# Engineering Thermodynamics
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## Lecture 24
## Throttling valve, mixing chamber and heat exchanger

Welcome back.

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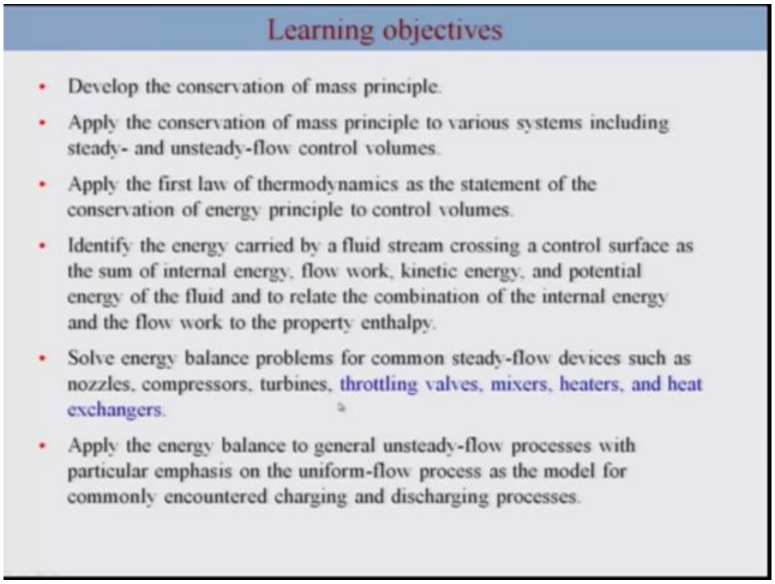

Learning objectives

- Develop the conservation of mass principle.
- Apply the conservation of mass principle to various systems including steady- and unsteady-flow control volumes.
- Apply the first law of thermodynamics as the statement of the conservation of energy principle to control volumes.
- Identify the energy carried by a fluid stream crossing a control surface as the sum of internal energy, flow work, kinetic energy, and potential energy of the fluid and to relate the combination of the internal energy and the flow work to the property enthalpy.
- Solve energy balance problems for common steady-flow devices such as nozzles, compressors, turbines, throttling valves, mixers, heaters, and heat exchangers.
- Apply the energy balance to general unsteady-flow processes with particular emphasis on the uniform-flow process as the model for commonly encountered charging and discharging processes.

So we were discussing the steady flow devices. We will continue our discussion in this particular lecture particularly we will take up throttling valves, mixers, heaters and heat exchangers, ok?

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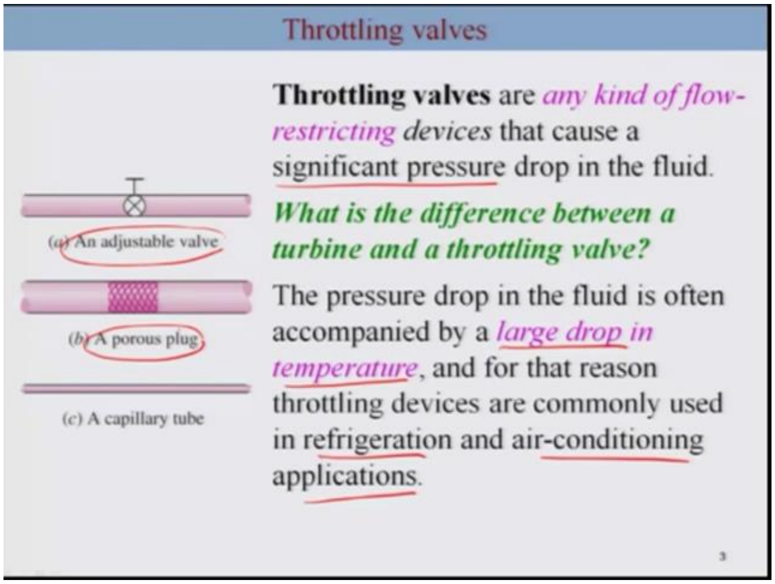

## Throttling valves

**Throttling valves** are *any kind of flow-restricting devices* that cause a significant pressure drop in the fluid.

***What is the difference between a turbine and a throttling valve?***

The pressure drop in the fluid is often accompanied by a *large drop in temperature*, and for that reason throttling devices are commonly used in refrigeration and air-conditioning applications.

(*a*) An adjustable valve

(*b*) A porous plug

(*c*) A capillary tube

So let us start with throttling valves. So throttling valve is basically any kind of flow restricting device and thus it cause significant pressure drop in the fluid. So there is a difference compared with respect to turbine and the turbine particularly do not lead to significant change in the in temperature but in case of a throttling valves it the pressure drop in a fluid is often accompanied by a large drop in temperature and this is a reason that throttling valves are commonly used in refrigeration, air conditioning applications.

There are different kind of throttling valves. You can have adjustable valves, you can have a porous plug based or a simple capillary tube, ok. These are all examples of throttling valves.

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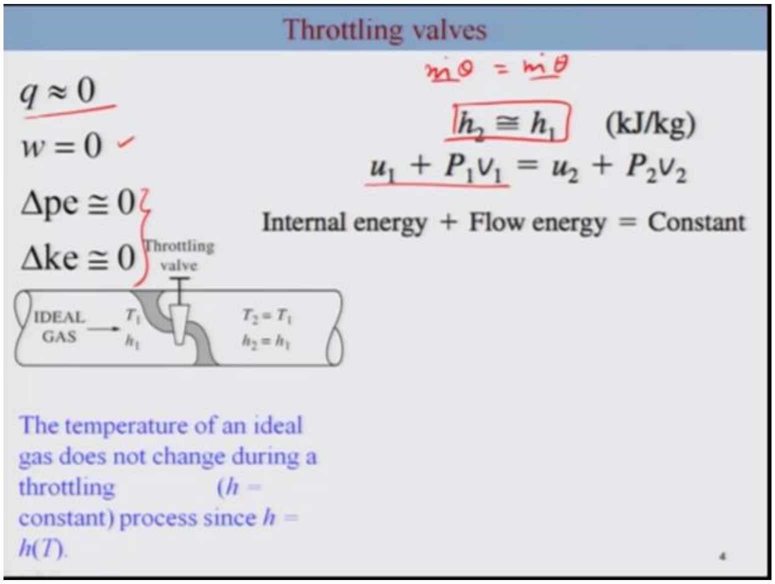

## Throttling valves

$\dot{m}\theta = \dot{m}\theta$

$q \approx 0$

$w = 0$ ✓

$\Delta pe \cong 0$

$\Delta ke \cong 0$

$\boxed{h_2 \cong h_1}$ (kJ/kg)

$u_1 + P_1 v_1 = u_2 + P_2 v_2$

Internal energy + Flow energy = Constant

The temperature of an ideal gas does not change during a throttling ($h$ = constant) process since $h = h(T)$.

