**Engineering Thermodynamics**
**Prof. S. R. Kale**
**Department of Mechanical Engineering**
**Indian Institute of Technology, Delhi**

**Lecture - 33**
**Applications. Problem Solving: Positive displacement devices.**

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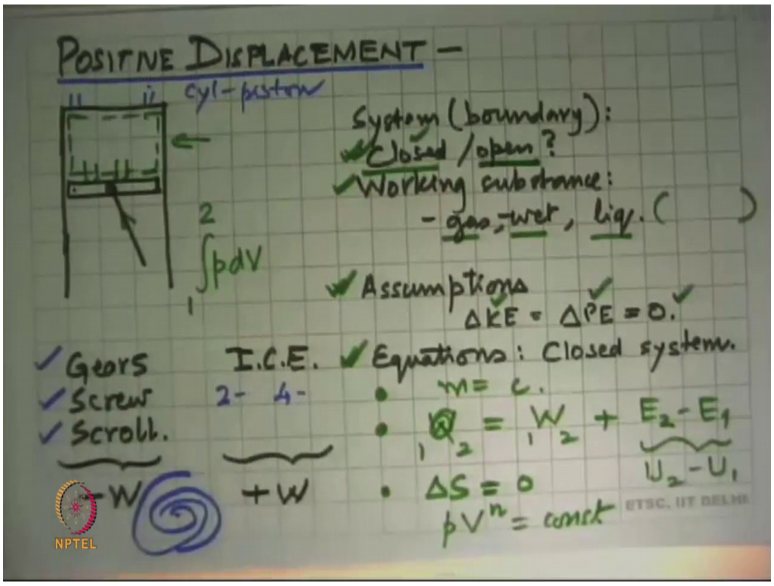

First thing that I will do that is what I have listed here as positive displacement devices and for positive displacement, we mean that once you have a substance in that take an inside the device, no matter what the outlet condition, when you operated, it will push it out. There is no way that it will just stay inside.

So, the way we can do it in the real world is the most classical thing that you have come across which is the cylinder piston arrangement. Once if there is a inlet and outlet on this, and this is say handling air or say air or liquid, then irrespective once the fluid inside this, the piston will compress it and the moment the pressure inside will more than the pressure outside across between these there is the valve, it will push it out, no matter how much pressure is there?

So, in the worst case, if the outlet valve outlet has been completely closed, the piston will still try to push it out. If that does not go out, the pressure will keep increasing that something in this will break; that is the critical thing of positive displacement devices. The other ways to achieve positive displacement is through a gear pump or a gear type of compressor, a screw device. You have two screws in mesh, one is powered, the other is idling. And as the fluid moves along the length of the screw, the volume that it occupies in which (Refer Time: 01:57) decreasing until it reaches the outlet and it is sent out. That is the screw compressor or a screw pump.

The third one is the scroll type of a device. Scroll is that you have two plates just something like this which are sitting with one another. And one of them is rotating, the other is stationary. And in the process, the fluid gets trapped, gets compressed, and pushed out. So, these are devices in which there is a negative work that means, they are work consuming devices. The other big example of positive work output is the internal combustion engine in which the same thing happens, but there is a network of pull. There could be two strokes or four strokes that does not matter. One of these strokes produces the power the other three or other stroke that is something else to keep the machine boil.

So, the way we analyze this. and in this course, we will assume that there is no fuel coming in is that we say that first in all these cases, I will define my system boundary. And the system boundary in this case is our system over there. And we know that as the piston goes up and down, this shape and size of this boom change and if there is an outlet, think would even be going out or there is the inlet as it comes down, it could be taking material in.

If these are open this becomes an open system, otherwise largely we will look at closed systems. Once we define that it is a closed system, the next thing we have got to see what is the working substance in this. And so we write down that the working system could be this gas or it could be a wet saturated state or it could be a liquid, and we write down the name on that nitrogen, oxygen or butane whatever it may be. So, we know that in subsequent solving, when I need to get property which material is there for which I have that standard data.

Then it tells us that once you have decided, whether it is a closed system or a open system in this case, we have looking at the close system. We know what are the equations we need to use, and we write both equations. And it is important as when we write your equations, we make no assumptions that this point, but we write the full equation. In this case of course, mass is constant and we know that for a closed system, you have to write the equation that Q 1 2 is equal to W 1 2 plus E 2 minus E 1, which is the first law of thermodynamic. So, conservation of mass, conservation of energy we write this.

