Engineering Thermodynamics
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Lecture 17
Energy analysis of closed system, unrestrained expansion

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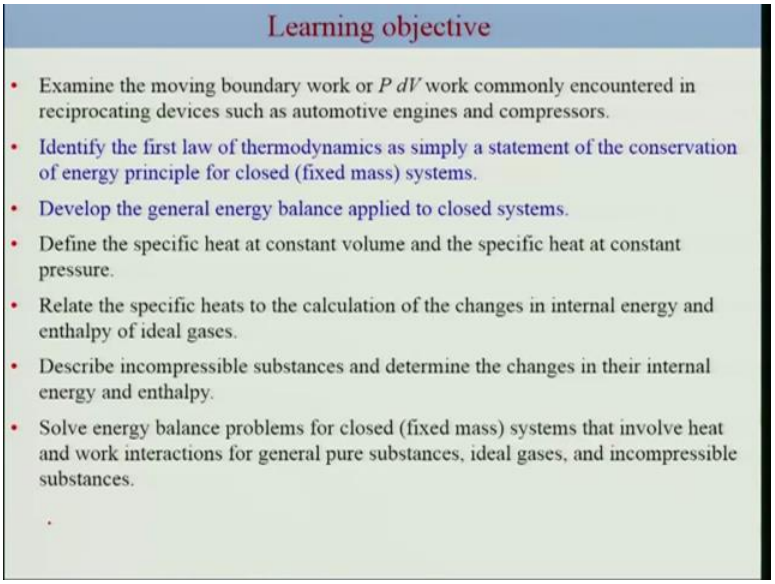

Learning objective

- Examine the moving boundary work or $P\,dV$ work commonly encountered in reciprocating devices such as automotive engines and compressors.
- Identify the first law of thermodynamics as simply a statement of the conservation of energy principle for closed (fixed mass) systems.
- Develop the general energy balance applied to closed systems.
- Define the specific heat at constant volume and the specific heat at constant pressure.
- Relate the specific heats to the calculation of the changes in internal energy and enthalpy of ideal gases.
- Describe incompressible substances and determine the changes in their internal energy and enthalpy.
- Solve energy balance problems for closed (fixed mass) systems that involve heat and work interactions for general pure substances, ideal gases, and incompressible substances.

Okay, welcome back we were discussing energy analysis of a closed systems. In this particular lecture we would like to understand the first law of thermodynamics for closed system that is fixed mass systems and we will develop the general energy balance applied to closed systems. Further we are going to take certain examples in order to apply the first law of thermodynamics for such a system.

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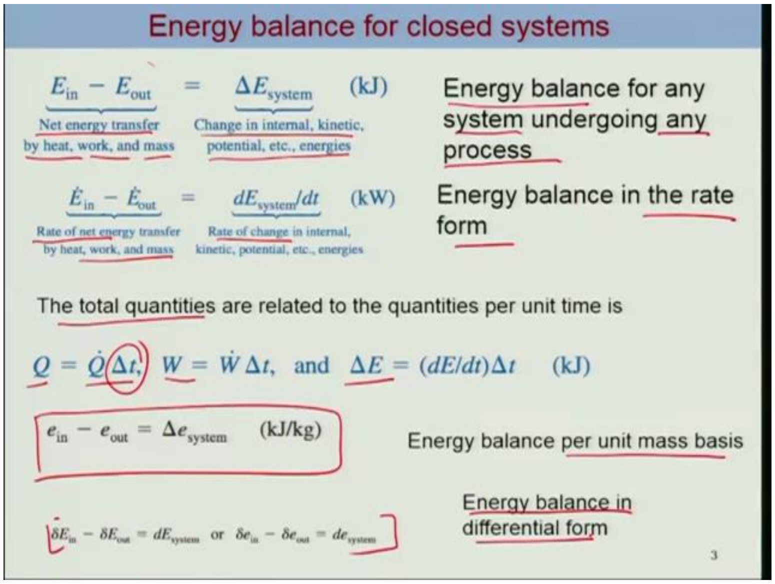

Energy balance for closed systems

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\substack{\text{Net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,} \\ \text{potential, etc., energies}}} \quad (\text{kJ})$$

Energy balance for any system undergoing any process

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{\text{system}}/dt}_{\substack{\text{Rate of change in internal,} \\ \text{kinetic, potential, etc., energies}}} \quad (\text{kW})$$

Energy balance in the rate form

The total quantities are related to the quantities per unit time is

$$Q = \dot{Q}\Delta t, \quad W = \dot{W}\Delta t, \quad \text{and} \quad \Delta E = (dE/dt)\Delta t \quad (\text{kJ})$$

$$e_{\text{in}} - e_{\text{out}} = \Delta e_{\text{system}} \quad (\text{kJ/kg})$$

Energy balance per unit mass basis

$$\delta E_{\text{in}} - \delta E_{\text{out}} = dE_{\text{system}} \quad \text{or} \quad \delta e_{\text{in}} - \delta e_{\text{out}} = de_{\text{system}}$$

Energy balance in differential form

So, let us try to revise what we have learned or as per as the energy balance is concerned. So, this is a generalized form of energy balance where the net energy transfer by heat, work and mass to the system should this equal to the change in the internal energy, kinetic, potential and another forms of energy. So, this is a energy balance for any system undergoing any process, okay. So, this is a generalized form of energy balance. You can write this expression in terms of rate form. So, here is the rate of that energy transfer by heat by work and mass should be the equal to the rate of change in the internal energy, kinetic energy other energies of the particular systems.

