Concepts of Thermodynamics
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Lecture – 31
First Law for Unsteady Problems – Examples (Contd.)

We have worked out a few problems on unsteady flow so far as first flow of thermodynamics is concerned and we will continue with the couple of more problems of that kind to give you a more comprehensive idea of problem solving.

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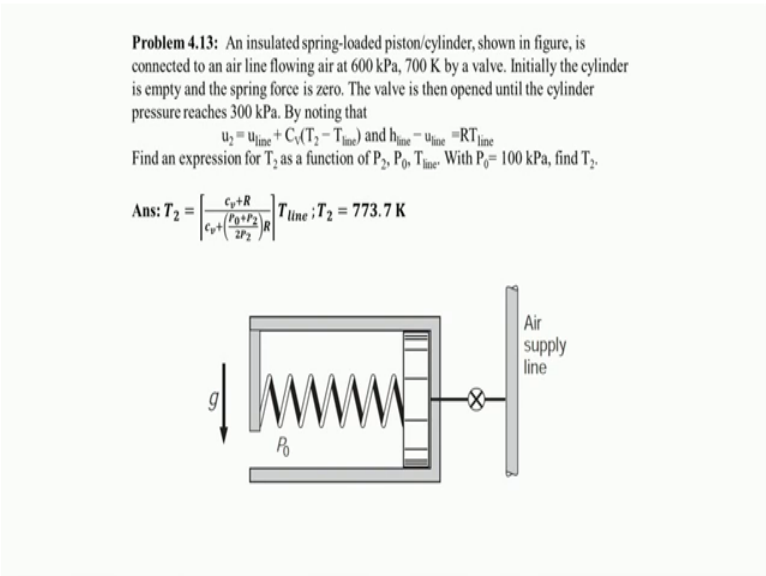

So, the next problem which is problem number 13 is something like this, an insulated spring loaded piston cylinder I have shown in the figure is connected to an air flow line flowing air at 600 kilo Pascal, 700 Kelvin by a valve. Initially the cylinder is empty and the spring force is 0. The valve is then opened until the cylinder pressures reaches 300 kilo Pascal.

Now, some relationship between is given between the internal energy inside the cylinder and internal energy of the line, find an expression for T 2 as a function of P 2 P naught and T line with P naught which is the atmospheric pressure 100 kilo Pascal, you find what is T 2?

So, this is also a tank filling problem, but you know this is not a rigid tank, this is a variable volume tank. So, this is more involved than the tank filling problem in a sense that because volume of the of the trapped air within the piston cylinder changes there is a worked on associated with it, which was not there for a rigid tank that makes this problem different from a traditional tank filling problem. So, as we have considered earlier.

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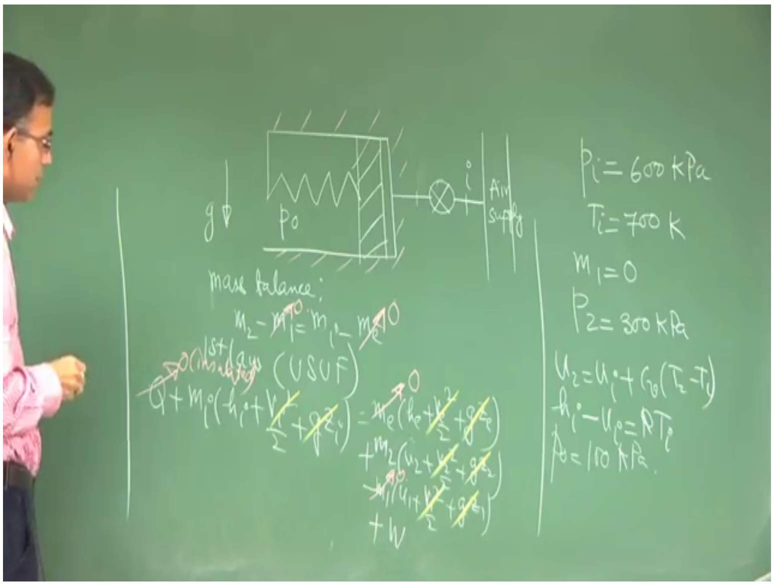

So, we will draw schematic, this is the piston and it is spring loaded. So, this is the gravity it shows that you know the weight of the piston is not important because it is the piston is not aligned in the cylinder is not aligned in the direction of gravity ok. So, let us see I mean what is given and what is not. So, this is I the property which is coming out coming in. So, I am writing I here you know not here; why? to be technically correct, see it is given that for the state i the air supply line, pressure is 600 kilo Pascal.

