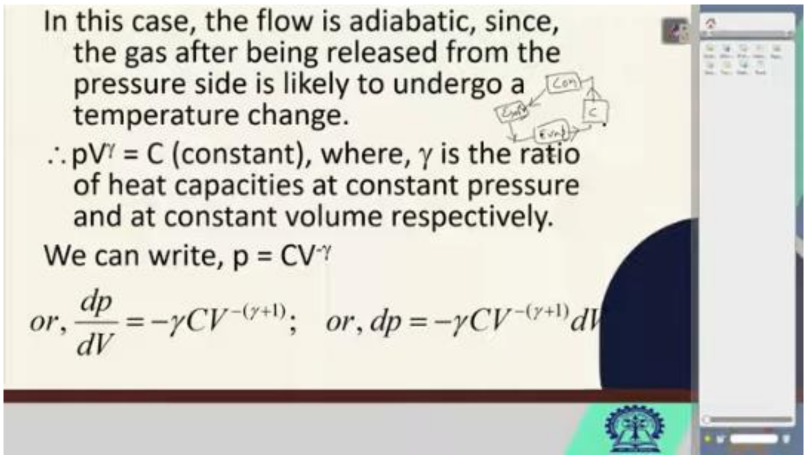
Oh, it would not be. Unless we do this, unless we do this, yeah. So, in this case, the flow is adiabatic. Which case? Any.



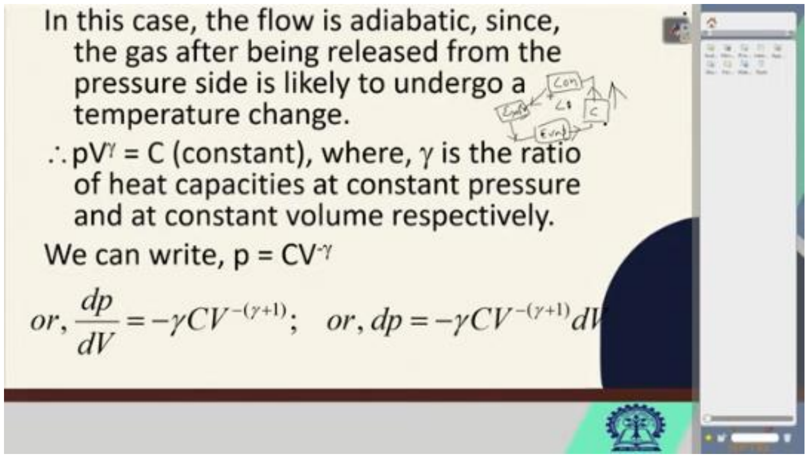
Since the gas After being released from the pressure side, the gas is likely to undergo a temperature change. I do not know whether you have read refrigeration or not. In refrigeration, though it is not a part of it, but still, since it has come, let me also tell you because it is saying that from pressure to very nozzles, right, very low. So, when it is coming, it is adiabatic because the temperature may change.

If the temperature changes, then it is not isothermal. So, there may be a change, but there is no heat transfer also; q is 0, dq is 0, right. So, why I am giving you this situation, this condition, is to know whether you have read refrigeration. The only reason being that in that refrigeration, I hope you know the cycle, but okay, let me tell you since it has come that there is one. So, what I was saying is that in refrigeration, you have one

compressor, one condenser, one expansion valve, and one evaporator. So, this is in a cycle, and that is called the vapor compression refrigeration cycle. So, this moves like this, like this, and like this, okay. My typical one is that Somehow I made something wrong, however, it does not matter.