Now, you can if it is rate is given to you can calculate the total quantities in terms of for given change in time. So, here for example, the Q is nothing but Q dot which is rate of heat transfer multiplied by delta t that would be your interest in specific time a range. And similarly, you can obtain W the work done and as well as the total energy change of a system. So, this is specifically for the energy balance per unit mass basis and you can one can also write , in a differential form for this . So, this is energy balance in differential form.

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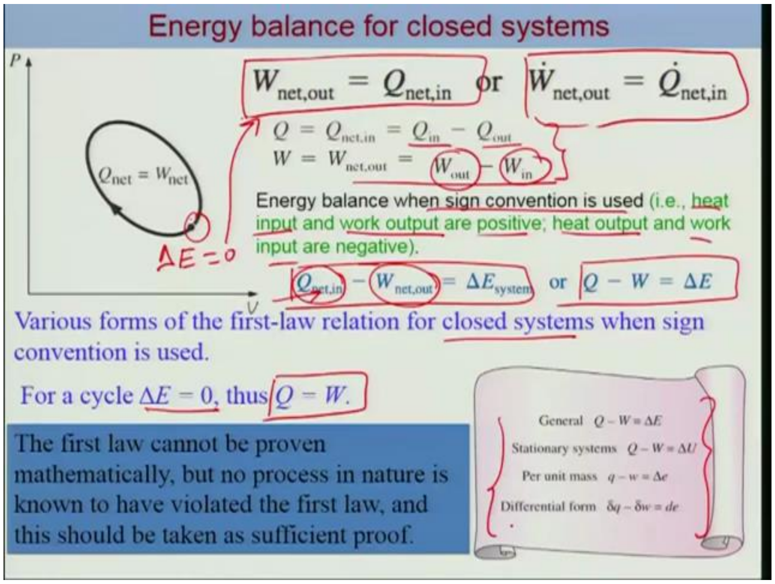

Energy balance for closed systems

$W_{net,out} = Q_{net,in}$ or $\dot{W}_{net,out} = \dot{Q}_{net,in}$

$Q = Q_{net,in} = Q_{in} - Q_{out}$

$W = W_{net,out} = W_{out} - W_{in}$

Energy balance when sign convention is used (i.e., heat input and work output are positive; heat output and work input are negative).

$Q_{net,in} - W_{net,out} = \Delta E_{system}$ or $Q - W = \Delta E$

Various forms of the first-law relation for closed systems when sign convention is used.

For a cycle $\Delta E = 0$, thus $Q = W$.

The first law cannot be proven mathematically, but no process in nature is known to have violated the first law, and this should be taken as sufficient proof.

General $Q - W = \Delta E$

Stationary systems $Q - W = \Delta U$

Per unit mass $q - w = \Delta e$

Differential form $\delta q - \delta w = de$

So, this we have already gone through in our earlier lectures. So, we are trying to revises in order to address some of the problems which we have going to undertake in this particular lecture. So, beware of the fact that , Wnet will be equal to Qnet for a cyclic process. So, this is a cyclic process . So, it returns back that here so, there is hence in this case the delta E should be zero and thus, you the Wnet out is same as Qnet in. So, you write in this form where Wnet out is nothing but the system work which is does on the surrounding minus the surrounding work which is does on the system and similarly, Qin minus Qout here. So, this basically by putting the in and out as a substrate we already have defined the sign of this Qin, heat and as well as the work.

Now, typical energy balance when sign conventions are to be used is basically heat an input and work output are going to be positive or heat output and work input are going to be negative. So, that to be our sign convention we are going to use it, if the direction of heat and work are not available for your given problem. So, that means we are assuming in this case the Qnet,in is heat supply to the system and work done by the system. So, the Q minus W is nothing but delta E or this can be a generalized expression for your first law for the closed system.

So, for cyclic as I said, delta E should be zero and thus you let heat in should be same as that work out. Now, from the prospective in first law of the heat and work are not distinguishable. So, it is difficult to distinguish in terms of because these are both related to the energy transfer dynamical form. But this become more relevant when we discuss the second law and then we will realize the importance (())(3:48) different type of dynamical transfer of energy in the form of heat and work.

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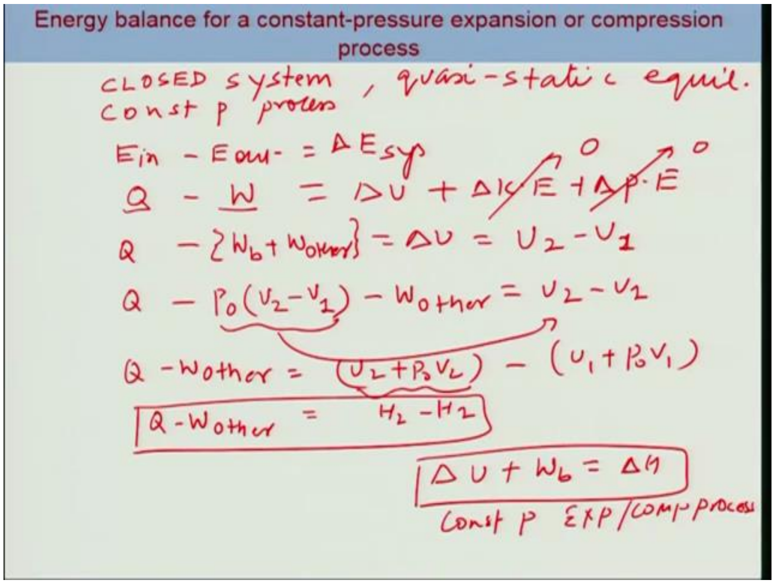

