2017

MADE EASY WORKBOOK

Detailed Explanations of Try Yourself *Questions*

Mechanical Engineering

Refrigeration and Air-conditioning

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1 Heat Engine, Heat Pump, Refrigerator and Reversed Carnot Cycle

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$(COP)_{RE} = (COP)_{HP} - 1 = 4 - 1 = 3$$

$$(COP)_{RE} = \frac{\text{Required cooling effect}}{\text{Power input}}$$

$$\Rightarrow \quad \text{Required cooling effect} = 3 \times 3 = 9 \text{ kW}$$

$$= 9 \times 60 \text{ kJ/min}$$

$$= 540 \text{ kJ/min}$$

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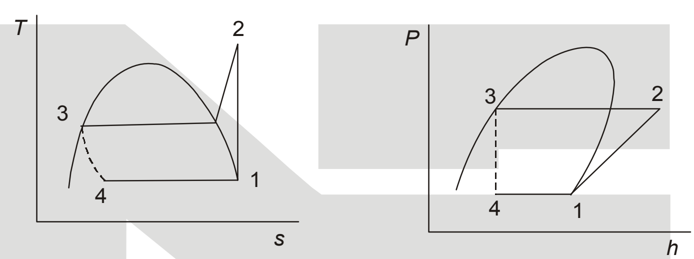
2 Vapour Compression Refrigeration System

Detailed Explanation of Try Yourself Questions

T1 : Solution



From table

$$h_1 = 183.2 \text{ kJ/kg}$$
$$h_2 = 222.6 \text{ kJ/kg}$$
$$h_3 = h_4 = 84.9$$ [3 to 4 is an Isenthelpic process]

$$V_s = \frac{1.5}{1000} \text{ m}^3$$

$$N = 1600 \text{ m}^3$$

$$\eta_{vol.} = 80\% = \frac{80}{100} = 0.8$$

$$\eta_{vol.} = \frac{\dot{m}V_1}{Vs \times \frac{N}{60}}$$

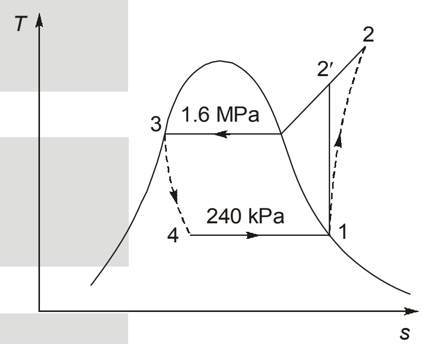
$$\therefore \quad \frac{80}{100} = \frac{\dot{m} \times 0.0767}{\frac{1.5}{1000} \times \frac{1600}{60}}$$

$$\dot{m} = \frac{80}{100} \times \frac{1.5}{1000} \times \frac{1600}{60} \times \frac{1}{0.0767} = 0.4172 \text{ kg/s}$$

$$\text{R.E.} = \dot{m}[h_1 - h_2]$$

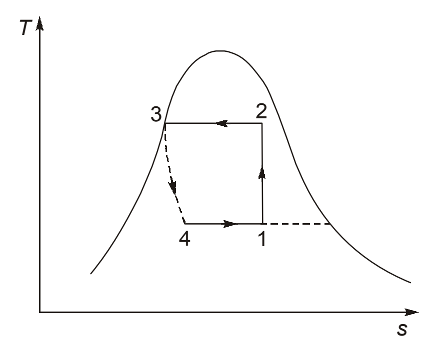
$$= 0.4172 \times [222.6 - 183.2] = 16.437 = 16.44 \text{ kW}$$

T2 : Solution



$$h_4 = h_3 = 134 \text{ kJ/kg}$$
$$h_1 = 244 \text{ kJ/kg}$$
$$h_{2'} = 285 \text{ kJ/kg}$$
$$h_2 = h_1 + \frac{h_{2'} - h_1}{\eta_{comp.}}$$
$$= 244 + \frac{285 - 244}{0.85} = 292.2 \text{ kJ/kg}$$
$$Q_R = (h_2 - h_3) = 292.2 - 134$$
$$= 158.2 \text{ kJ/kg}$$
$$W_{input} = h_2 - h_1 = 292.2 - 244$$
$$= 48.2 \text{ kJ/kg}$$
$$\text{COP} = \frac{Q_R}{W_{input}} = \frac{158.2}{48.2} = 3.2821$$

T3 : Solution



$$s_1 = s_{f_1} + \frac{x_1 h_{fg_1}}{T_1}$$
$$= 0.5443 + \frac{x_1 \times 1297.68}{263}$$
$$= 0.5443 + 4.934x_1$$
$$s_2 = s_{f_2} + \frac{x_2 h_{fg_2}}{T_2}$$

$$= 1.2037 + \frac{0.95 \times 1145.8}{303}$$

$$= 4.796$$

$$0.5443 + 4.934\, x_1 = 4.796$$

$$x_1 = 0.86$$

$$h_1 = h_{f_1} + x_1 h_{fg_1}$$

$$= 135.37 + 0.86 \times 1297.68$$

$$= 1251.4 \text{ kJ/kg}$$

$$h_2 = h_{f_2} + x_2 h_{fg_2}$$

$$= 323.08 + 0.95 \times 1145.8$$

$$= 1411.6 \text{ kJ/kg}$$

We know that theoretical C.O.P.