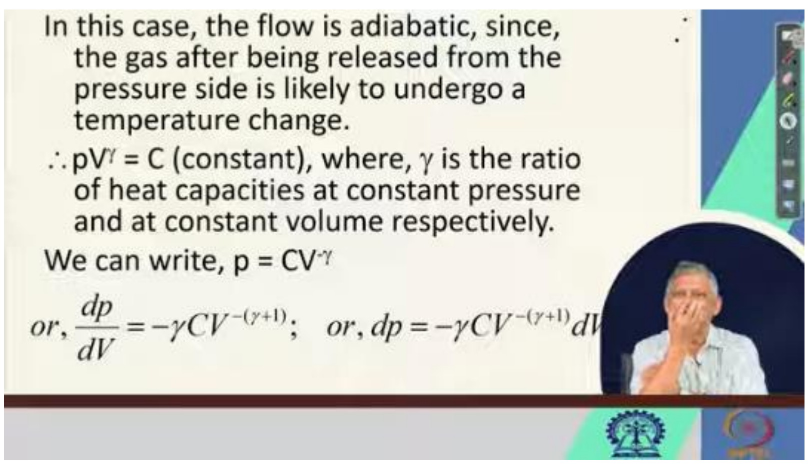


So, it is called the refrigeration cycle, okay. So, in that cycle. The one which we have just shown you, that diagram of the nozzle, right? A similar thing happens in that refrigerator. The compressed liquid goes to the condenser and gets liquefied. Then, that high-pressure, high-temperature liquid goes to an expansion valve, where from a high-pressure P condenser to P evaporator, there is a huge pressure drop, right? And this pressure drop, because of that, this



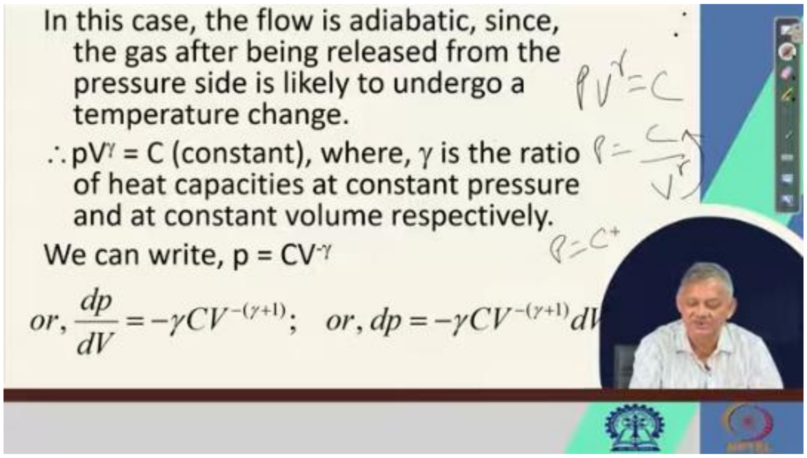
refrigerant gets cooled, okay. This refrigerant gets cooled, and that is why it is called, as we said, adiabatic, right? So, there is no heat transfer, but the temperature is getting changed. So, that is the reason why I told you that refrigeration is required to know, right? It is similar, right? The way you are doing it here, a similar way it is also done there.

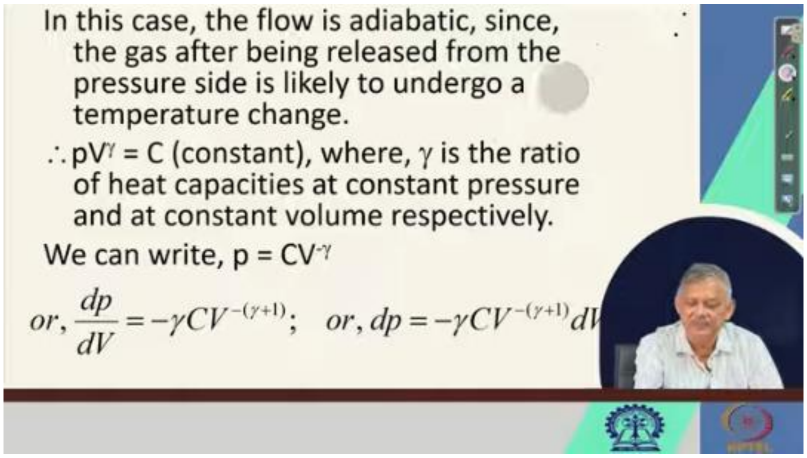
From a high pressure to a low pressure, that is why there is a temperature drop. This you also can feel. Typically, during hot summer when your mouth is having a higher temperature, right? You make a very narrow your mouth. And blow and see in your hand, you will feel that there is a little cold, right.