Energy balance for a constant-pressure expansion or compression process

CLOSED system, quasi-static equil.
const P process

$$E_{in} - E_{out} = \Delta E_{sys}$$

$$\underline{Q} - \underline{W} = \Delta U + \overset{0}{\cancel{\Delta K.E}} + \overset{0}{\cancel{\Delta P.E}}$$

$$Q - \{W_b + W_{other}\} = \Delta U = U_2 - U_1$$

$$Q - \underbrace{P_0(V_2 - V_1)} - W_{other} = U_2 - U_2$$

$$Q - W_{other} = \underbrace{(U_2 + P_0V_2)} - (U_1 + P_0V_1)$$

$$\boxed{Q - W_{other} = H_2 - H_2}$$

$$\boxed{\Delta U + W_b = \Delta H}$$

Const P EXP/COMP process

General energy balance system summarize a list here okay, just for quick reference. So, let us consider now, as example for a constant-pressure expansion and compression process, okay. So, what we have is a closed system, okay we are going to consider quasi-static equilibrium, we are where going to consider a constant pressure process. Okay, we can start with our generalized energy balance of first law of thermodynamics, Ein minus Eout is delta Esystem or in other word we can say if (())(4:45) energy transfer is in the form of heat and work then you have changes are given in this form of Q and W and this we can write as delta U plus Delta KE plus delta P.

Considering no change in kinetic energy and potential energy of system, these two terms are going to be zero, okay. What about work? So, Q is a net heat provided in Qin W we can write as sum of all possible work done by the system. So, this could be the boundary work plus other set of work, okay could be electrical work also and then you have this Q, okay. Now, which is nothing but U2 minus U1 okay.

Now, for a constant pressure boundary work we know, we have done this exercise earlier is nothing but P zero which is a constant multiplied with the change in volume V2 minus V1 and then you have this other work. You can take this term and bring it here and we can rewrite this expression as U2 plus P0V2 minus U1 plus P0V1.

And we know this from our earlier exercise that this term the internal energy plus PV term, we have identified or rather represented this term as enthalpy. So, this is going to be H2 minus H1. So, this is the energy balance expression for the case of constant pressure expansion or compression on the system and in this case , your delta U plus boundary work is going to be change in enthalpy of the systems. So, this is only true for constant pressure expansion or compression, okay process.

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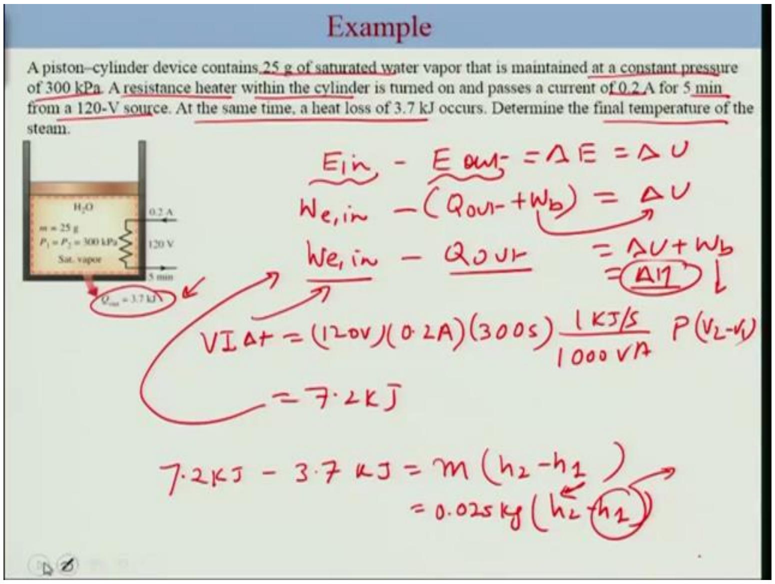

Example

A piston–cylinder device contains 25 g of saturated water vapor that is maintained at a constant pressure of 300 kPa. A resistance heater within the cylinder is turned on and passes a current of 0.2 A for 5 min from a 120-V source. At the same time, a heat loss of 3.7 kJ occurs. Determine the final temperature of the steam.

$$E_{in} - E_{out} = \Delta E = \Delta U$$

$$W_{e,in} - (Q_{out} + W_b) = \Delta U$$

$$W_{e,in} - Q_{out} = \Delta U + W_b = \boxed{\Delta H}$$

$$VI\Delta t = (120 V)(0.2 A)(300 s)\frac{1 kJ/s}{1000 VA} \quad P(V_2 - V_1)$$

$$= 7.2 kJ$$

$$7.2 kJ - 3.7 kJ = m(h_2 - h_1)$$

$$= 0.025 kg(h_2 - h_1)$$

So, now let us a make use of this analysis of an unsolved certain set of problems. Okay. So, we have a piston-cylinder device which contains the 25 gram of saturated water and it is maintained at a constant pressure of 300 kilo Pascal. A resistance heater within the cylinder is turned on which pass 0.2 ampere for 5 minutes from a 120 volt source, okay. So, there is a electrical work which is done on the system. At the same time, there is a heat loss of 3.7 kilo joules. So, we have to find the final temperature of the system.