If we put i here there is a pressure drop so pressure is no more 600 kilo Pascal in terms of enthalpy does not matter because this is treated as an ideal gas where enthalpy does not depend on pressure, but depends on temperature. So, enthalpy here is same as enthalpy here and you know so temperature here roughly same as temperature here if it is an ideal gas. For enthalpy does not matter anyway whether it is ideal gas or not for temperature it matters, because if enthalpy here is same as enthalpy here, temperature here is same as temperature here provided it is an ideal gas you know otherwise not. So, then so this is air supply so, p i even if it is not required let us write, T i 700 Kelvin.

Initially the cylinder is empty so m 1 is 0. So, the control volume is the gap between the piston and the cylinder, the air within that. So, it is no more a control mass system despite being a piston cylinder arrangement. So, piston cylinder arrangement by default is not a control mass system, here it is not a control mass system because of continuous mass supply the mass within it is continuously changing with time. So, m 1 equal to 0 and p 2 is 300 kilo Pascal, what is also given as u 2 is equal to u i plus C v into T 2 minus T i and h i minus u i is equal to R T i, p naught is 100 kilo Pascal.

So, initially although the mass inside is 0, but there is a resistance pressure same as p naught to keep this in equilibrium. So, let us write the first law of or the control valve yes for the control volume first mass balance. So, m 2 so, m i you have some m i, there is no m e, there is no m 1. So, m 2 is equal to m i, then we will apply the first law for USUF Uniform State Uniform Flow ok.

Let us see what is the situation for heat transfer, it is told that this is insulated piston cylinder. So, I want to schematically represent that we may show a insulation here. So, this is 0 because it is insulated, then there is no m 2 term 0, there is no m e term, this is 0 there is no m 1 sorry very sorry, there is no m 1 right initial is 0 right plus m 2 is very much there, there is no m 1 ok. So, then your usual neglecting changes in kinetic energy and potential energy will work for this problem as well.

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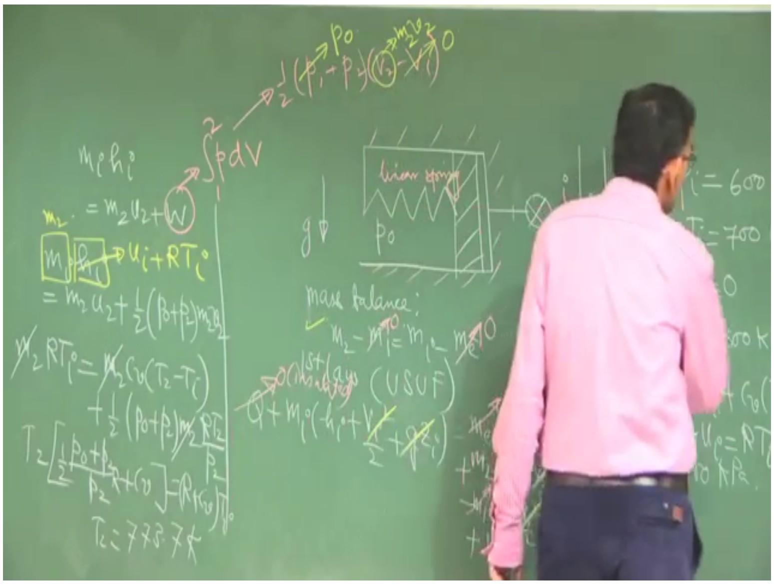

So, you are left with m i h i is equal to m 2 u 2 plus W right, now a key question what expression we will substitute for W, can we write W as integral pdV from state 1 to state 2? Yes we can write. Some students develop a false idea that integral pdV is valid only for a control mass system, the reason is that it is derived first by taking an example of a control mass system, but it is just work done for a moving system boundary for a simple compressible pure substance undergoing a quasi equilibrium process.

Whether the system is a closed system or open system that is not under the jurisdiction of these, this is this simply follows from the resistance force times the displacement integrated ok. So, that essentially means that you can use here pdV and because it is a linear spring these for a pressure volume diagram will be linear. So, the area under the P V diagram is area under a trapezium. So, this is eventually half into p 1 plus p 2 into v 2 minus v 1 right.

So, now p 1 is same as p 0 and v 2 you do not know, v 1 is 0 and in place of v 2 you can write mass into specific m 2 into specific volume at state 2. So, let us see how we can write this m i into h i is equal to m 2 u 2 plus half into p 0 plus p 2 into m 2 v 2 then it is just algebra I mean your problem solving is complete here. So, then what is given here you just try to write in place of h i you write u i plus R T i right. So, in place of h i u i plus R T i and m i will be same as m 2.