This you can only see when there is a temperature difference; otherwise, you may not be able to visualize it, or it may not be feasible for you to understand, right. So, that is why we have said here in this The flow is adiabatic since the gas, after being released from the pressure side, is likely to undergo a temperature change. That is why, just in the previous slide, we said PV^{γ} is constant or PV^{γ} is constant, right. So, one was for isothermal, and the other is for adiabatic.

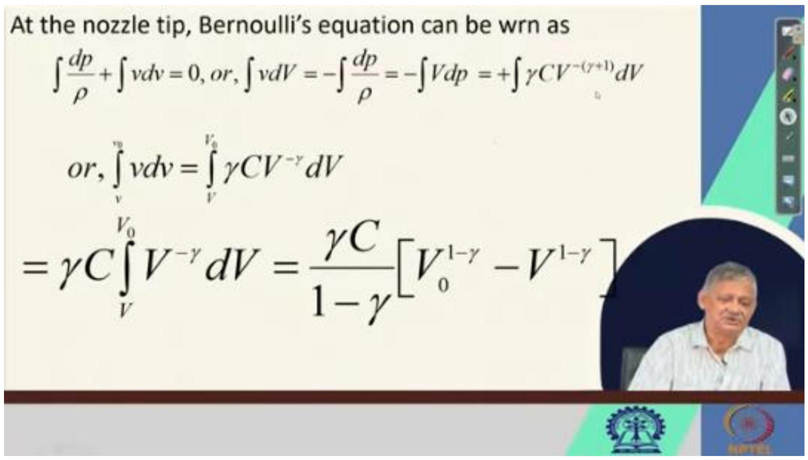
So, for adiabatic, we take PV^γ equals constant, right, where γ is the ratio of heat capacities at constant pressure and constant volume, right. So, we can write then P equals C V to the power minus γ. I hope you understand why it has become, right. So, PV^γ equals constant. So, P equals C divided by V to the power γ, and you know that when you take it to the top, then you can write P equals to C multiplied by V to the power minus γ, right. I hope you know that, okay. It is having γ; if it is not γ, say V squared, 1 divided by V squared, then when you take V, it is V to the power minus 2. I hope you know this; I am not exaggerating it anymore. Okay. Then, when you have seen that PV^γ is constant, you can make it like this: P equals C V to the power minus γ, right. Now, if you differentiate with respect to