So, we will start with the first law. So, we can write as Ein minus Eout is delta E or you can write is delta U because there is no change in kinetic energy or potential energy. So, what would be Ein and Eout? So, the energy being provided to the system is Welectrical,in and what is Eout?

Eout is your, the heat which is out from the system, okay which is this Plus any boundary work done by the system on the surrounding. Thus, we can write this expression.

Now, we can take this here and we already discussed about this constant pressure energy balance where you can write okay, that Wb plus delta U as delta H. So, this is nothing but We,in minus Qout equal to delta H and what is Wb here is Wb (())(8:47) some this pressure of 300 kilo Pascal multiplied by the change in volume.

So, we have these expression now, we need to find out the We,in which is nothing but the voltage is already given to you. The voltage multiplied by the current multiply be the delta t and this is going to be 120 volt 0.2 ampere 300 seconds and then you can use the conversion of 1 kilojoules per second is 1000 volt ampere, okay and they should be 7.2 kilojoules.

So, you can plug in here and the final expression would be 7.2 kilojoules minus 3.7 kilojoules. What is delta H? We have to use some tables. So, we would make use of for appendix tables there the values are given in terms of specific enthalpies. So, this is we write delta H as m times h2 minus h1where m is nothing but 0.025 kg times h2 minus h1. So, we need to find for here this expression we need to find h2, h1 we can make use of tables because we have all the information.

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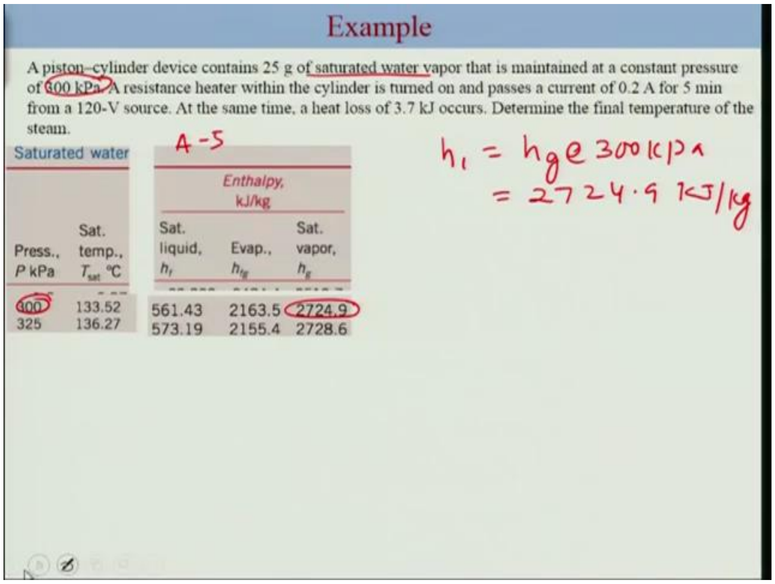

Example

A piston–cylinder device contains 25 g of saturated water vapor that is maintained at a constant pressure of 300 kPa. A resistance heater within the cylinder is turned on and passes a current of 0.2 A for 5 min from a 120-V source. At the same time, a heat loss of 3.7 kJ occurs. Determine the final temperature of the steam.

A -5

Saturated water

Press., P kPa	Sat. temp., T_{sat} °C	Enthalpy, kJ/kg Sat. liquid, h_f	Enthalpy, kJ/kg Evap., h_{fg}	Enthalpy, kJ/kg Sat. vapor, h_g
300	133.52	561.43	2163.5	2724.9
325	136.27	573.19	2155.4	2728.6

$h_1 = h_g @ 300 \text{ kPa}$

$= 2724.9 \text{ kJ/kg}$

Let us see how we do this exercise. So, what is h1? H1 is if you look at the states we given the saturated because this is the saturated water vapor at 300 kilopascal. So, h1 is going to be gas of saturated vapor at 300 kilopascal. So, let us look at the table, so table is given here. So, this table is going to be saturated water pressure table which is your A-5 okay. So, here is a 300 kilopascal, the corresponding hg is 2724.9. So, we are going to write this as 2724.9.

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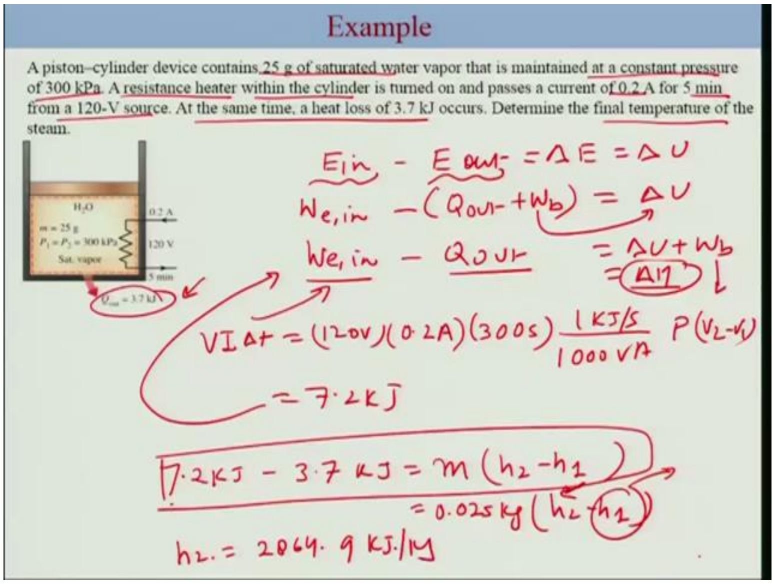