So, you have m 2 into RT i is equal to now m 2 into u 2 minus u i, u 2 minus u i is C v into T 2 minus T i. So, m 2 C v into T 2 minus T i plus half p 0 plus p 2 m 2 and v 2 is R T 2 by p 2 right, m 2 gets cancelled from all the terms. So, that gives you an expression for T 2 in terms of T i right that is what is asked. So, you can write T 2 into p 0 plus p 2 by p 2 into half plus C v is equal to R plus C v into T i right

There is an R here right, P naught plus these into R ok. So, then you can I mean. So, this is the expression where you can substitute all the relevant values and you can get what is T 2 as a function of T i. So, the answer to this problem is T 2 is 773.7 Kelvin. So, we will work out one last problem related to this before we move on to a different chapter Problem number 14.

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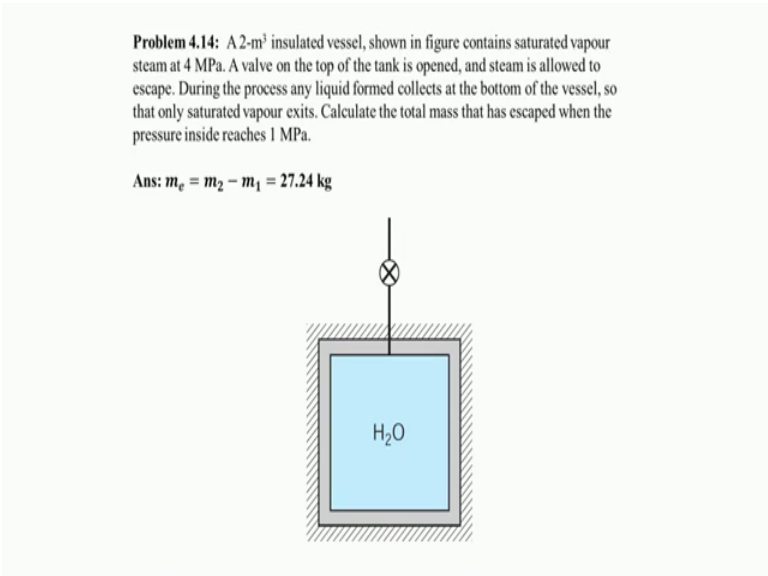

A 2 meter cube insulated vessel shown in a figure contains saturated vapour steam at 4 MPa ok. A valve on the top of the tank is opened, and steam is allowed to escape this is a tank empting problem, but not for ideal gas. During the process any liquid formed collects at the bottom, so that only saturated vapour exits. So, this sentence tells that the exit state is saturated vapour state, calculate the total mass that has escaped when the pressure inside reached 1 MPa.

So, initially pressure was 4 MPa, the pressure is released as the valve is opened and eventually the final pressure is 1 MPa. So, you have to find out what is the total mass that has escaped. So, we will work out this problem as per our practice we will draw the schematic in the board.

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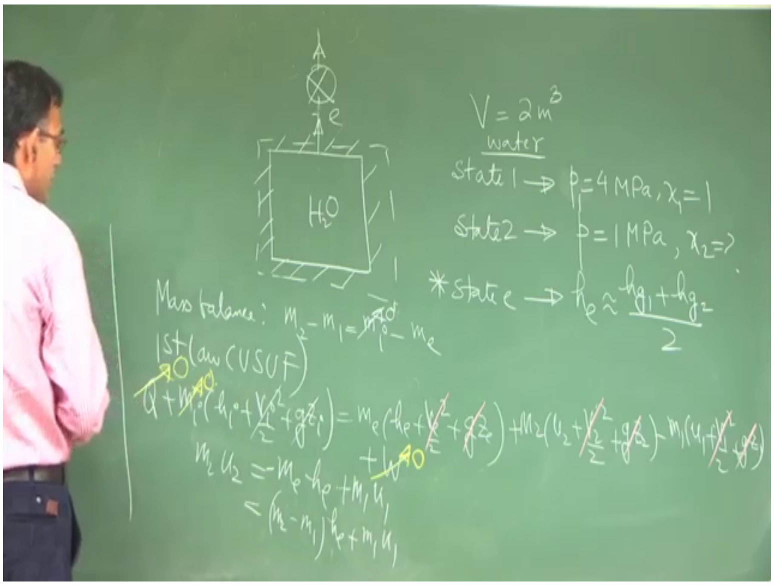

So, this is a rigid vessel let us write what is given V is equal to 2 meter cube state 1. So, fluid is water state 1, x equal p equal to 4 MPa, x equal to 1 state 2 p equal to 1 MPa then in state 2 you have a. So, see the physical situation you have to assess initially there is vapour now vapour is exiting. So, then the energy state of the system is going down and that is reflected in terms of that vapour now getting converted to a 2 phase mixture liquid vapour mixture. So, state 2 will be associated with some quality value. So, x 2 is there, but you do not know what it is.