You could also write the second law equation, and second law; what can I say about the entropy for this system. In many calculations, this may not be required. But, if we say that this is an isentropic process, then we can write down like entropy change in this is 0, otherwise this is a increase entropy. So, after writing the equation, the next thing we need to do with, what are the assumptions that I can reach that will make in make in this analysis. It requires a little bit of a physical fee for the machine, and the problem and the real world thing that is the best way to say will what is the good assumption, but is not good assumption.

When we look at this, something we can make clearly that this volume is small enough that the centre of gravity of the system does not change so much with (Refer Time: 05:34) doing this process. It may be a few millimetres, few centimetres, but not like 100 meters or something like that. Then you would have to worry about for its energy changes. So, we can say that delta P E is 0, and the system itself is not moving is it stationary, so we considered delta P E is 0. So, this is something we can put here.

At the moment we do that, we know that life becomes a little easier, you can write U 2 minus U 1 as U 2 minus U 1 and we know what the equations that we will need to solve. If you know what is the heat transfer is that has been known, if we know that it is adiabatic system, we know that Q 1 2 is equal to 0. In that case, this is the relation that we have listed. Then the several how can I calculate work for this, and say where there is work being done at the system boundary, when there is the force there and this will doing the work against, what the piston does.

The piston could be having forces coming on the connecting rod, or also frictional forces between the piston, piston rings and liner. All of that will be equal to the work done by the gas on the piston or the opposite chain, but the by the piston on the gas that we all know can be done as integral p dV, going from whatever the initial state was the final state. And we need to have some relation between pressure and volume (Refer Time: 06:57). The common thing we came across or that we could this say that this is some sort of a polytropic process p V to the power n is equal to constant. This could be for a gas or even the saturated substance. And then we can say well how do I get the problems. And this is where we get normal to two lines of action.

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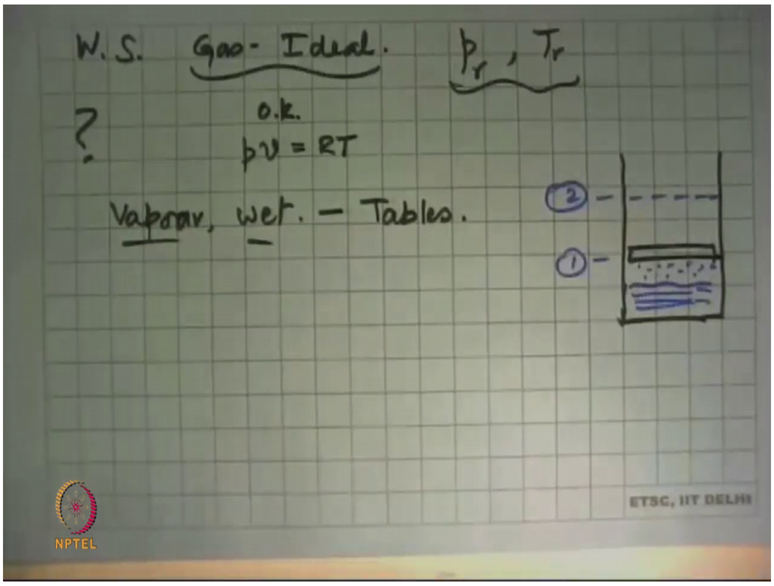


If this whole thing work only a gas, and that is something we need to say. The working substance property, say we have a gas, and can I assume this to be an ideal gas. They are not necessarily going to keep on calculating p r and T r in every case. But, largely by looking at it and saying if it is air being compressed or nitrogen being compressed at ambient conditions, we can write it. But, we must say explicitly that until these conditions, we can say that throughout the process from beginning to end, we can assume that these conditions are such that ideal gas assumption is ok.

Once we do that, we have the luxury of using p v is equal to RT, and going ahead with the solution. If the problem explicitly states that there is a vapour, the word vapour comes in or the word wet comes in, then we got to be careful that we cannot make the ideal gas assumption. The moment we come across these words, we must go to property charts and tables, and get data from there.

So, this is a important distinction one has to make, it is a decision that you have to take quickly on well then we will know what numbers to put the problem by solving this problem. An example of a wet system, there are some problems that we had given in the assignment is that rate we have a cylinder piston arrangement. In which we have a piston sitting over there say, and inside this there is a certain amount of liquid, and certain amount of vapour over there. And we hit this against a certain pressure, so that the piston rises from some other point which is this is state 1, this is state 2, and we want to know what happens during this process.

