Engineering Thermodynamics
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Lecture - 39
Applications. Problem Solving: Unsteady processes. Filling. Evacuation.

Now, that takes a through all the flow processes steady state flow processes that we have looked at the cylinder piston arrangement is not a steady state steady flow processes, it is a closed system. So, that is treated differently then we got a bunch of processes which are steady state.

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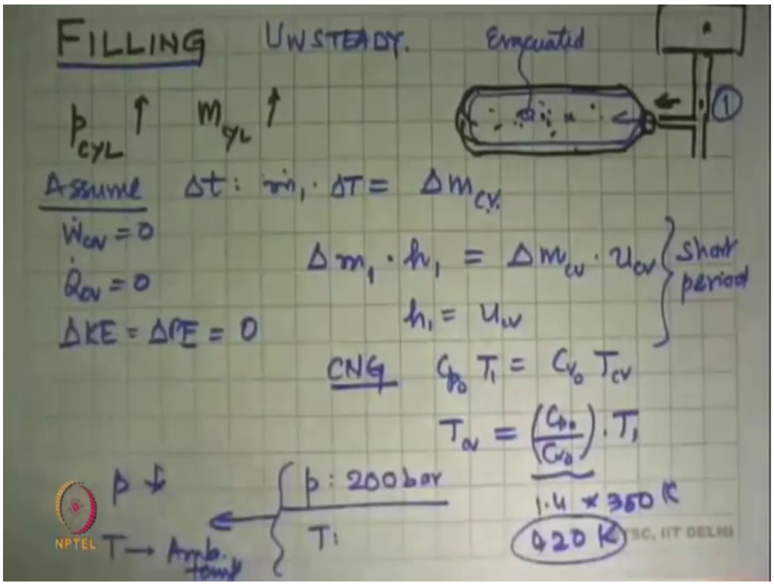

Now, we look at some processes which are open systems, but they are not in steady state. So, we look at filling and evacuation. So, what filling means is that we have a tank, and into this from the supply line we are filling gas, is a common example around us all the time, that when vehicle which has got a c h which is running on CNG it has got a CNG tank in the vehicle. And the tank pressure keeps going down with use some point it goes back to the filling station and the filling station they connect a hose a pipe to it. That is fed by a gas from a high pressure reservoir.

So, you can say that this is a high pressure reservoir there. And then this valve is opened it this gas starts going into it and starts filling up the cylinder; that means, during this process they got flow going through this. And the mass of this and the pressure inside this keeps increasing the p in the cylinder keeps increasing mass in the cylinder keeps increasing. So, I keeps doing this through an automatic system it senses what is the pressure inside this adds little more. And as soon as the pressure of this that is the safe working pressure of the cylinder will reached it stops and your vehicle is fed then you are go away.

Now, let us see what happens in this case, this is an example where we draw the system boundary which is the space inside this cylinder. And say well there is one inlet taking place, but the state inside this keeps changing with time. So, this is not a steady state situation at all it is an unsteady situation. So, what is they apply the first law, we have derived the very long equation and we make various assumptions on that. We say that the state at which it is coming in this is fixed and this is constant this is state one and the state here keeps gradually changing.

The mass conservation equation tells you that in a period of time in delta t time this m dot 1 into delta t is equal to the change in the mass of the system. And we can so assume that there is no work being done here, work done is 0. It is adiabatic process this whole thing is insulated 2 dot cv equal to 0. No change in kinetic energy or potential energy of either the system or the moving through it both are 0. And when we do that what we will find is that this mass that went in. So, a certain amount of mass delta m in it is enthalpy h 1 this is equal to this mass that got ideally over there. This one be so, this was evacuated initially this will be delta m c v into u c that long equation that we had if we solve it we move things this is what we will get and it tells you h 1 is equal to u c v.

We are assuming that initially this work evacuated. And what are the steps? If you are looking at CNG which is methane h 1 we can say, then Cp 0 T1 this is equal to Cv 0 Tcv it tells you that temperature of the gas inside the control volume Tcv this will be Cp 0 by Cv 0 multiplied by the temperature here. If this is ambient temperature means that this gas here. Then increase by 1.4 times the absolute value. So, this becomes 1.4 into say 300 and that whatever becomes 420 Kelvin approximately there.

So, the temperature of the gas in the cylinder increases and if you actually go there and touch the cylinder after filling is done. In fact, that it is quite hot you cannot touch it so it has reached a high temperature, but the pressure is equal to the maximum possible pressure to which it can be filled, which was 200 bar. So, you got gas at 200 bar, but temperature which is much higher. And the safety of the cylinder required that pressure should not to be exceeded which means that if you fill it up here and this is at a higher temperature as you go away after some time even if you do not use the gas too much the pressure inside withdrawn at the temperature which is the ambient temperature.

So, instead of say about 80 90 100 degree Celsius, this will then come down and the pressure will be less, but you cannot initially fill it up to more than this hoping that after it cools down it will come to 200 bar that is not permitted because the mechanical design of the cylinder does not permit us that. So, that is what happens in a filling process there. And this is one set of problems that we are tackle the trouble is that since that change the state of the substrate inside this change is very time, when I have to be very careful that when you applied this equation it is only for short periods of time.

