Engineering Thermodynamics
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Lecture - 18
Laws of Thermodynamics:
Thermodynamic relations.
Bernoulli's equation

So that is an example of textile. So, now let us go on and do a few things, the first thing we will do is look at some Thermodynamic relations.

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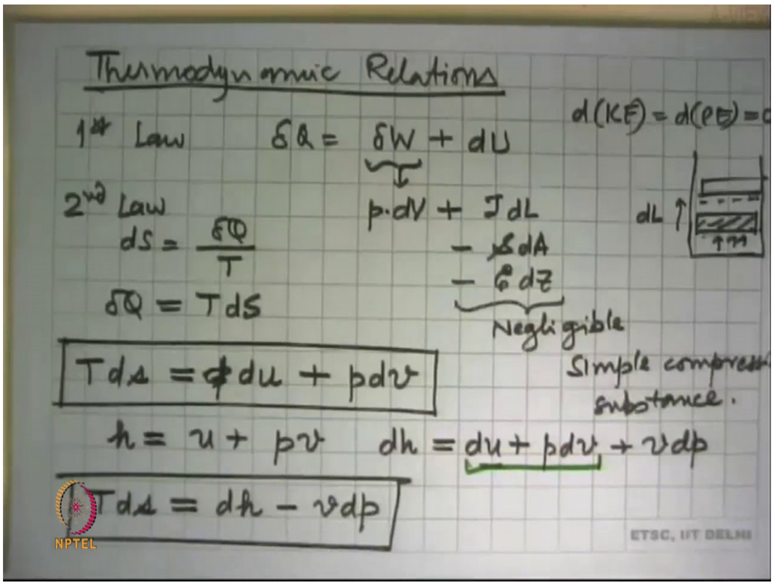

And we start with something that we already have the first law that delta Q is equal to delta W plus dU, we are assuming that delta K E and P E are negligible. Now, let us look at what delta W actually comprise of. And this includes work done at the system boundary that, if there was a cylinder piston arrangement, there were a piston over there, and the system pushes this.

So, system boundary moves up over there, and thus adjust into the piston, then that little movement it did if pressure during the time was infinitely during a small change, then this was p multiplied by the volume change and the weight comes about it that distance that it going through as d L, area is A, and force is p into to A. So, p A d L is the work done, A d L is the volume change. So, this is one type work.

But this could be any other types of work also that include by stretching. So, there the tensile strength multiplied by the length stretching of a rubber band or something or a surface tension work that the surface tension into the increase in area or you could have electric charge going through of electric field, all of that get kind of. And for this particular round, we said that look of these things are all negligible, then we have a substance here which is a simple compressively substance till. And now we say what did the second law tell us we say that for a reversible process dS is del Q by T or del Q is equal to T dS.

So, now be combined these two put delta Q from here into this as p dV, and we will write in terms of specific properties because now we got only properties in this equation remaining. So, we get T ds is equal to du plus p dv. This is one relation we will use. And say it involves only properties there is no restriction on where it is used where it is not use. The second properties we will get it by the definition of enthalpy, the specific enthalpy is specific internal energy plus p v. And if it is open it up in elementary form dh is equal to du plus p dv plus v dp.

And we say that if you look at here this is du plus p dv and this equation also we got here du plus p dv. So, we can substitute that and we get the next equation we are looking for that T ds is equal to this term goes to the other side and this becomes dh minus v dp. So, this is the second of the equations that are of interest to us ok. So, we will just keep that in mind that later on also when we come next module and we will look at the properties, we will start exploiting all of them.

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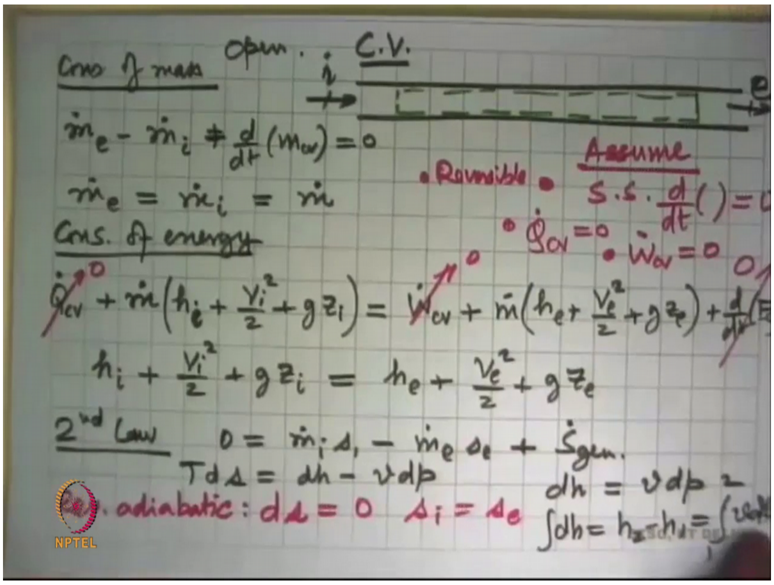

Let us now look at one special case and see how we can start applying what we have learned and the simplest case we will take is that there is say a flow. And in this we make a system we will say that this is the system that we have. There is one inflow; there is one out flow. So, this we will call as 1 and this is 2. And we say this is the simplest system, and I want to analyze this. And this is conservation of mass for this system, there is one inflow, there is one outflow. So, this becomes or else I will just keep it as i and e, m dot e minus m dot i plus d dt m cv is equal to 0.