So, here we have to go for vapour properties. If the problem says that a gas is contained here, and if by intuition we wrote nitrogen or oxygen it above, ambient condition are higher temperatures, ideal gas assumption is (Refer Time: 09:38) perfectly fine. But, if the temperatures are closed to the critical temperature or even lower than that, then we have to looking this, please keep that in mind, so that is the way we get the properties.

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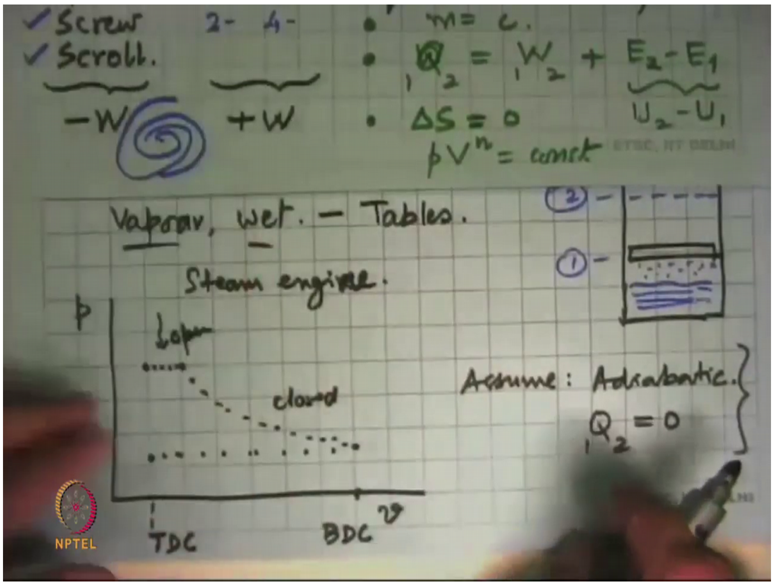


And then we begin solving this problem, and get whatever we want. It always helped to show all these processes on some property diagram. For example, here I am going to show this process on say a pv diagram. I said where the initial state, and say if it we take the example of say a steam engine.

Now, we do not see this, but twenty five years back, and the beginning of the industrial revolution the machine that change the world. So, there the inlet state was here, this is a topmost position with the piston can take which you know this is called the top dead centre. The bottom most position it can take, it will be bottom of position there the bottom dead centre.

For some time, we admitted the steam, then the steam valve closes. And then this follow a series of paths process a series of states, until the piston details at the end at which point the exhaust valve opens and the steam is it out. And it is now only got (Refer Time: 11:07) steam at the ambient pressure slightly above ambient pressure. And then it comes back, and as it coming back it pushes that steam out. So, these are the state it goes, but now it is an open system, this part was an open system, because steam was coming in. This is a closed system, we can assume it to be (Refer Time: 11:27) that it is adiabatic, and this is the outlet.

And once it comes to the top, again we start exposing it to the boiler, and it again generate this, so that that sort of classical steam engine usual. So, this is open system, this is closed system. And unless it is explicitly stated that there is so much heat transfer taking place into the surroundings in the piston, we can assume that this type of a device will be adiabatic, its own adiabatic means heat transfer is 0.

So, whenever we make an assumption, we should explicitly right that I am going to (Refer Time: 12:19) that in this problem nothing is said, I will assume this is adiabatic Q 1 2 equal to 0, and then we go ahead. Because, in the absence of anything else, there is no way we can calculate Q 1 2. So, we assumed it to be 0, and proceed it with the analysis. So, this sets of the problem, again if nothing is mentioned what type of process is there, then I get we have an issue, so we need to us to again say that.

Let us assume that is isentropic. And then get p V to the power n equal to constant, and then solve the problems from there. So, there are many many problems that you will come across, where you have a cylinder piston arrangement like this happening, it could be like the gases expanding or it could be the piston will doing work, and there will be various or variants on this.

For example, there could be a spring loaded thing or the heavy piston thing or types of things could be there. Practical applications of this; this is the reciprocating device. And the most common thing is a positive displacement type of a compressor, and most refrigerators, window air conditioners would have reciprocating compressors, when they compress the refrigerator, and put it out. So, what we are shown in the earlier picture here as this. If it were a reciprocating compressor, it will be doing it slightly different things.