So let us look at how are we going to apply simple energy balance, the material balance is very obvious that this is mass fluid should remain constant for the case of steady flow conditions. So what about the energy balance here? So you will be considering Q to be zero and the reason for that is or considering the device is very small and hence we will be considering such a flow adiabatic.

The work would be also zero and as well as your change in the potential energy and kinetic energy to be zero, ok? And thus you m Theta inlet should be same as m Theta outlet and since your kinetic energy potential energy is zero, so you have this condition considering that m dot is same for the inlet and outlet.

So you have for the throttling valve a simple enthalpy, a constant enthalpy process. So throttling valve essentially means that the enthalpies are same. You have internal energy plus the flow energy term as a part of the enthalpy. They can interchange but the total value should remain constant. Ok, so if you consider ideal gas, now we know that the for the case of ideal gas the enthalpy is only function of temperature and hence if enthalpy is constant which means the temperature is constant for ideal gas throughout this valve.

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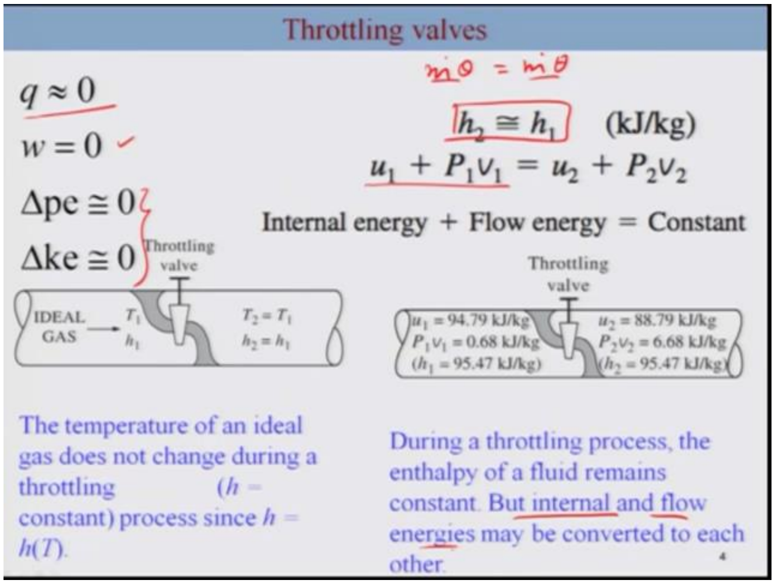

## Throttling valves

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Internal energy + Flow energy = Constant

The temperature of an ideal gas does not change during a throttling ($h$ = constant) process since $h = h(T)$.

During a throttling process, the enthalpy of a fluid remains constant. But internal and flow energies may be converted to each other.

And during this throttling process, enthalpy of a fluid as I said can remain constant but internal flow energy may convert into each other. So that means the flow energy can lose some energy and the internal energy can gain through during this process. That is some aspect which we are going to look at in an example. Ok so let us take this and understand a bit more about throttling valves.

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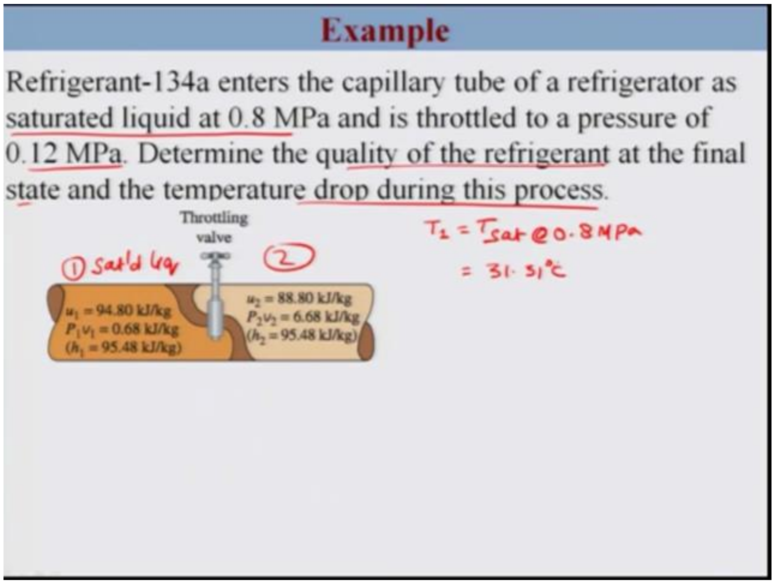

## Example

Refrigerant-134a enters the capillary tube of a refrigerator as saturated liquid at 0.8 MPa and is throttled to a pressure of 0.12 MPa. Determine the quality of the refrigerant at the final state and the temperature drop during this process.

$T_1 = T_{sat @ 0.8 MPa}$

$= 31.31°C$

So this is an example of refrigerant, ok? Which enters this capillary tube of a refrigerator at condition which is saturated liquid at 0.8 MegaPascal, and is throttled to a pressure of 0.12 MegaPascal. So there is a huge jump in the pressure. Ok, and hence the temperature should also change. Determine the quality of the refrigerant at the final state and a temperature drop during this process.

Ok? So we consider this as one and this is as two. So now start with temperature at 1, 1 is at saturated liquid, ok? So this is equivalent to T sat at 0.8 MegaPascal ok which is nothing but 31.31 degrees C from the table.