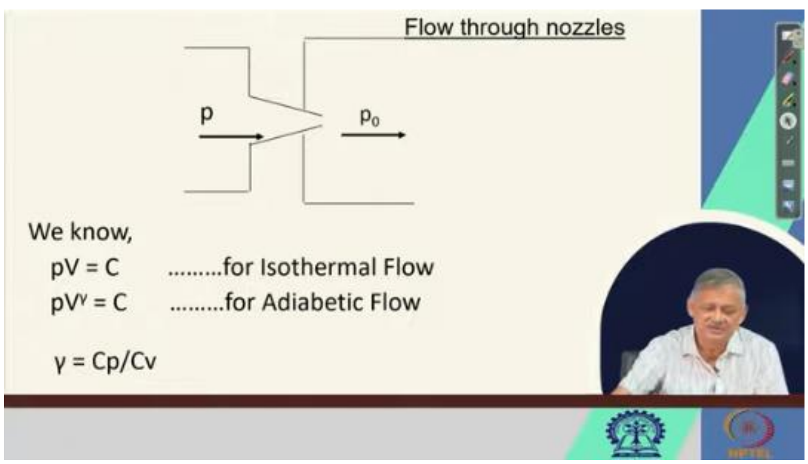




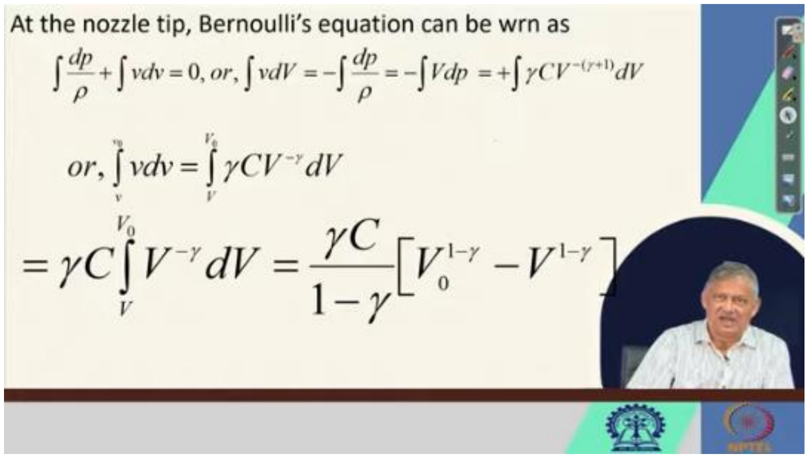
V that is with respect to specific volume, that dp / dV is minus gamma C V to the power minus gamma plus 1. Right, minus gamma plus 1, that is minus gamma is there. That is, if you differentiate P with respect to V, right, then dp / dV is minus gamma from V to the power minus gamma and C V to the power minus gamma plus 1. Obviously, this is a derivative that we know how it is not differentiation, right? Or we can take dp is equal to minus gamma C V to the power minus gamma plus 1, dV, we have taken in that to this side, right.

Now, we can integrate. So, at the nozzle tip, if we use Bernoulli's equation, what is the nozzle tip? I go back to that. This is the nozzle tip, yeah. This is the nozzle tip. Is this ok? So, at the nozzle tip, we can definitely use Bernoulli's equation, right? And from that, we can say