And the mass that is put in is also of a very small unit in the mark otherwise technically the type of integration that we did to get delta m cv that cannot be them. One then has to say that ok I will take a small time see what happened then I will take that on the starting condition and see what happens after a little more filling. Then I will take that as my starting condition see what happens filling and that is all the calculation will proceed.

It is a little more complicated and so we do not do it in this beginning course, but it is important to know that this is what filling does and there are many other cases where such things happen. We can look at the fact that if this was saturated liquid and this was evacuated what will happen. And that is the example when your LPG cylinder was for filled it is initially evacuated and then you are pumping liquefied you tend into, it you can say that whether hoping it pump it if a butane. Am I actually getting liquid butane inside the cylinder at all times. I leave that question do you think of.

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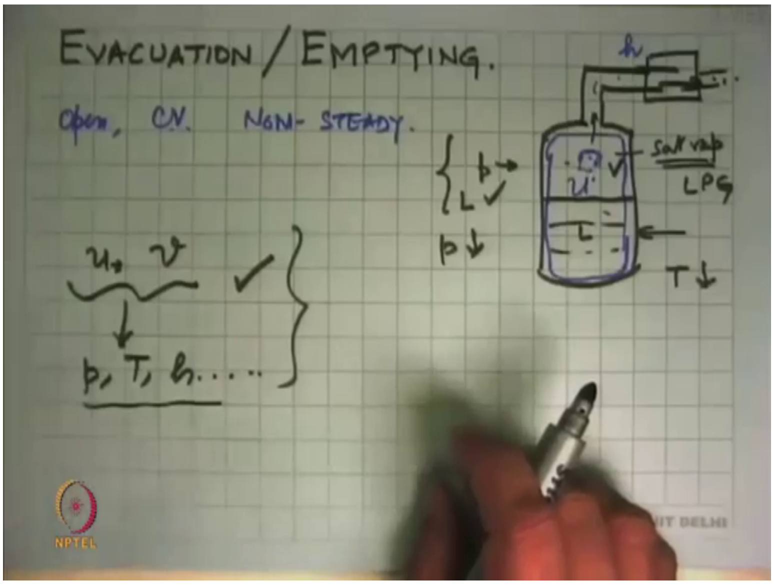

The opposite of this if evacuation or emptying and what we do here is they are the opposite of what we have just looked at you have a reservoir say and here is reservoir from which we are taking in n. Almost every manufacturing unit every factory will be have some requirement of compressed air. So, from a compressor we keep filling into it and keep going there. So, the analysis of this if you want to do we want to know that what is the relation between mass flow rate and the pressure in the cylinder. We will do the same analysis like what we just do not filling into that.

But this is our system boundary, we say that this is an open system control volume approach, but this is not steady. So, we apply the same equations and say that look there was certain mass here went out which internal energy became it is enthalpy over here because there will flow work coming it. So, this enthalpy and the internal energy that going here it would be equal and you will start g decrease in temperature and you draw of the gas.

One of the problems in the one of the assignment that I have put is that instead of just having gas inside this or air inside this. I give you the example of the domestic LPG cylinder. And what do we actually do in the domestic LPG cylinder in that we are drawing air from the top and of course, there is a regulator sitting on top of between there.

So, you are drawing of only the saturated vapor and we keep drawing out this evaporates the temperature inside this you can do the calculation and see that temperature keeps decreasing a fortunately in domestic cooking you do it. So, slowly that you do not see this temperature right whatever temperature fell the ambient would supply energy and to come back with the same temperature.

So, we are drawing of saturated vapor dry saturated vapor even though in the cylinder as a whole we had a wet state then liquid there then vapor over there. And I will keep drawing out this vapor keeps going down, but if the temperature were constantly always had the same, the wet state at the same condition. The dryness fraction of the system kept going down. So, inside supply pressure remains constant as long as there is liquid inside the cylinder and that is the nice thing about the cylinder and the pressure regulator is a do a job quite nicely.

Once the liquid is gone your dry saturated vapor and then when you keep drawing out there is no more liquid to evaporate. Then the pressure on the cylinder we needs to go down and that is what I just mentioned the pressure regulator then cannot do it is job the pressure regulator is design for the fact and butane will come out at a certain pressure, it will throttle it and produce a pressure which your LPG store at filling marks. Analysis of this procedure exactly the same way I have before I was not repeated, but you can write the cool equation. Again make the similar assumptions that heat transfer is 0, work transfer is 0, kinetic potential analysis is changing from 0 and simplify the equation and solve it.

The only difficult thing that happens in this type of problem. In fact, if you want to figure out and say what is the pressure after I do out so many grams of this substance. Then in the final case you are left with something like 2 properties which are specific internal energy and specific volume. And knowing these two properties the state is completely defined, but we do not have any nice property tables which tells you that if you know u and you know v, this is the way to calculate p, T, h and all the other properties. This is complicated quite troublesome and you have to in some cases do iteration and even online programs which are there very few rarely if any give to you the option that you specify u and v and it tell you what the state is here. It is not all that straightforward a calculation.

But even if you get to the point where u and v are correctly identified the state is only know you can say well actually start 399 percent if the problem has been solved 1 percent is to use the properties tables enthalpy is there. They do not even get time quoted at this part. So, that is one of the issues of filling and emptying.