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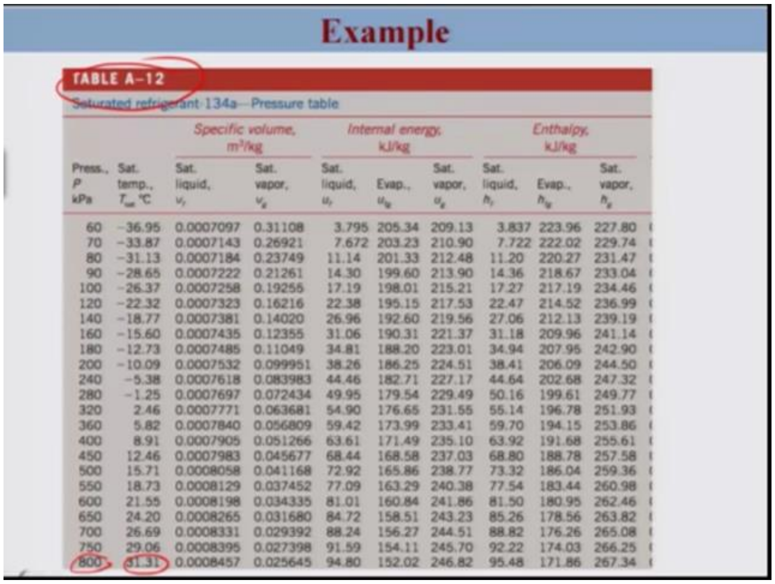

## Example

**TABLE A-12**

Saturated refrigerant-134a—Pressure table

| | | Specific volume, $m^3/kg$ | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | |
|---|---|---|---|---|---|---|---|---|---|
| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | 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, $h_g$ |
| 60 | −36.95 | 0.0007097 | 0.31108 | 3.795 | 205.34 | 209.13 | 3.837 | 223.96 | 227.80 |
| 70 | −33.87 | 0.0007143 | 0.26921 | 7.672 | 203.23 | 210.90 | 7.722 | 222.02 | 229.74 |
| 80 | −31.13 | 0.0007184 | 0.23749 | 11.14 | 201.33 | 212.48 | 11.20 | 220.27 | 231.47 |
| 90 | −28.65 | 0.0007222 | 0.21261 | 14.30 | 199.60 | 213.90 | 14.36 | 218.67 | 233.04 |
| 100 | −26.37 | 0.0007258 | 0.19255 | 17.19 | 198.01 | 215.21 | 17.27 | 217.19 | 234.46 |
| 120 | −22.32 | 0.0007323 | 0.16216 | 22.38 | 195.15 | 217.53 | 22.47 | 214.52 | 236.99 |
| 140 | −18.77 | 0.0007381 | 0.14020 | 26.96 | 192.60 | 219.56 | 27.06 | 212.13 | 239.19 |
| 160 | −15.60 | 0.0007435 | 0.12355 | 31.06 | 190.31 | 221.37 | 31.18 | 209.96 | 241.14 |
| 180 | −12.73 | 0.0007485 | 0.11049 | 34.81 | 188.20 | 223.01 | 34.94 | 207.95 | 242.90 |
| 200 | −10.09 | 0.0007532 | 0.099951 | 38.26 | 186.25 | 224.51 | 38.41 | 206.09 | 244.50 |
| 240 | −5.38 | 0.0007618 | 0.083983 | 44.46 | 182.71 | 227.17 | 44.64 | 202.68 | 247.32 |
| 280 | −1.25 | 0.0007697 | 0.072434 | 49.95 | 179.54 | 229.49 | 50.16 | 199.61 | 249.77 |
| 320 | 2.46 | 0.0007771 | 0.063681 | 54.90 | 176.65 | 231.55 | 55.14 | 196.78 | 251.93 |
| 360 | 5.82 | 0.0007840 | 0.056809 | 59.42 | 173.99 | 233.41 | 59.70 | 194.15 | 253.86 |
| 400 | 8.91 | 0.0007905 | 0.051266 | 63.61 | 171.49 | 235.10 | 63.92 | 191.68 | 255.61 |
| 450 | 12.46 | 0.0007983 | 0.045677 | 68.44 | 168.58 | 237.03 | 68.80 | 188.78 | 257.58 |
| 500 | 15.71 | 0.0008058 | 0.041168 | 72.92 | 165.86 | 238.77 | 73.32 | 186.04 | 259.36 |
| 550 | 18.73 | 0.0008129 | 0.037452 | 77.09 | 163.29 | 240.38 | 77.54 | 183.44 | 260.98 |
| 600 | 21.55 | 0.0008198 | 0.034335 | 81.01 | 160.84 | 241.86 | 81.50 | 180.95 | 262.46 |
| 650 | 24.20 | 0.0008265 | 0.031680 | 84.72 | 158.51 | 243.23 | 85.26 | 178.56 | 263.82 |
| 700 | 26.69 | 0.0008331 | 0.029392 | 88.24 | 156.27 | 244.51 | 88.82 | 176.26 | 265.08 |
| 750 | 29.06 | 0.0008395 | 0.027398 | 91.59 | 154.11 | 245.70 | 92.22 | 174.03 | 266.25 |
| 800 | 31.31 | 0.0008457 | 0.025645 | 94.80 | 152.02 | 246.82 | 95.48 | 171.86 | 267.34 |

So this table is here given A-12. Now this is your 0.8 MegaPascal, this is your saturation temperature (())(3.46) 800 kiloPascal.