Now, the first thing before we can even do this, it will tell us what type of system is this, this is an open system, what type of a treatment shall we apply to this to control volume treatment. And so this equation came if it one a control mass this equation would not have been there. Now, we start making series of assumptions, and say my first we would say assume and this is very purely our own judgment, we can assume something, we need not assume something one study state which means that d dt of everything whatever is 0.

So, if ones we do that, this equation simplifies and we get m dot e is equal to m dot i, and this we can say in generically just m dot. So, this is what we got from a conservation of mass. And remember every system has to obey conservation of mass, conservation of energy and the second law. So now, we got to the second one conservation of energy which is the first law equation and for a control volume. And here we will get that long equation. So, let us put that down together Q dot cv plus there is only one inflow, so this becomes m dot from this equation into h e h i plus V i square upon 2 plus g z i this is equal to W dot cv plus m dot into h e plus V e square by 2 plus g z e plus rate of change of energy in the control volume.

So, coming from the more general equation of that we derived that summation sign will gone, because there will be one inflow and one outflow. And we instead m dot e and m dot i, since there is only one inflow one out flow this m dot is comes over here. And since we assume steady state, what it means is that this term is 0. And now we say that the fluid is just flowing there, and if there is no this is the next assumption we make Q dot c v is equal to 0, that means, there is no heat transfer of the surroundings. It is not being heated; it is not being cooled, it is just flowing. If Q dot c v is 0 and W dot c v is also 0, that means, we are not doing to any work on it there is no pump or any or any something else going on into.

So, we assume these two are also 0, then this term goes off, this term goes off and we are left with the simple term. Now, then m dot will also cancel out on both sides, and what we are left with h i plus V i square upon 2 plus g z i is equal to h e plus V e square upon 2 plus g z e, so that is the simplest thing that the conservation energy told us in which we also we invoke conservation of mass. Now, we go into the second law, and since ever this is an open system, so what do I get. And it tells us that for the open system that equation that I have just written there, this will come in.

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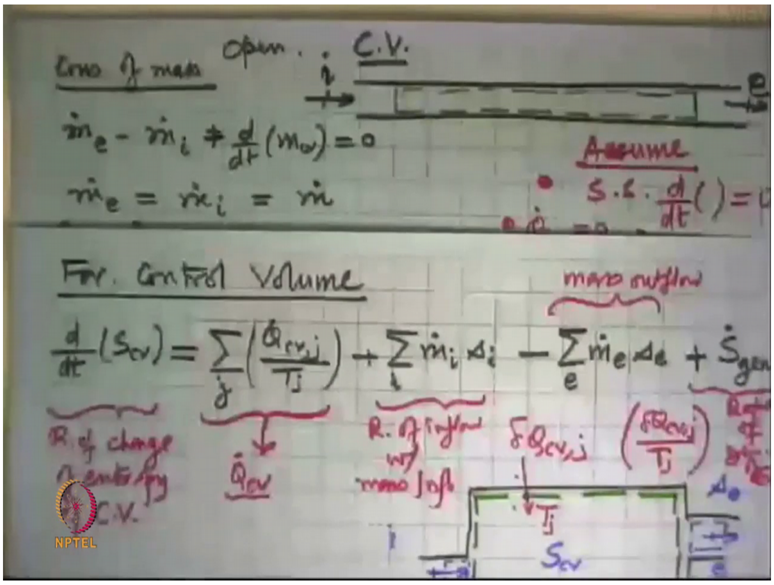

This long equation comes in where, now this is 0 - steady state, no heat transfer this is 0, and we are left with these two terms. So, which is m dot s i minus m dot s e is equal to S dot generation. So, we have 0 is equal to m i s i minus m dot e s e plus S dot generation. Now, we do not know: what is s dot generation, so it does not help us too much and this is where we will express one of the equations we just wrote two minutes back.

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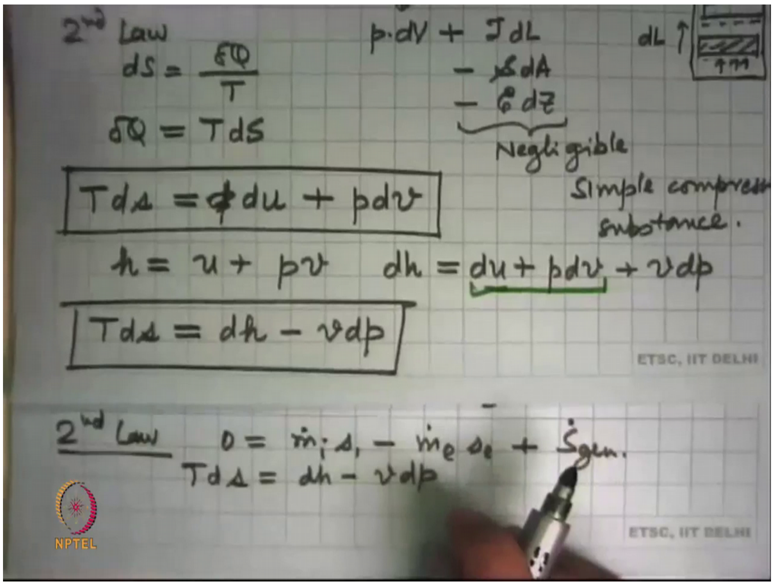

