Tutorial 9

30 March 2022 17:55

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Thermodynamics Tut - 9.

① $COP_H = \frac{\dot{Q}_H}{\dot{W}}$

The following simplification can be used in the case of reversible heat pumps

$$COP_{H,rev} = \frac{T_H}{T_H - T_L}$$

$$COP_{H,rev} = \frac{297.15K}{297.15K - 280.15K}$$

$$COP_{H,rev} = 17.479$$

Then, input power needed for the heat pump is:

$$\dot{W} = \frac{\dot{Q}}{COP_{H,rev}}$$

$$\dot{W} = \frac{300KW}{17.749}$$

$$\dot{W} = 16.902KW$$

By 1st law of Thermodynamics, heat pump works at steady state and likewise heat released:

$$-\dot{Q}_H + \dot{W} + \dot{Q}_L = 0$$

$$\dot{Q}_L = \dot{Q}_H - \dot{W}$$

$$\dot{Q}_L = 300KW - 16.902KW$$

$$\dot{Q}_L = 283.098KW$$

from second law of thermodynamics, a rev. heat pump should have an entropy

generation rate equal to zero.
The second law for this;

$$\dot{S}_{in} - \dot{S}_{out} - \dot{S}_{gen} = 0$$

$$\dot{S}_{gen} = \dot{S}_{in} - \dot{S}_{out}$$

$$\dot{S}_{gen} = \frac{\dot{Q}_L}{T_L} - \frac{\dot{Q}_h}{T_h}$$

$$\dot{S}_{gen} = \frac{283.098\,kW}{280.15\,K} - \frac{300\,kW}{297.15\,K}$$

$$\dot{S}_{gen} = 9.318 \times 10^{-4}\ KW/K$$

Albeit entropy generation rate is positive

(20) from steam tables
At 2 MPa and 360°C
Interpolating b/w 350°C and 400°C

$$h_1 = 3137.7 + \frac{360-350}{400-350} \times [3248.4 - 3137.7]$$

$$h_1 = 3159.84\ KJ/kg$$

$$s_1 = 6.9583 + \frac{360-350}{400-350} \times [7.1292 - 6.9583]$$

$$s_1 = 6.99248\ KJ/kg\,K$$

It is a isentropic process so entropy remains constant $s_1 = s_2$

At 100KPa

$s_f = 1.3028\ KJ/kgK$ $\quad s_{fg} = 6.0562\ KJ/kgK$

$h_f = 417.51\ KJ/kg$

$s_1 = s_2 = s_f + x\, s_{fg}$ $\quad h_{fg} = 2257.5\ KJ/kg$

$$6.99248 = 1.3028 + x \times 6.0562$$

$x = 0.93948$

$h_2 = h_f + x h_{fg}$

$h_2 = 417.51 + 0.93948 \times 2257.5$

$h_2 = 2538.3861 \text{ KJ/kg}$

work produced $w = h_1 - h_2$

$w = (3159.84 - 2538.3861)$

$\boxed{w = 621.4539 \text{ KJ/kg}}$

3 part (a)

$T_{sat \to 140kpa} = -18.77°C \to$ table A-12

we make a conversion °C → °K

$K = 273 + (-18.77°C) \longrightarrow 254.23°K$

the entropy change of cooled space

$$\Delta S_{refridgerant} = \frac{Q_{in}}{T_{refridgerant}}$$

we replace the values in the equation

$$\Delta S_{refridgerant} = \frac{180KJ}{254.23°K} \to \Delta S_{refridgerant}$$

$$= 0.70754 \text{ KJ/K}$$

part (b)

the entropy change of the cooled space

$$\Delta S_{space} = -\frac{Q_{out}}{T_{space}}$$

we replace the values in the equation

$$\Delta S_{space} = -\frac{180\,KJ}{263\,K} \longrightarrow \Delta S_{space} = -0.6844\frac{KJ}{K}$$

part (c)

the total entropy change for this process

$$\Delta S_{total} = \Delta S_{refrid.} + \Delta S_{space}$$

we replace the values in the eq^n

$$\Delta S_{total} = 0.70754\frac{KJ}{K} - 0.6844\frac{KJ}{K}$$

$$\Longrightarrow \Delta S_{total} = 0.02314\,KJ/K$$