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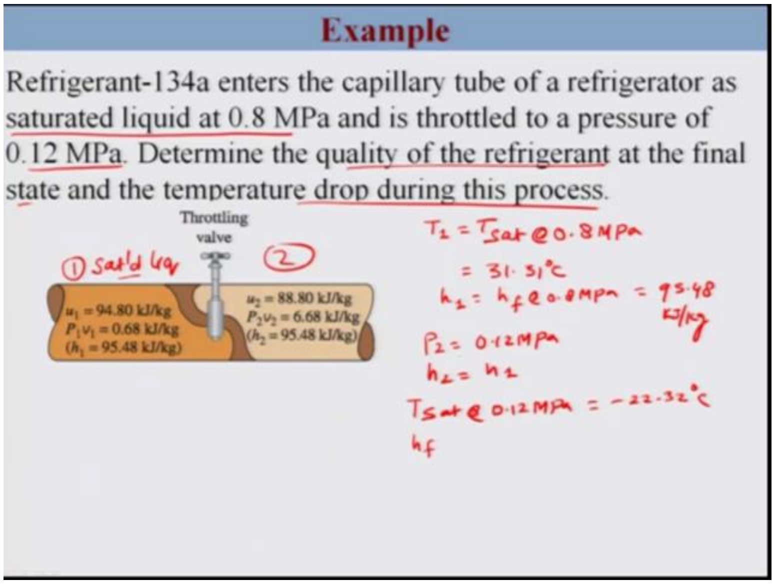

**Example**

Refrigerant-134a enters the capillary tube of a refrigerator as saturated liquid at 0.8 MPa and is throttled to a pressure of 0.12 MPa. Determine the quality of the refrigerant at the final state and the temperature drop during this process.

$T_1 = T_{sat} @ 0.8\,MPa$

$= 31.31°C$

$h_1 = h_f @ 0.8\,MPa = 95.48$ kJ/kg

$P_2 = 0.12\,MPa$

$h_2 = h_1$

$T_{sat} @ 0.12\,MPa = -22.32°C$

$h_f$

Now T as saturation is given, now what we are going to assume, ok? What we have to consider now is the enthalpy because we know that the enthalpy is constant which essentially means h 1 should be equal to s 2 and h 1 is nothing but h f because this is saturated liquid, ok? At 0.8 MegaPascal, ok?

So the table tells you this is nothing but 95.48. So this is your 95.48 kiloJoules per Kg, ok? What about your p 2? What about your condition at 2 here? So The question being asked here is the quality which means there is some change in the state, so let us look at it, whether there is vaporisation which during this process. So let us look at first p 2. What is p 2 here? p 2 is your 0.12 MegaPascal, ok? And h 2 is nothing but h 1. So the corresponding T sat at p 2 is T sat at 0.12 MegaPascal is minus 22.32.

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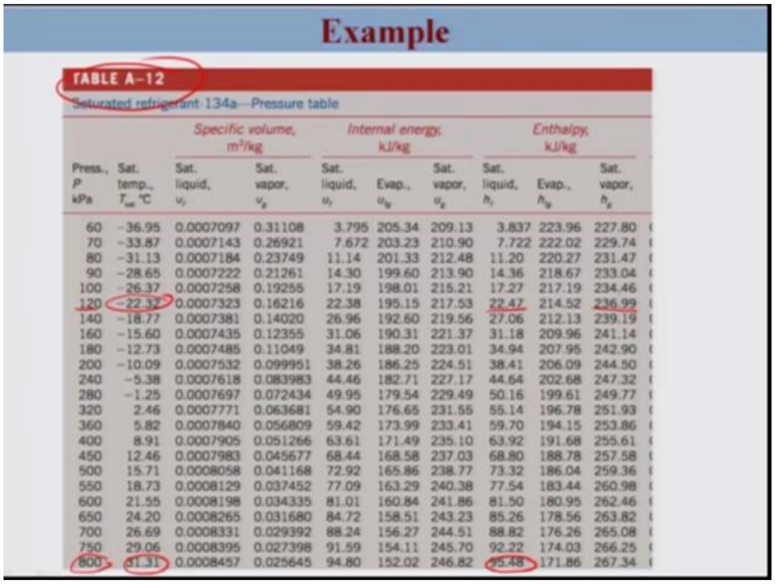

## Example

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So this is nothing but minus 22.32 degree celsius and the corresponding h f at this pressures can be obtained here, h f is 22.47 and saturated 236.99. Since h is constant and h 1 is 95.48. This means this lies between these two points.

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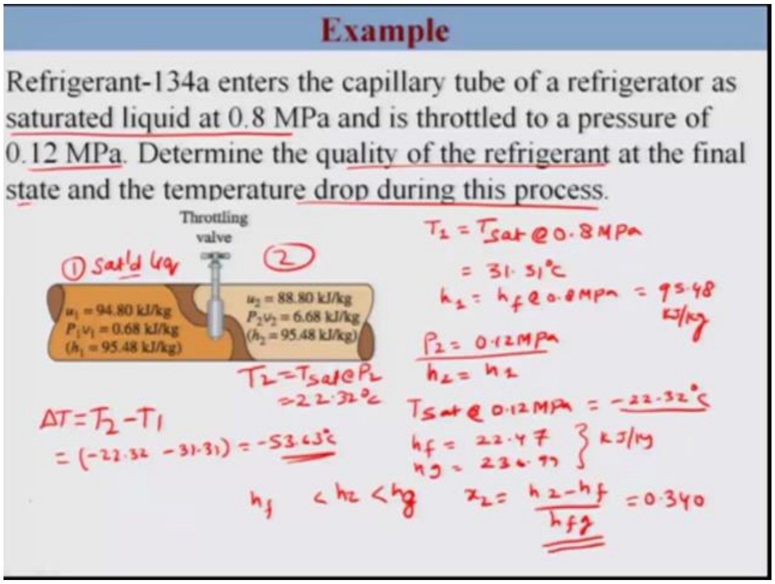

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Refrigerant-134a enters the capillary tube of a refrigerator as saturated liquid at 0.8 MPa and is throttled to a pressure of 0.12 MPa. Determine the quality of the refrigerant at the final state and the temperature drop during this process.