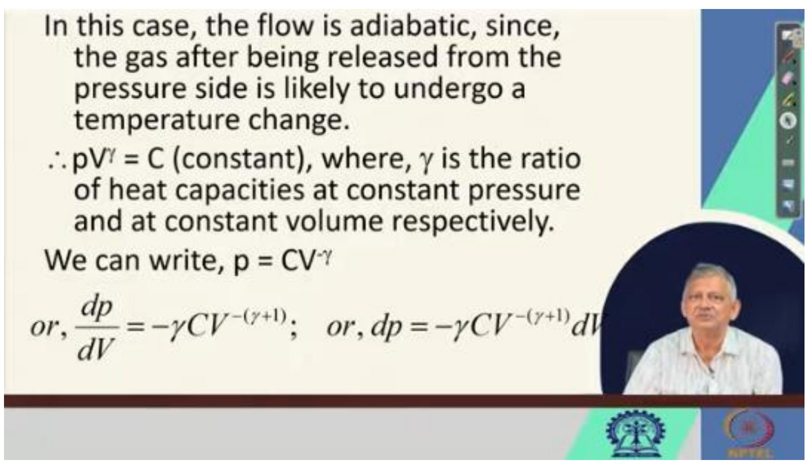


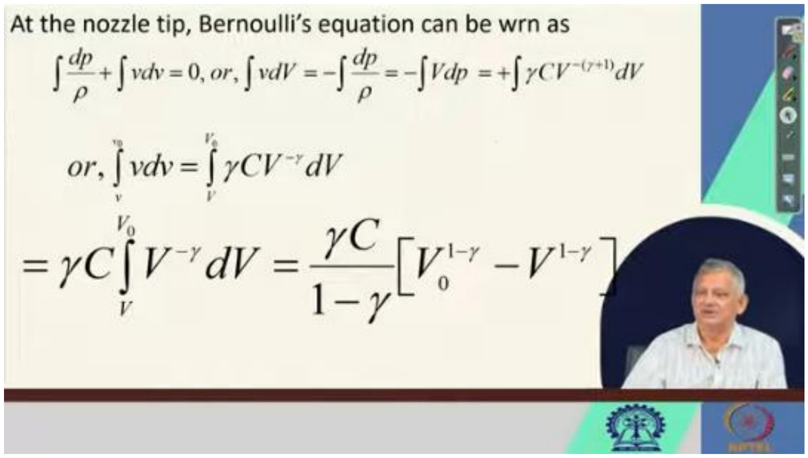
that the integral of d P over rho plus V d V integral or integration of V d V is equal to 0, assuming no other thing like forces, like this is pressure head, that is velocity head, or yeah, and other parts you are not taking, ok. So, then the integral of d p over rho or integration of d p over rho plus integration of V dV, this is equal to 0. Bernoulli's equation we can imply at the tip of the nozzle. So, we can say V dV, right.

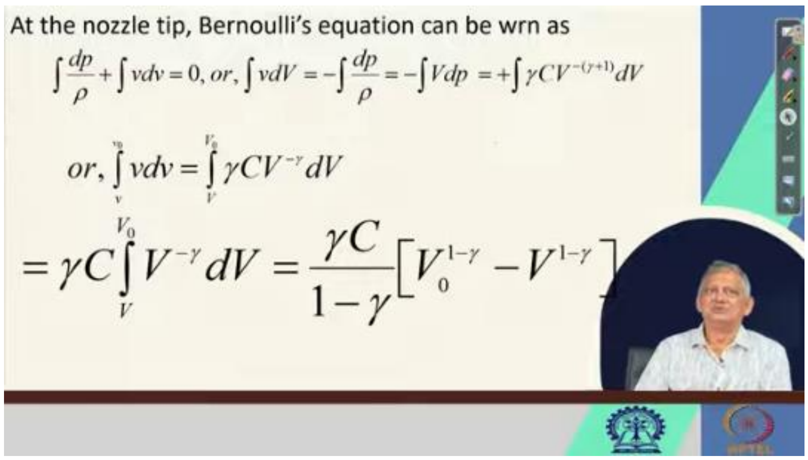


Integration of V dV is equal to minus, because it has come to the other side, minus dP over rho, right. Obviously, since there is rho, you can write minus integration of V dP, right. So, we can write that is equal to, we are substituting dP with dV. We are substituting dP with dV; you go to the previous slide, here you see dP / dV is this.

So, dP is minus gamma C V to the power minus gamma plus 1 into dV; this we are substituting there, right. That is why, I have brought it to the previous one, right. In that case, another minus and this minus makes it plus, the integration of gamma C V to the power minus gamma plus 1 into dV. So, therefore, if we say between small v to vo or vo, vo is the tip velocity, right, small v that is the velocity at the reservoir side,