And it is that T d s is equal to d h minus v d p. So, we will write that one and that can I simplify further and say we have looked we have already assumed that Q dot c v is 0.

Now, let us also assume that this system is internally reversible, it is reversible, it does not exchange heat. So, this process is reversible adiabatic. And we had seen yesterday that is if that is the case then d s is 0, basically it says that s i is equal to s e.

So, with that assumption we are now left with 0 equal to d h minus v d p or d h is equal to v d p. And now let us integrate this and say if I have to do integration on this one d h will be h 2 minus h 1, but this will be integral v d p 1 to 2. So, if we know the relationship between v and p, we can solve it.

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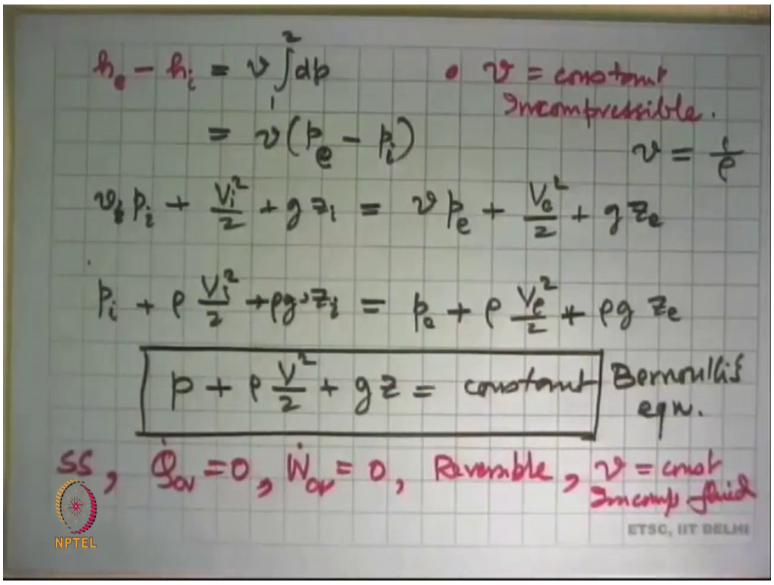

But we will make another assumption to make life easy. And say that v is constant that means the fluid is incompressible that being the case with this integration then helps us and it becomes h 2 which we will put h e minus h i this is equal to v integral 1 to 2 d p which is v p 2 minus p 1. And we can now sorry p 2 is p e p 1 is p i. And now we put this back into this equation, and what you get is v i v times p i plus V i square by 2 plus g z i is equal to v p e plus V e square by 2 plus g z e.

And to make it look familiar, we will just write v we know this is 1 upon density by rho. So, this becomes p i plus rho V square by V i square by 2 plus rho g z i is equal to p e plus rho V e square upon 2 plus rho g z e, or by looking at it tells us that p plus rho v square upon 2 plus g z this is constant. And, that is the equation you probably came across in school which is your Bernoulli's equation.

This may come up in fluid mechanics where you derive it in a straight regiment way, but that is how the equation came. The thing is we made so many assumptions and listed out we said that this is in steady state, then we said Q dot c v is equal to 0, W dot c v is equal to 0, and then we said it is reversible, no irreversibility. And the last one we said v is constant incompressible fluid. Bernoulli's equation is applicable only when all of these are satisfied, any one of these is violated, we cannot apply Bernoulli's equation. So, what looks so simple and we have used this so many times has a very good number of restrictions before you are going to use it.

So, I just wanted to show this, how we can take a very simple system in which there no work transfer, no heat transfer, do an analysis applying all the three conservation equations and come up with the relation which can be used quite in general ok. So, before I proceed to the questions, the question is what is entropy of real gases, yes module 3, we will come to the point of how do you calculate entropy of real gases and all type of things ok. You know the question here: what is the difference between open system and closed system. So, I refer you back to the first module where we spend time on this.

But very quickly an open system is the one where there is mass inflow or outflow across the system boundary. A closed system is one where there could be energy inflow outflow, but no mass is flowed out. And the third question is: what is a Rankine cycle? I have not yet come to that we have only talked about the Carnot cycle. After looking at the properties of a substance, when we look into the last module at applications, we will look at Rankine cycle in going to be completed. So, it is basically a modification of the Carnot cycle using steam which is practicable, so that is very quickly that is what it is, but the thermodynamic details of it we will take it up in the last module.