So, there is a state e here again you have to make an assumption. So, initially it 4 MPa finally, it is 1 MPa so, line pressure here also cannot remain always you know fixed. So, the line pressure exit line pressure will be something which will be varying between 1 MPa to sorry 4 MPa to 1 MPa, but always these what is living is saturated vapour. So, we can argue that for all practical purposes h e is roughly hg 1 plus hg 2 by 2 average of hg between state 1 and state 2 this is a very important assumption. So, I am putting an asterisk here, you do not make this assumption you cannot proceed further because you have no information on state e you need to have an information on state e.

So, then with this information let us write the mass balance and energy balance, this is your control volume. So, what is m e it is something which is their m 1 and m 2 there,

there is no m i right, first law USUF. So, heat transfer is 0 because it is insulated work done is 0 because this is rigid tank, there is no m i. So, this term is 0 neglect changes in kinetic energy and potential energy if you do all that of course, here also although it is not really went, but still. So, you have m 2 into u 2 is equal to m e h e sorry minus m e h e plus m 1 u 1 right and minus m e is m 2 minus m 1 right.

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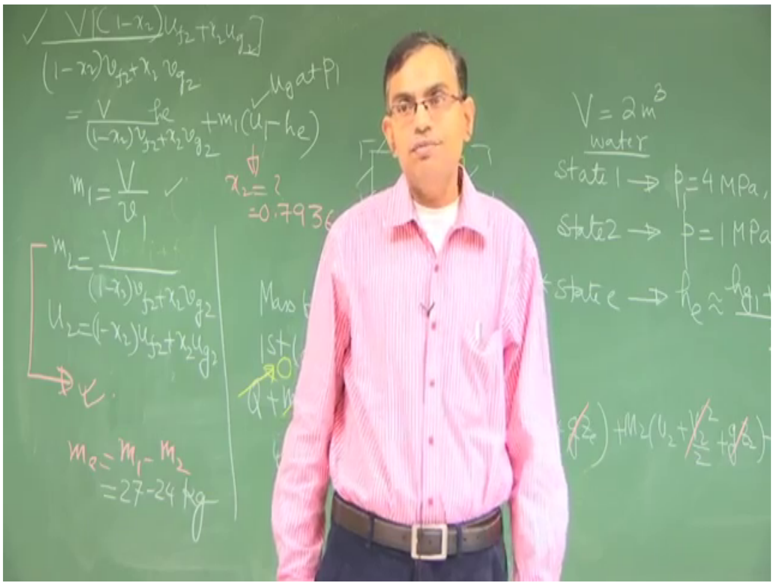

So, u 2 we require to find out what is state 2 so, u 2 is ok. So, let us write now, we know what is m 1 and what is we do know we know what is m 1, but we do not know what is m 2 right. So, m 1 is what? So whatever we know let us write V by v 1. So, we know m 2 we do not know what is it what we know this is definitely 1 minus x 2 into v f 2 plus x 2 into v g 2. It depends on what is x 2 that what will be the value of m 2 V is fixed u 2 is 1 minus x 2 into u f 2 plus x 2 into u g 2 ok.

So, these equation let us write, m 2 is V by 1 minus x 2 into v f 2 plus x 2 v g 2 into u 2 1 minus x 2 into u f 2 plus x 2 u g 2. So, this is the left hand side is equal to m 2 into h e; m 2 into h e is again V by 1 minus x 2 v f 2 plus x 2 v g 2 into h e plus m 1 into u 1 minus h e u 1 you know from table state 1 u 1 is u g at P 1 because quality is 1 and h e is this approximation.

So, this is an equation this equation where you have everything known except x 2. So, from here you can solve for x 2 what is x 2. So, if you solve for x 2, x 2 will be 0.7936 ok. So, if you solve for x 2 then you will immediately find out what is m 2 because m 2 is a function of x 2. So, then what is m e is nothing, but m 1 minus m 2 ok. So, m e is equal to m 1 minus m 2 this is 27.24 k g ok. So, again this is quite an involved problem where by using the energy balance you are calculating the quality of a state right, it involves both mass and properties.

So, to summarize we have discussed so far the basic concepts of heat and work and also the first law of thermodynamics considering energy transfer of through heat and work for control mass system and control volume undergoing steady state process as well as unsteady state process. So, that brings us to a junction where we have got a basic feel of how to apply energy balance in the per view of the first law, but all processes which satisfy the energy balance may not actually occur in practice. So, what inhibits those so called unrealistic or impractical processes to occur despite satisfying energy balance, we will consider or take that up in our next lectures.

Thank you.