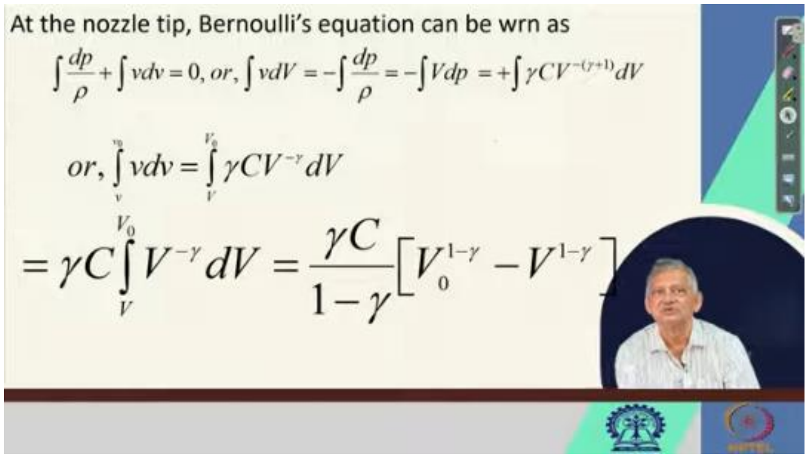




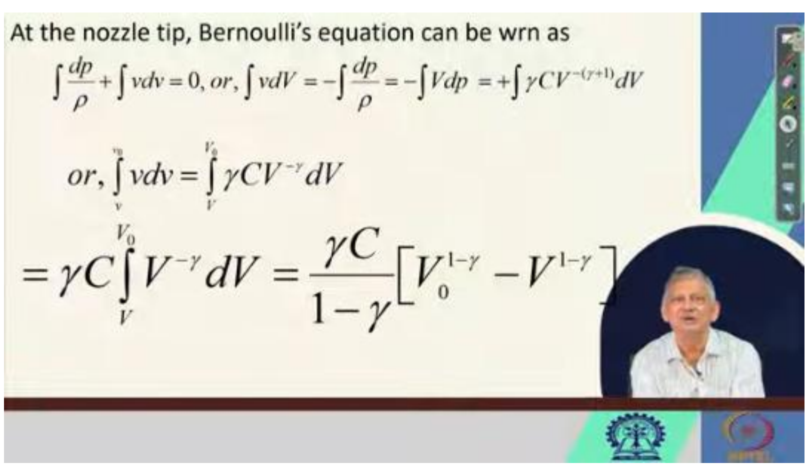


v. So, v dv integration of that within the limit of v to vo, right. So, this is equal to V to Vo gamma C V to the power minus gamma dV, gamma C V to the power minus gamma dV. How has it happened? Because v dv was earlier there, right.

So, we remain, we kept it, v dv, and now we are making it to v to vo, ok, capital V to capital Vo, that is specific volume, ok, gamma remains gamma, C remains there, and v dv. So, V to the power minus gamma because one more V has come right, one more V was there. So, that has taken care of that one more. So, gamma C V to the power minus gamma dV is the v dv, integration of v dv between v to vo



and integration of capital V, that is specific volume, again between V to Vo, Vo corresponds in this case to the tip, right. Therefore, we can write this gamma C, it comes out of the integration between V to Vo. capital V to the power minus gamma dV. So, the moment we write that capital V to the power minus gamma dV, it is differentiated. So, gamma C V that 1 minus gamma it becomes, right, and between V to Vo, it is Vo to the power 1 minus gamma minus V to the power 1 minus gamma. You see that it would have been gamma minus 1, but we have made it gamma, 1 minus gamma, because we have kept the Vo left side and capital V only on the right side, right. It would have been ok, 1 minus gamma, 1 minus gamma, that is gamma minus gamma plus 1 minus gamma plus 1, right. So, we write integration of v to vo, v dv is equal to integration between capital V to Vo, gamma C V to the power minus gamma dV, and on integration of this, it becomes gamma C, because that is constant, again between V to Vo, capital of course, that is specific volume, capital V to the power minus gamma on integration.



It becomes minus gamma plus 1, right. So, 1 minus gamma, and that we put both the limits that is Vo at the top minus V to the power 1 minus gamma, right? 1 minus gamma by 1 minus gamma, and here also it would have been 1 minus gamma divided by 1 minus. So, with this, we have come to the beginning of the adiabatic flow of fluid through a nozzle, right. Here, this nozzle flow will make Ok.

In the next class, we will find out what is the value of v dv between v to vo, and vo we are referring to the tip of the, tip of the nozzle, right? Ok. Thank you for this class, and we will meet again for the next class to find out the value of V.

Thank you.