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$W_{e,in} - Q_{out} = \Delta U + W_b$

$= \boxed{\Delta H}$

$VI\Delta t = (120V)(0.2A)(300s)\frac{1\,kJ/s}{1000\,VA}$ $P(V_2 - V_1)$

$= 7.2\,kJ$

$\boxed{7.2\,kJ - 3.7\,kJ = m(h_2 - h_1)}$

$= 0.025\,kg\,(h_2 - h_1)$

$h_2 = 2864.9\,kJ/kg$

So, we plug in this value in the previous expression and from there we can, so from here we can get h2, okay by plugging in this value of h1, okay which is 2864.9 kilojoules per kg, okay.

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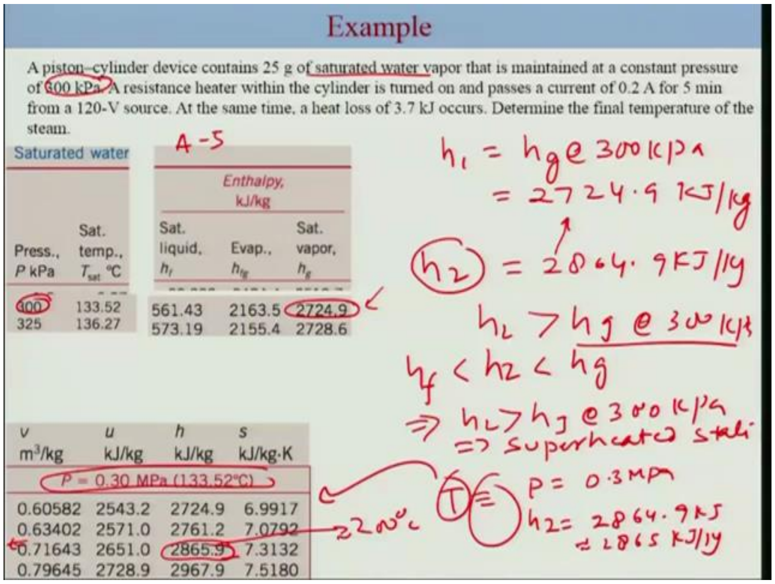

Example

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A -5

Saturated water

Press., P kPa	Sat. temp., T_{sat} °C	Enthalpy, kJ/kg: Sat. liquid, h_f	Enthalpy, kJ/kg: Evap., h_{fg}	Enthalpy, kJ/kg: Sat. vapor, h_g
300	133.52	561.43	2163.5	2724.9
325	136.27	573.19	2155.4	2728.6

v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
P = 0.30 MPa (133.52°C)			
0.60582	2543.2	2724.9	6.9917
0.63402	2571.0	2761.2	7.0792
0.71643	2651.0	2865.9	7.3132
0.79645	2728.9	2967.9	7.5180

$h_1 = h_g @ 300\ kPa$

$= 2724.9\ kJ/kg$

$h_2 = 2864.9\ kJ/kg$

$h_2 > h_g @ 300\ kPa$

$h_f < h_2 < h_g$

$\Rightarrow h_2 > h_g @ 300\ kPa$

$\Rightarrow$ superheated state

$T = ?$ $P = 0.3\ MPa$

$h_2 = 2864.9\ kJ$

$\simeq 2865\ kJ/kg$

$\simeq 200°C$

So, this is the value which we have now. Okay, from the expression 2864.9 kilojoules per kg. Now, the question is whether h2 lies within the saturated water system or is it in a super-heated way. So, in order to find ouit the state we compare h2 values with the hg values at 300 kilopascal because the pressure is given constant. So, the question is if this is this greater than hg or if this is less than hg and greater than hf.

So, let us look at 300 kilopascal again. So, we know this 300 kilopascal the value of hg was 2724 and our value is greater than 2724. So, thus it means h2 is greater than hg at 300 kilopascal. This indicates superheated state, okay. So, now the next thing is we have to take look at the table of superheated state. So, this is the your superheated state for the specific pressure 0.3 mega Pascal or 300 kilopascal and for that we will specifically, obtain this value 2864.9 which is almost close to this value and this corresponds to the temperature which is on the left side is corresponds around 200 degree Celsius.

So, that would be your temperature because this temperature corresponds to pressure 0.3 mega Pascal or 300 kilopascal and your h2 which is given to 2864.9 kilojoules or approximately 2865 kilojoules per kg. Temperature based on this table is close to 200 degree Celsius which corresponds to this particularly, okay. So, this is the way to solve a typical problem on based on the tables for the constant pressure system.