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$= 31.31°C$

$h_1 = h_f @ 0.8 MPa = 95.48$ kJ/kg

$P_2 = 0.12 MPa$

$h_2 = h_1$

$T_{sat} @ 0.12 MPa = -22.32°C$

$h_f = 22.47$, $h_g = 236.99$ } kJ/kg

$x_2 = \frac{h_2 - h_f}{h_{fg}} = 0.340$

$h_f < h_2 < h_g$

$T_2 = T_{sat} @ P_2$

$= -22.32°C$

$\Delta T = T_2 - T_1$

$= (-22.32 - 31.31) = -53.63°C$

So as I said h f is 22.47 and h g is 236.99. So our h 2 which is nothing but h 1 is greater than h f and less than h g. Ok? At of course 0.12 MegaPascal. Which essentially means that since lies between the fluid and gas enthalpies, the state at exit would be saturated vapour liquid conditions. So there would be a quality involve of the vapour. So e can calculate the quality x 2 which is nothing but h 2 minus h f by h f g and this if you plug in this value and h f g is nothing which is this h f g. So if you plug in the value the value comes out to be 0.340, ok?

This is a quality. So that was the question, that we had to find the quality of the refrigerant at the final state. This is the quality. What about the temperature drop? So let us find the temperature drop. So what would be the state t 2 of the final state. T 2 is nothing but t 2 is T saturation at p 2 because the fact that the final state is at saturation vapour liquid condition and hence t 2 is nothing but your minus minus 22.32 degree celsius, ok?

Thus your change in the temperature delta T or the temperature drop is t 2 minus t 1 which is nothing but minus 22.32 minus 31.31 degree celsius which is minus 53.63 degree celsius. So it is very clear that there is a significant drop in the temperature and the saturated liquid vaporized. The energy to vaporise it takes its own enthalpy, ok? That is something which is quite interesting, ok.

Because the energy required is not taken from any specific external source but it changes its own state through this particular capillary tube and make use of it for vaporizing from a saturated liquid to saturated vapour liquid conditions.

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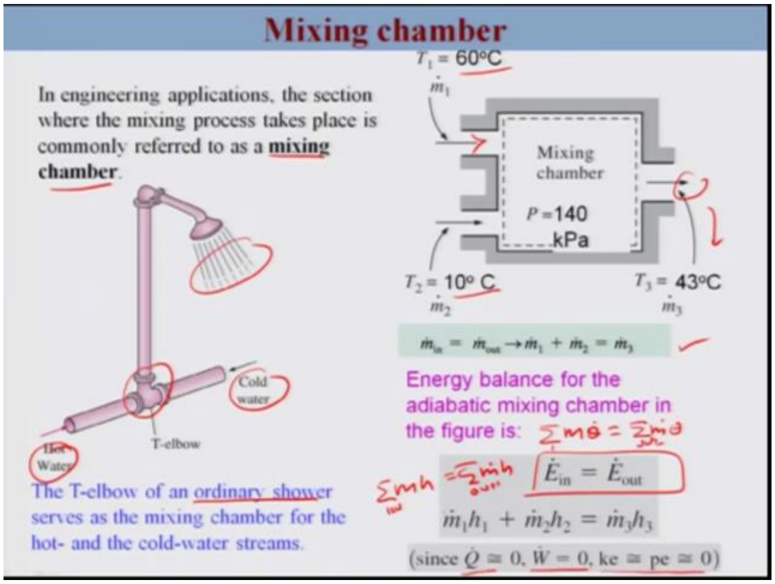

## Mixing chamber

In engineering applications, the section where the mixing process takes place is commonly referred to as a **mixing chamber**.

The T-elbow of an ordinary shower serves as the mixing chamber for the hot- and the cold-water streams.

$\dot{m}_{in} = \dot{m}_{out} \rightarrow \dot{m}_1 + \dot{m}_2 = \dot{m}_3$

Energy balance for the adiabatic mixing chamber in the figure is: $\sum \dot{m}\theta = \sum \dot{m}\theta$

$\sum_{in} \dot{m}h = \sum_{out} \dot{m}h$ $\boxed{\dot{E}_{in} = \dot{E}_{out}}$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

(since $\dot{Q} \cong 0$, $\dot{W} = 0$, ke $\cong$ pe $\cong 0$)

Ok, so now we are going to take another device and this is your mixing chamber and this is a common operational device which you can see normal at different hotels, household conditions. This example is ordinary shower, ok? So you have a mixing of a hot and cold led into average temperature water flow and this is called mixing chamber, ok where basically you have a direct contact, you you are making use of hot and cold fluid and passing it that means mixing them physically.

Ok, so there is a heat transfer from of course the hot to cold. Ok, so you can put this in a schematic form. This is a simple mixing chamber. Ok here the mixing chamber could be a this elbow but here we can represent in this form. So this is your two inlet fluids. One at 60 degree celsius and one is 10 degree celsius and is mixing at certain temperature and the outlet stream has a specific temperature, ok?

So based on simple mass balance, you can clearly show that this would be m 1 plus m 2 is equal to m 3. Considering this to be a steady flow device so you will have this condition which is very clear. Ok, you can also come up with energy balance here. Now, considering steady flow, we now well aware that this would be the case for steady flow.

Now we will be considering that there is no heat supply to it, ok? So that mean Q dot is zero and as well as the work there is no work done or by the system. And we will be assuming the changes in the kinetic energy, potential energy to be zero. In that case, your simple energy balance would be your summation m theta inlet is equal to summation m theta outlet or in a generalized form it will be simple. For the case of this system where your kinetic energy and potential energies are zero. Other changes are zero.

Your h inlet should be equal to m h outlet, ok? And this is what we is written here. So this is a simple energy balance for in the case of mixing chamber.