$$= \frac{h_1 - h_{f_3}}{h_2 - h_1} = \frac{1251.4 - 323.08}{1411.6 - 1251.4} = 5.8$$

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3 Vapour Absorption Refrigeration System

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$\text{COP} = \frac{T_G - T_0}{T_G} \times \frac{T_R}{T_0 - T_R}$$

T_R = Evapourator Temperature
T_G = Generator Temperature
T_0 = Ambient Temperature (condenser temperature)

$$\text{COP} = \frac{360 - 310}{360} \times \frac{260}{310 - 260}$$

$$= 0.72$$

$$0.72 = \frac{T_G - 310}{T_G} \times \frac{250}{310 - 250}$$

$$T_G = 374.9 \text{ K}$$

4 Refrigerants

Detailed Explanation of Try Yourself Questions

T1 : Solution

R-502 is an azeotrope. A azeotrope a mixture of two or more refrigerants in which the liquid and vapour have same composetion at equilibrium. Azeotropes behaves like pure component refrigerants because there is no change in boiling temperature or shift in composition during phase change, equipment operation or leakage.

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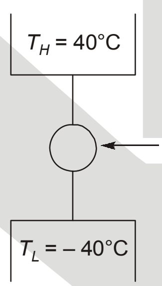
5 Refrigeration Equipment and Gas Refrigeration

Detailed Explanation of Try Yourself Questions

T1 : Solution



Initial COP

$$= \frac{-40 + 273}{40 - (-40)}$$

$$= \frac{230}{80} = 2.9125$$

$$\text{Final COP} = 3.5$$

Let the change in higher temperature and lower change be "ΔT".

$$\text{New higher temperature} = T_h - \Delta T$$

$$\text{New lower temperature} = T_L + \Delta T,$$

$$[\text{COP}]_{\text{final}} = \frac{T_L + \Delta T}{(T_H - \Delta T) - (T_L + \Delta T)}$$

$$3.5 = \frac{233 + \Delta T}{(40 - \Delta T) - (-40 + \Delta T)}$$

$$3.5 = \frac{233 + \Delta T}{80 - 2\Delta T}$$

$$280 - 7\Delta T = 233 + \Delta T$$

$$280 - 233 = 7\Delta T + \Delta T$$

$$\Delta T = \frac{47}{8} = 5.875°C$$

Hence new higher temperature $= 40 - 5.875 = 34.125°C$

$= 307.125$ K

New lower temperature $= -40 + 5.875$

$= -34.125°C$

$= 238.875°C$

Checking

$$\text{New COP} = \frac{(T_L)_{NEW}}{(T_H)_{NEW} - (T_L)_{NEW}}$$

$$= \frac{238.875}{307.125 - 238.875} = 3.5$$

6 Air-conditioning

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$P_{atm} = 1 \text{ bar} = 100 \text{ kPa}$$
$$\text{DBT} = 30°\text{C}$$
$$\phi = 70\% = 0.7$$
$$P_{vs} = 4.25 \text{ kPa}$$

Specific humidity, $\omega = ?$

$$\phi = \frac{P_v}{PV_s}$$
$$0.07 = \frac{P_v}{4.25}$$
$$P_v = 2.975 \text{ kPa}$$

Specific humidity,

$$\omega = 0.622 \times \frac{P_v}{P - P_v} = 0.622 \times \frac{2.975}{100 - 2.975}$$
$$= 00.0191 \frac{\text{kg water vapour}}{\text{kg dry air}}$$

T2 : Solution

$$\text{Wet bulb depression at the inlet} = (t_{db} - t_{wb})_{\text{inlet}} = (38 - 18)_{\text{inlet}} = 20°\text{C}$$
$$\text{Wet bulb depression at the outlet} = (24 - 18) = 6°\text{C} \quad (\because t_{wb \text{ inlet}} = t_{wb \text{ exit}})$$
$$\text{Percentage change} = \frac{20 - 6}{20} = 70\%$$

T3 : Solution

$$\text{Inlet bulb depression at inlet} = DBT_1 - WBT_1$$

$$\text{Range} = T_{w1} - T_{w2}$$

$$\text{Approach} = T_{w2} - WBT_1$$

$$\text{Sum of range and approach} = T_{w1} - T_{w2} + T_{w2} - WBT_1$$

It is said wet bulb depression at inlet is equal to seem of approach and range

$$\therefore \quad DBT_1 - WBT_1 = T_{w1} - T_{w2} + T_{w2} - WBT_1$$

$$DBT_1 = T_{w1}$$

$$\therefore \quad DBT_1 - T_{w1} = 0$$

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