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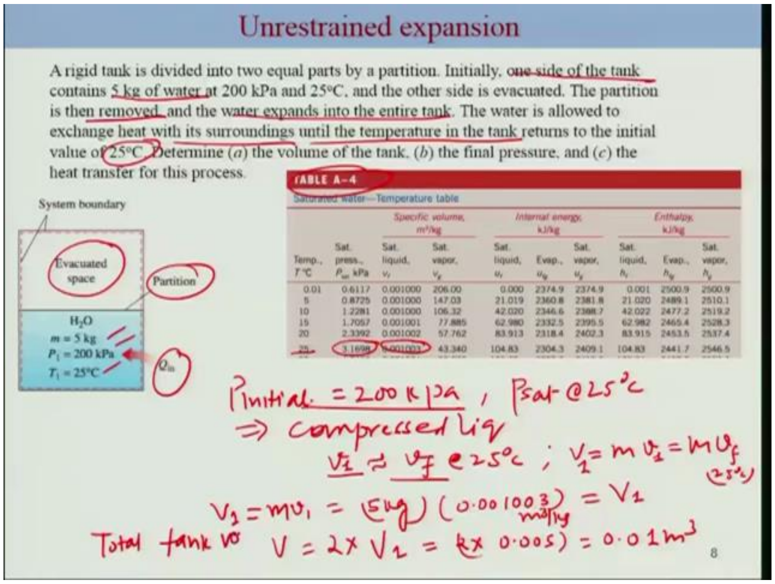

Unrestrained expansion

A rigid tank is divided into two equal parts by a partition. Initially, one side of the tank contains 5 kg of water at 200 kPa and 25°C, and the other side is evacuated. The partition is then removed, and the water expands into the entire tank. The water is allowed to exchange heat with its surroundings until the temperature in the tank returns to the initial value of 25°C. Determine (*a*) the volume of the tank, (*b*) the final pressure, and (*c*) the heat transfer for this process.

TABLE A-4

Saturated water—Temperature table

		Specific volume, m³/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5

$P_{initial} = 200$ kPa , P_{sat} @ 25°C

$\Rightarrow$ compressed liq

$v_1 \approx v_f$ @ 25°C ; $V_1 = m v_1 = m v_f$ (25°C)

$V_1 = m v_1 = (5 \text{ kg})(0.001003 \text{ m}^3/\text{kg}) = V_1$

Total tank vol $V = 2 \times V_1 = (2 \times 0.005) = 0.01 \text{ m}^3$

We can take another example and this is Unrestrained expansion. So, what we have here is a rigid tank which is divided into 2 equal parts by a partition which is here. Initially, one side of the tank contains 5 kg of water so the 5 kg of water is here, the pressure is 200 kilopascal, temperature is 25 degree Celsius and other region is evacuated which means the vacuum okay.

So, the partition is removed and the water expands in the entire tank. Water is allowed to exchange heat within its surrounding. So, there is the heat exchange, okay heat transfer until the temperature in the tank returns to the usual 25 degree Celsius. So, this is a final temperature, initial temperature is also given. So, what we need to find out the volume of the tank, final pressure and the heat transfer for this process.

So, let us first look at the volume. What is given to us is P initial, okay which is 200 kilopascal, okay and the first thing is to identify the initial state. Is it a saturated vapor liquid system or is it a compressed liquid or it is superheated vapor? So, let us first look at based on the knowledge of very initial pressure and as well as the table. So, P initial is given and the temperature is given what is the corresponding saturation pressure at 25 degree celsius. So, this is your 25, we look at table A4, this is your 25 degree Celsius. The cost (())(14:36) forming pressure is this and this pressure is a much lower than what the initial pressure is.

In other word this pressure which is playing, the initial pressure of the system is much higher than this of saturation pressure at 25 degree celsius which essentially means that system is already compressed because the pressure is much higher than the Psat. So, this is a compressed liquid, okay. So, what we are going to do is, we going to approximate, okay, we going to say that well a initial volume, the specific volume is almost same as the saturated fluid or liquid at 25 degree celsius.

So, this is approximation we going to make use of it because we do not have question as state at this point or we do not have any other means to calculate. So, we going to make this kind of approximation and we will be often making such approximation. Okay, for the compressed liquid or we going to assign this volume as simply the volume of the fluid at 25 degree celsius.

So, with we can find out the initial volume V1 as simply V. So, this is our specific volume so write this is at 25 degree celsius and this value is here. So, we have V1 is 5 kg we know multiplied by specific liquid which is 0.001003, okay. So, this will going to be this one. So, what is the total volume here? Total volume of this is going to be 2 times the initial volume. So, this is your meter cube per kg. So, this will be your volume of the system. This we can write as two times 0.005 we neglect the other beyond 1 and this would be your 0.01 meter cube. So, this is the total tank volume. Okay.

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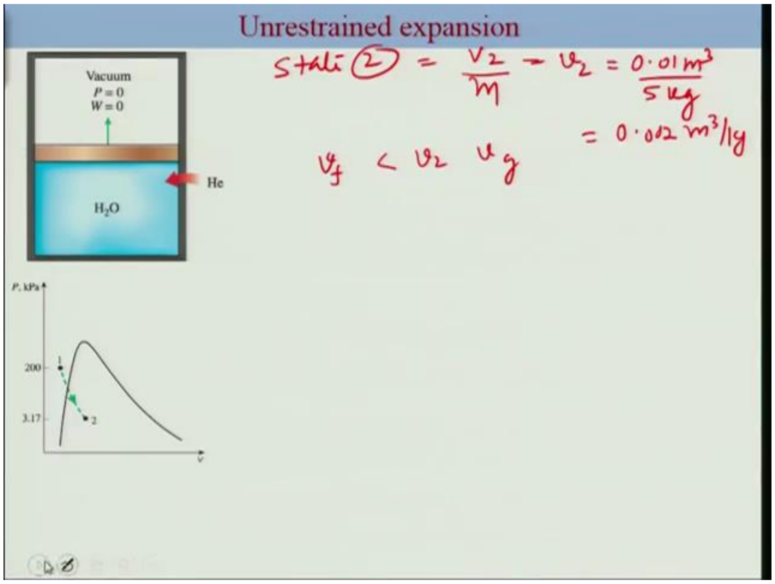