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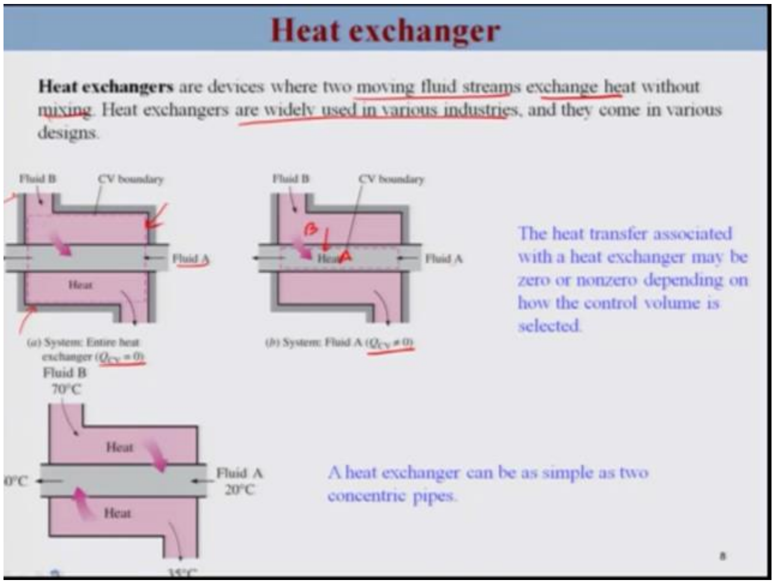

## Heat exchanger

**Heat exchangers** are devices where two moving fluid streams exchange heat without mixing. Heat exchangers are widely used in various industries, and they come in various designs.

(a) System: Entire heat exchanger ($Q_{CV} = 0$)

(b) System: Fluid A ($Q_{CV} \neq 0$)

The heat transfer associated with a heat exchanger may be zero or nonzero depending on how the control volume is selected.

A heat exchanger can be as simple as two concentric pipes.

So we can take another device. Now in this case which is a heat exchanger, this device allows heat transfer without direct contact of the fluids. So a generalized definition is, these are the device where two moving fluid streams exchange heat without mixing.

It does the same operation but it does not allow the physical mixing of the two fluids for the heat transfer. And this is commonly used in various industry and they can in a different design. So this is a simple analysis of heat exchanger for example here you can this is a let us say fluid A passing through a pipe and then we have another fluid through this control volume and if you consider the control volume as a dash line here, ok?

There is no additional heat transfer at the boundary from the surrounding to this control volume. It happens within this control volume. So thus your overall control volume heat exchange would be zero. But on the other hand if you cover with the control volume boundary as a within the pipe of fluid then there is a transfer from the outside of this control volume that is from B to A, ok? And thus your Q c v is not equal to zero.

So it depends on the how you come up with your control volume and depending on the control volume, your heat exchange may be zero or nonzero. Ok, that is a heat transfer associative with a heat exchanger example. So we will try to do some example in order to get a more insight to this.

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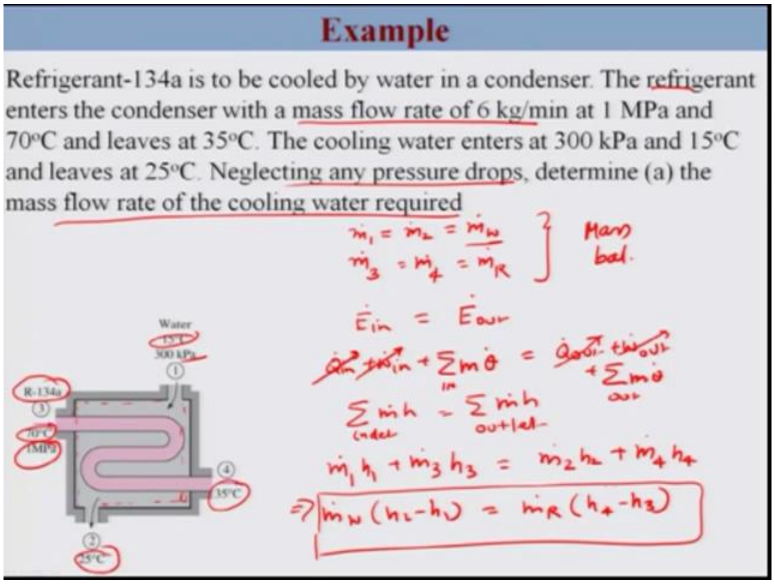

## Example

Refrigerant-134a is to be cooled by water in a condenser. The refrigerant enters the condenser with a mass flow rate of 6 kg/min at 1 MPa and 70°C and leaves at 35°C. The cooling water enters at 300 kPa and 15°C and leaves at 25°C. Neglecting any pressure drops, determine (a) the mass flow rate of the cooling water required

$$\left.\begin{aligned}\dot{m}_1 = \dot{m}_2 = \dot{m}_w\\ \dot{m}_3 = \dot{m}_4 = \dot{m}_R\end{aligned}\right\}\ \text{Mass bal.}$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\cancel{\dot{Q}_{in} + \dot{W}_{in}} + \sum_{in} \dot{m}\theta = \cancel{\dot{Q}_{out} + \dot{W}_{out}} + \sum_{out} \dot{m}\theta$$

$$\sum_{inlet} \dot{m}h = \sum_{outlet} \dot{m}h$$

$$\dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_2 h_2 + \dot{m}_4 h_4$$

$$\Rightarrow \boxed{\dot{m}_w (h_2 - h_1) = \dot{m}_R (h_4 - h_3)}$$

So this example is a refrigerant which is to be cooled by water either condenser and the refrigerant enters the condenser with a mass flow rate of 6 Kg per minute. So which essentially means you have a refrigerant 134 A, ok? Which is at 70 degrees celsius 1 MegaPascal and it exits at 4 with at 35 degree celsius. Water enters at 15 degrees celsius at 300 kiloPascal and it exits at 25 degrees celsius.

So the water heats up a bit and there is a drop in temperature in the refrigerant. So mass flow rate of refrigerant is given and what we have to do is we have to neglect any pressure drop and determine the mass flow rate of the cooling water required.

So we can do a simple mass balance. Based on the mass balance being these two fluid water and refrigerant, they do not mix and hence mass flow rate should remain constant which essentially means that the mass flow rate for the refrigerant at the inlet condition should be same as outlet condition and for the same is true for for the case of water.

So we can write that, you can say that m 1 dot is equal to m 2 dot and that will be let us say water flow rate and m 3 dot is nothing but m 4 dot, that will be your m r, that is the flow rate for the refrigerant, ok? So this is your simple mass balance. Now we can write your energy balance and considering it is a steady flow device, we can write this as simply E in dot equal to E in out, ok?