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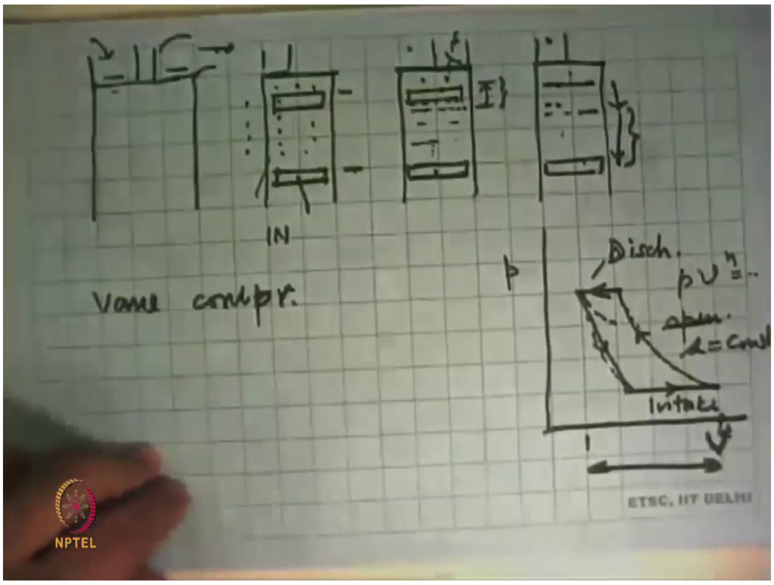


So, let me just explain, how the reciprocating compressors work. So, what we have done is here the device, and return was two valves. One and this is connected to the inlet, this is connected to the outlet. What this valve does in that when the pressure inside is less than the pressure here, this opens and allows the gas to flow in on the vapour. So, this is what will happen at some point, and what this valve does in that when the pressure here is more than the pressure here, it push the gas out.

So, there are two valves which to this job. So, there is one process which could be the intake process, when the valve is opened up. And this happens, when the piston is up here, and begins to move down, and comes to this point. And as it is doing so if the valve were kept closed, this pressure would be less than the inlet pressure. But, since there is a valve that valve opens, because entirely because the pressure difference between the two sides, and this thing moves in, and so the working substance is sub this space.

So, now the piston has reached its bottom most position, it cannot go any further down. And so what happens now is the adjusting begins to do move up, the electric motor is driving this. The moment it starts moving up, the pressure inside here becomes more than the pressure here. So, this valve will now remain shut.

And we let to now see what the outside valve does, so this begins to move up and as it moves up the pressure keeps increasing. And at some point, this pressure is equal to the pressure here. And after that the step movement up here, the pressure here will be more than this pressure here in which case this valve in open, and some of this vapour will be pushed up. So, this it will keep doing it, until it reaches its topmost position. So, from here to here, it is an open system very pushed it out. After it reaches the top, this pressure is equal to this pressure, this valve closes, this pressure is greater than the inlet pressure, this valve closes, now you have a closed system valve.

And then what happens, the piston now begins to move that which was what I do first here. But, in moving from this position as it comes down to say some position over there; it is the closed system in which the pressure inside is decreasing, and it will decrease up to a point, when equal to this pressure. After that when the pressure here is less than this pressure, then come there till the bottom part this much, it will suck in the fresh refrigerator.

So, then the push this travel, when it takes in air and this part, when it pushes it out. So, even though the total displacement is from top to bottom is this much, the actual amount of vapour that is taken in is less than this total volume, because there was some dead volume here already which is always going to be there. And only a certain volume is what going to out.

This is try to draw it on the pressure volume diagram here is what we will get; or you can put PV also capital. So, at the when the piston moves from top dead centre to the bottom dead centre these are the two states, here the pressure begins to decrease, and then it reaches the point, and then it goes in. So, this is when it takes in fresh gas, then from here it begins to compress, it reaches the top pressure and then from here this is the discharge, and this is Intake.

So, this much of the total volume that we had, which was this much only that much volume that was actually taken in; this ratio to this ratio is an important indicator of how this thing works. And that is how much work discharged there, so that is the type of thing it happens. These two processes are shown dotted simply, because they are both these are this is the expansion process, this is the compression process. So, both we will assume to be isentropic in the ideal case.

If it is not isentropic, then because it is a vapour, we can say that p V to the power n is equal to constant that n could be different from J. So, you have this isentropic expansion, isentropic compression followed by a constant pressure discharge and constant pressure intake, so that is actually what happens in all these reciprocating compressors. In the case of liquids, this compression is not too much. The moment it reaches here and it starts to compress, the pressure inside becomes higher, this work will open it start, pushing it down.

So, a liquid this much will get pushed out, in a vapour less will get pushed out, so that is the weight difference between these two devices in vapour and the gas path liquid path. You do not see too many liquid type of compressors with reciprocating thing, but when you want extremely high pressures say 200 Bar, 400 Bar, 1000 Bar, then either it is this type of a device or what is called a green compressor. I would go into the details of this, but you can look up on the web and see the devices.