Unrestrained expansion

State ② $= \frac{V_2}{m} \rightarrow v_2 = \frac{0.01\, m^3}{5\, kg}$

$= 0.002\, m^3/kg$

$v_f < v_2 \quad v_g$

So, what is a state two? Okay. The state two you already know your V2 the volume of the state 2 and the mass is still the fixed. So, what is the specific volume for the state two is 0.01 meter cube by 5 kg okay. So, this is going to be 0.002 meter cube per kg, okay. So, now we need to find out we have the specific volume of the state 2. So, we need to find out whether it is in a saturated liquid state or vapor state.

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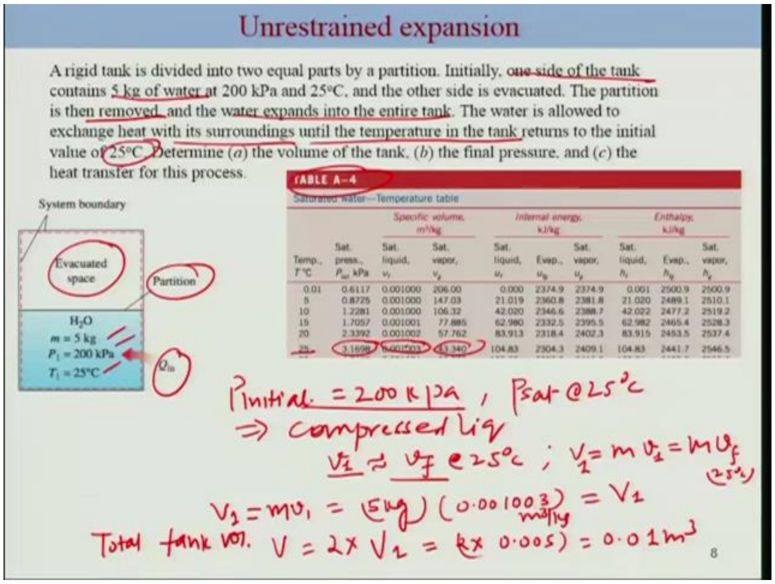

Unrestrained expansion

A rigid tank is divided into two equal parts by a partition. Initially, one side of the tank contains 5 kg of water at 200 kPa and 25°C, and the other side is evacuated. The partition is then removed, and the water expands into the entire tank. The water is allowed to exchange heat with its surroundings until the temperature in the tank returns to the initial value of 25°C. Determine (*a*) the volume of the tank, (*b*) the final pressure, and (*c*) the heat transfer for this process.

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0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1
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20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5

$P_{initial} = 200$ kPa , P_{sat} @ 25°C

$\Rightarrow$ compressed liq

$v_1 \approx v_f$ @ 25°C ; $V_1 = m v_1 = m v_{f\,(25°C)}$

$V_1 = m v_1 = (5 kg)(0.001003 \ m^3/kg) = V_1$

Total tank vol. $V = 2 \times V_1 = (2 \times 0.005) = 0.01 m^3$

So, again we should check whether this V2 lies in between Vf and Vg and so we can go back and check our table. The table tells you that Vg is quite large 43 and V2 is larger than this one.

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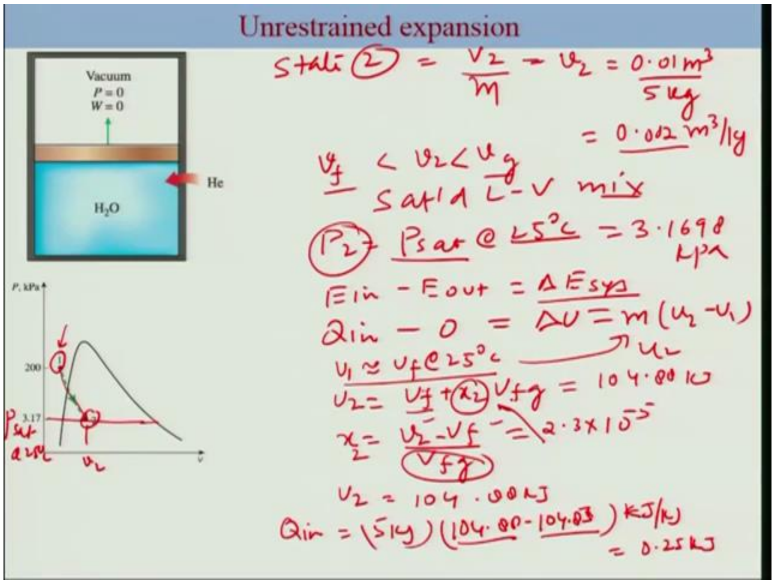