Or in other word, your Q in plus W in for the case of inlet streams is equal to Q out plus W out outlet. The heat we are assuming is the considered to be the complete control volume. Ok? In that case you Q dot and W dot should be zero. And assuming the kinetic energy and potential energy to be zero, this can be simply written as m dot h inlet should be equal to m dot h outlet, ok?

Or in other word, the inlet are 1 and 3, so we can write m 1 h 1 plus m 3 h 3, this is same as m 2 h 2 plus m 4 h 4. Now m 1 is equal to m 2, this is what we are saying is m w. So we can rewrite as… Ok, we can take the common terms and we can rewrite this energy balance in this form. Ok? Now what is the next thing to do is to find out the enthalpies. And for that we have to make use of lots of table.

Let me just summarise the procedure to solve the rest of the problem. Now the first important thing is to look at whether the given conditions which are given for the water, is it in a compressed state or superheated state or saturated liquid state? So the temperature given is a 25 in 15 degree celsius at 300 kiloPascal, ok? And since there is no pressure drop, so we are assuming that this 300 kiloPascal remains same across the end (())(14.49) both the inlet and outlet condition.

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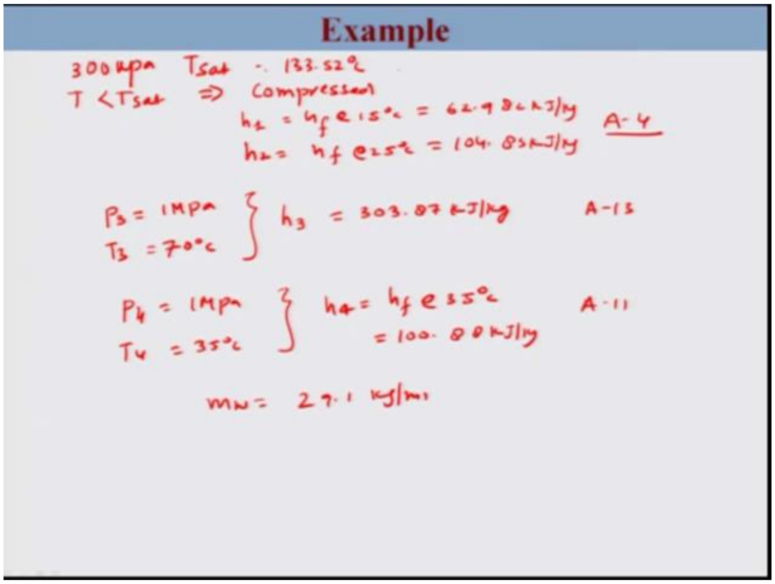

**Example**

300 kPa $T_{sat}$ ∴ 133.52°C

$T < T_{sat} \Rightarrow$ Compressed

$h_1 = h_f @ 15°C = 62.982$ kJ/kg   A-4

$h_2 = h_f @ 25°C = 104.83$ kJ/kg

$\left.\begin{matrix} P_3 = 1\text{MPa} \\ T_3 = 70°C \end{matrix}\right\}$ $h_3 = 303.07$ kJ/kg   A-13

$\left.\begin{matrix} P_4 = 1\text{MPa} \\ T_4 = 35°C \end{matrix}\right\}$ $h_4 = h_f @ 35°C = 100.80$ kJ/kg   A-11

$m_w = 29.1$ kg/min

So at 300 kiloPascal your T sat for water is 133.52 degree celsius. The temperature which is given to us is much less than T sat. So thus we are going to consider this to be a compressed liquid. So in that case we can consider h 1 to be simply the saturated fluid condition at 15 degree celsius and h 2, at h f at 25 degree celsius. Now this information you can get it from table A 4 and these values are 62.982 kiloJoules per Kg and this is 104.83 kiloJoules per Kg.

So the water is known, so what about your refrigerant? For that you have to look at the tables like A 13 and A 11. So if you look at your conditions of refrigerant p 3 is at 1 MegaPascal and t 3 70 degrees celsius. So these are the condition based on the A 13 will tell you that this is a super heated vapour condition. And hence, you can take the value as three from the table A 13 which comes out to be 303.87.

Ok, similarly you can find P 4, Ok? And this will be your compressed case for the case of your refrigerant. Ok, so this is your compressed and this is your h 4 is… ok? Now you plug in this value, here ok? In thin equation. You will obtain m 2.

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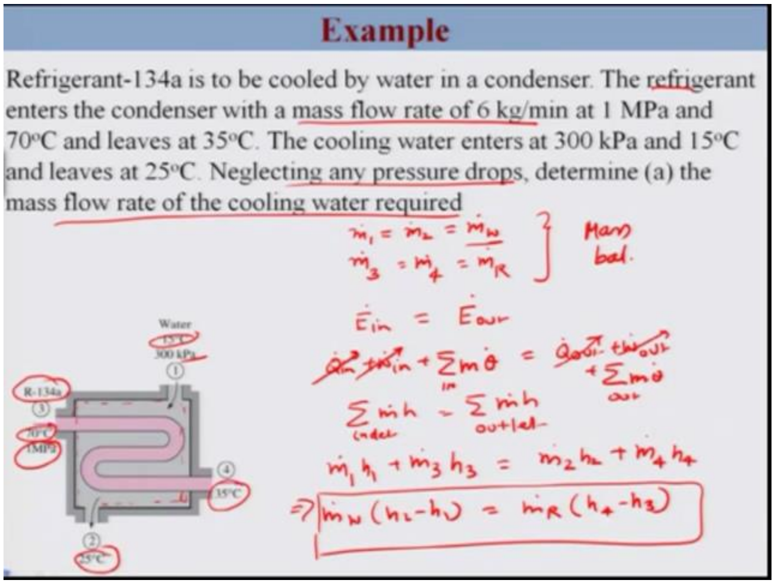