All gear pumps, they deliver very very high pressures. There would be need such high pressures, it hydraulic control systems for example. In an aeroplane, where the wings and the flux are to be adjusted, factor is done by giving (Refer Time: 19:44), cylinder piston arrangement with a high pressure oil unit that oil pressure is flow air pressure was regulated by electronic controller. There which get signals from its name would like computers, so that is one example of that.

Now the example, where you have liquid going in and out, what you may see all your bulldozers and excavators, where the bucket goes in, scoopes it out in fact, that long cylindrical thing, it basically cylinder piston arrangement in which you are putting not gas, but compressed oil into it, and duct does all the work for us. So, these are all analysis would be done from this type of a system ok, so that is the first device that we have looked at, and that is we have positive displacement device or if you what about the other ones gears is basically like two gears in mesh, and what you have done is created a space.

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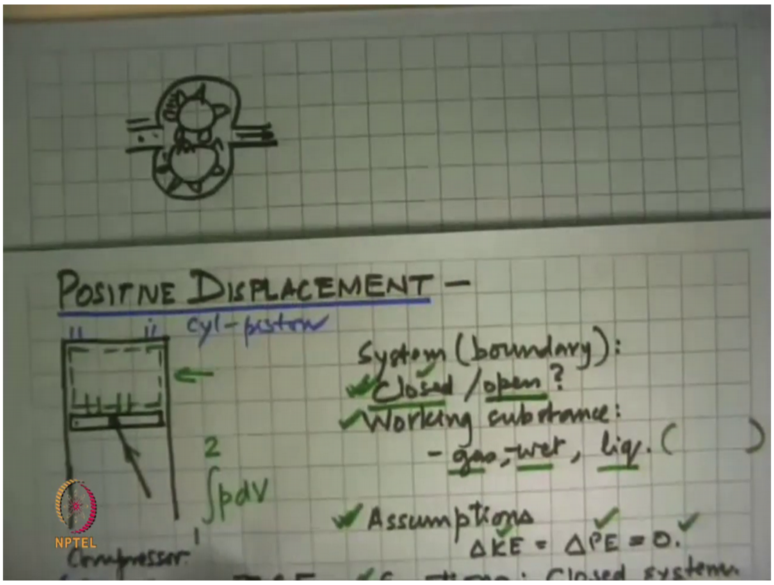


So, there; this is the gear, and this is in mesh with another gear and the space around this is very tightly controlled, there are very small clearance between them. One of this is connected to the inlet, this is connected to the discharge. And what it does is its track this fluid which was trapped here, it will be carried forward and physically pushed into this thing, so that is how you can have two gears in mesh doing the job of a compressor or a job of a pump.

This is the; this is the two type two of external gears here, one could be one an external gear, the other could be internal gear. In the most common example of this is the lubricating oil pump in every internal combustion engine, you would not see any diesel engine or petrol engine anywhere, if you just does not have at least one of this or lubricating oil, and possibly a second one for in the case definitely for diesel engine for the feeding of diesel fuel up to the engine. So, typically engine will have two gear pump to the positive displacement device.

Screw compressors, I will mentioned are too screw in mesh. So, the flow happens normal to the plane of the vapour, very difficult for me to show it here. But, we can see some pictures of screw later on and see, how two screws in mesh can be made to behave like a compressor. And these days; the reason for bringing up this discussion is that if you look at the large compressors for central air conditioning devices or think, where you will be very high pressure, then in a very compact way. One is going for screw compressors very largely, and in some cases you and your domestic refrigerators or air conditioners without a scroll compressor. The reason for doing this is that what I mentioned just about how this device works.

In fact out of this much displacement volume you are only taking in this much fresh substance; compressing it and throwing it out. The volumetric efficiency of these devices very low, they are bulky and screw compressors, gear pumps or scroll compressors, they do this in much more higher efficiency, so that is the reason why they are used, and they are becoming; they have already become much more popular than your reciprocating compressors. So, that is the reason for bringing it up in this discussion that one must know that yes., you want to buy a fridge or an air conditioner, we will say that we have a scroll, the scroll compressor in this air conditioner will be more efficient than or reciprocating compressor. The geometry is bit complicated, I suggest you only way to understand the geometry I will made this a cartoon out here, but it is actually have to look at engineering drawing of these devices to understand, what are the very fine points by which these devices are made.