Unrestrained expansion

state ② $= \frac{V_2}{m} \rightarrow v_2 = \frac{0.01\,m^3}{5\,kg}$

$= 0.002\,m^3/kg$

$v_f < v_2 < v_g$

Sat'd L-V mix

$\textcircled{P_2}$ Psat @ 25°C $= 3.1698$ kPa

$E_{in} - E_{out} = \Delta E_{sys}$

$Q_{in} - 0 = \Delta U = m(u_2 - u_1)$

$u_1 \approx u_f @ 25°C$

$u_2 = u_f + \textcircled{x_2} u_{fg} = 104.88$ kJ

$x_2 = \frac{u_2 - u_f}{u_{fg}} = 2.3 \times 10^{-5}$

$u_2 = 104.88$ kJ

$Q_{in} = (5\,kg)(104.88 - 104.83)\,kJ/kg$

$= 0.25$ kJ

So certainly, our V2 is larger than Vf and thus than Vg. So, this means this is a saturated liquid vapor state mixture which essentially means that in this process, the state one from here the compressed liquid has went to the saturated liquid and now, it has saturated. So, this is your Psat, okay at 25 and now, it is in a saturated liquid mixture state.

So, till your P2 is fixed this Psat at 25 degree celsius. So, still their temperature is fixed because your final temperature is known 25 degree celsius. Considering it is a saturated liquid mixture. The P2 is nothing but Psat which is given from the table. So, this is already given Psat, okay. So, now I will write the energy balance here, okay. What about the work (())(18:55) specific energy which is taken out from the system.

So, what is being provided to you is Qin what about Eout? So, there is no specific work because when it expands it expands against zero pressure. So, you have Qin minus zero is whatever the change is occurring is occurring in the system internal energy. Considering the kinetic energy and the potential energy is zero. This we can be written as m U2 minus U1. So, we going to approximate again the U1 because of the fact that U1 is a one is (())(19:31) compress so, it so U1 is approximated as Uf at 25 degree celsius.

Now, in order to find out this that is Qin because we need to find out the heat transfer, we need to also find out U2, okay and you know the U2 is nothing but Uf plus x2 Ufg. So, you need to find out x2. Now, this is easy because now, you have the information of your volume 2. So, x2 is nothing but your V2 minus Vf by Vfg, okay. So, Vfg is known from your table. Okay. So, you know your Vfg, Vg minus Vf and you know your Vf and as well as you know your V2. So, this becomes 2.3 times into the minus 5 okay.

So, from here you can obtain now you can plug this end and now, use the Uf and Ufg specific internal energy from the table, okay. So, from there you can obtain the value and it turns out to be 4.88 kilojoules. So, now you can find out Qin, because Qin is now 5 kg and then you plug in this value okay. So, 104.88 minus 104.83 and this is of course extremely small, okay. This is in kilojoules per kg and this turns out to be 0.25 kilojoules okay.

So, remember that we have considered U1 as U of liquid, okay. So, that was our assumption this, okay. This was 104.83 and this we calculated based on the quality and the values of the fluid and Fg from the table. So, this is the way we solves certain problems based on the using the tables, note that Qin in this case is positive so that means our assumption is correct we have to provide energy to the system in the form of heat for this particular Unrestrained expansion. So, such that the temperature and the final state is fixed.

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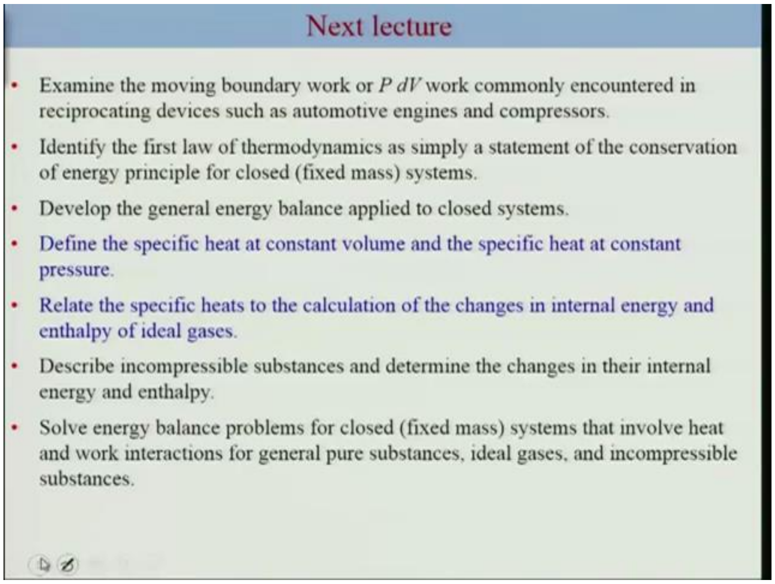

Next lecture

- Examine the moving boundary work or *P dV* work commonly encountered in reciprocating devices such as automotive engines and compressors.
- Identify the first law of thermodynamics as simply a statement of the conservation of energy principle for closed (fixed mass) systems.
- Develop the general energy balance applied to closed systems.
- Define the specific heat at constant volume and the specific heat at constant pressure.
- Relate the specific heats to the calculation of the changes in internal energy and enthalpy of ideal gases.
- Describe incompressible substances and determine the changes in their internal energy and enthalpy.
- Solve energy balance problems for closed (fixed mass) systems that involve heat and work interactions for general pure substances, ideal gases, and incompressible substances.

So, let us the end the lecture, in the next lecture we are going to define specific heat at a constant volume and other way of or different ways of making use of specific heat for calculating change in internal energy and change in enthalpy, okay. So, see you in the next lecture.