## Example

Refrigerant-134a is to be cooled by water in a condenser. The refrigerant enters the condenser with a mass flow rate of 6 kg/min at 1 MPa and 70°C and leaves at 35°C. The cooling water enters at 300 kPa and 15°C and leaves at 25°C. Neglecting any pressure drops, determine (a) the mass flow rate of the cooling water required

$$\left.\begin{aligned}\dot{m}_1 = \dot{m}_2 = \dot{m}_w\\ \dot{m}_3 = \dot{m}_4 = \dot{m}_R\end{aligned}\right\} \text{Mass bal.}$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\cancel{\dot{Q}_{in}} + \cancel{\dot{W}_{in}} + \sum_{in} \dot{m}\theta = \cancel{\dot{Q}_{out}} + \cancel{\dot{W}_{out}} + \sum_{out} \dot{m}\theta$$

$$\sum_{inlet} \dot{m}h = \sum_{outlet} \dot{m}h$$

$$\dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_2 h_2 + \dot{m}_4 h_4$$

$$\Rightarrow \boxed{\dot{m}_w (h_2 - h_1) = \dot{m}_R (h_4 - h_3)}$$

So that was the question which we ought to solve. you can also try to find out what is a effective heat transfer in this system by taking a control volume.

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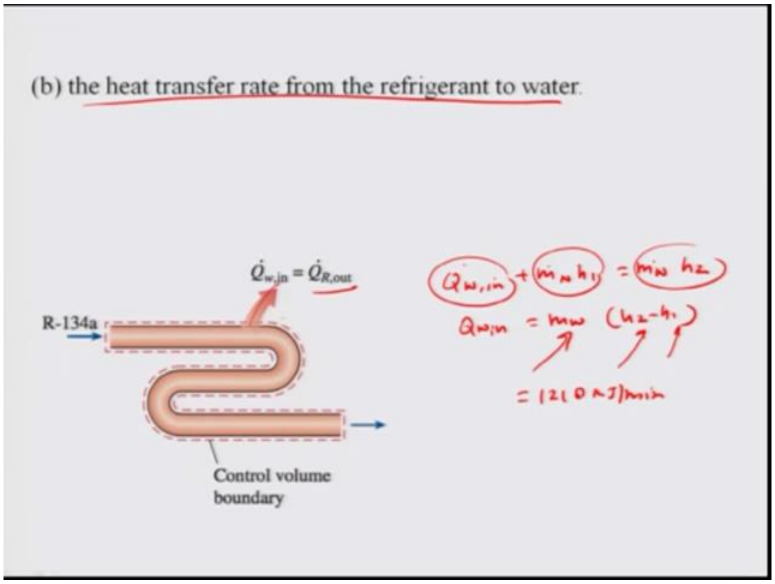

(b) the heat transfer rate from the refrigerant to water.

$$Q_{w,in} + \dot{m}_w h_1 = \dot{m}_w h_2$$

$$Q_{w,in} = \dot{m}_w (h_2 - h_1)$$

$$= 1218 \text{ kJ/min}$$

So you can also try to try to solve this problem of heat transfer rate from the refrigerant to the water by applying a simple energy balance. So for this specific case here, write your Q w in… so what we have done is that we have specifically considered this control volume in order to find the heat transfer from the refrigerant to the water and thus this dash line represents the control volume.

You apply the same energy balance equation but now you have to consider this Q w in here, ok which is nothing but Q r out and this terms related to flow energies. Now so based on these you already have m w and you have the values of h 2 and h 1 from your previous slides here. So this value turn out to be 1218 kiloJoules per minute. Ok. You can also consider not just this control volume but the control volume which encompasses the water only and obtain the same expressions.

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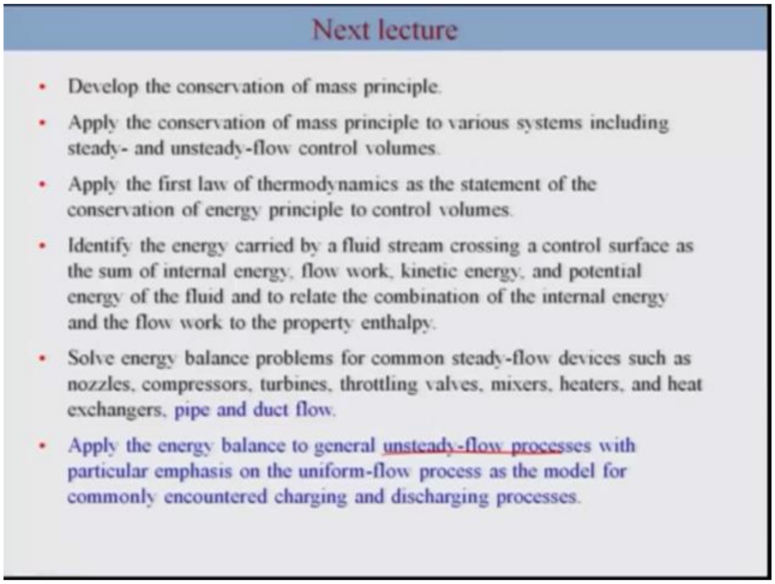

### Next lecture

- Develop the conservation of mass principle.
- Apply the conservation of mass principle to various systems including steady- and unsteady-flow control volumes.
- Apply the first law of thermodynamics as the statement of the conservation of energy principle to control volumes.
- Identify the energy carried by a fluid stream crossing a control surface as the sum of internal energy, flow work, kinetic energy, and potential energy of the fluid and to relate the combination of the internal energy and the flow work to the property enthalpy.
- Solve energy balance problems for common steady-flow devices such as nozzles, compressors, turbines, throttling valves, mixers, heaters, and heat exchangers, pipe and duct flow.
- Apply the energy balance to general unsteady-flow processes with particular emphasis on the uniform-flow process as the model for commonly encountered charging and discharging processes.

So this was a simple exercise for making use of the heat exchanger to solve problems related to based on the mass balance energy balance and in next lecture we will be considering pipe and duct flow followed by your unsteady flow process and that will be the end of this particular module. Ok? So see you in the next lecture.