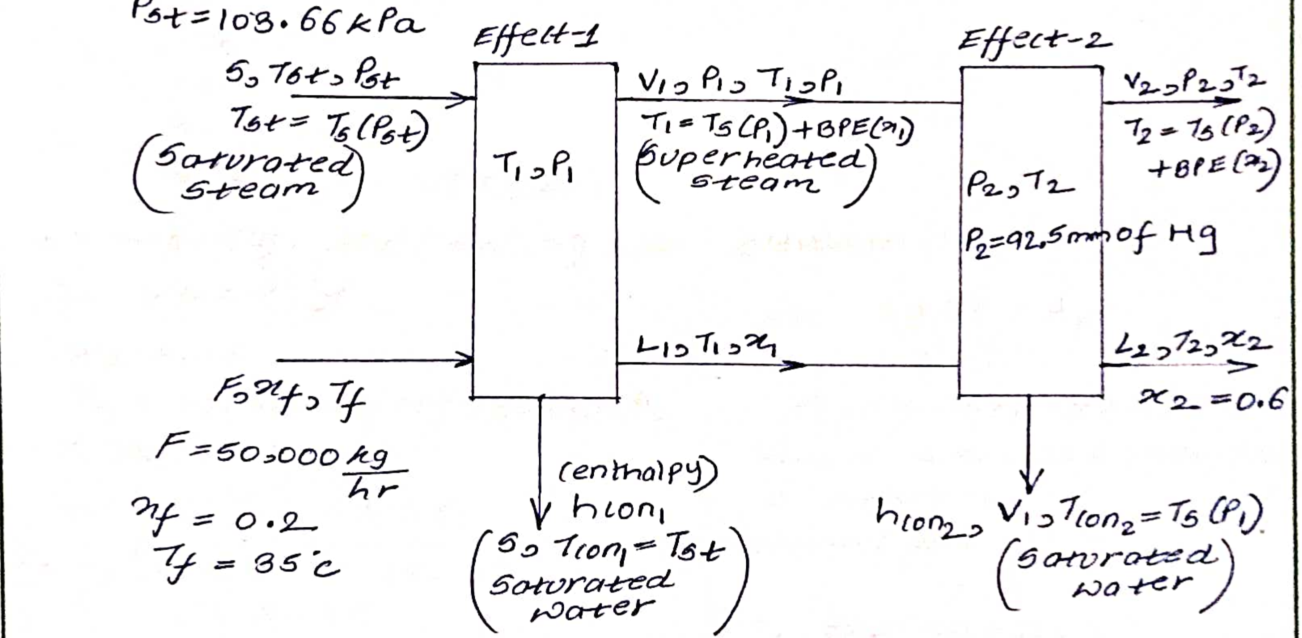
DATE 4/11/23 | PED-1 Assignment-4 Group-1 | SHEET NO.

21CH30027, 21CH10077, 21CH8FP60

Design of 2 effect evaporator,



Mass balance on effect 1,

$$F = V_1 + L_1 = \frac{50,000}{3600} \quad --- (1)$$

$$F x_f = L_1 x_1 = 2.78 = L_1 x_1 \quad --- (2)$$

Mass balance on effect 2,

$$L_1 = V_2 + L_2 \quad ---- (3)$$

$$L_1 x_1 = L_2 x_2 \quad --- (4)$$

Mass balance on entire system,

$$F + \cancel{S} = \cancel{S} + V_1 + V_2 + L_2$$

$$F = V_1 + V_2 + L_2 \quad ---- (5)$$

Assuming, $V_1 = V_2 \quad --- (6)$

solving, ①, ②, ③, ④, ⑤ & 6 :-

$F = 13.889$ kg/sec

$L_2 = 4.63$ kg/sec

$x_2 = 0.6$

$L_1 = 9.26$ kg/sec

$x_1 = 0.298$

$V_1 = V_2 = 4.63$ kg/sec

Estimating BPE (Boiling point elevations),

for effect-2,

$x_2 = 0.6$

$P_2 = 92.5$ mm of Hg $\equiv 0.012$ MPa

$T_S(P_2) = 49.415°C$

$T_{actual}(P_2) = 57.6$.

$\therefore$ $\boxed{\begin{aligned} BPE &= 57.6 - 49.415 \\ &= 8.185 \\ T_2 &= 57.6 \end{aligned}}$

for effect-1,

$x_1 = 0.298$

$P_1, T_1 \Rightarrow$ not known.

From BPE table provided in question.

average BPE at $x = 0.298$
$= 2.5$

$\therefore$ BPE$(x_1) = 2.5$.

$$\Sigma BPE = BPE(x_2) + BPE(x_1) = 8.185 + 2.5 = 10.685°C$$

$$\Delta T_{ov} = T_S(P_{steam}) - T_S(P_2) = 99.606 - 49.415 = 50.191°C$$

$$(\Delta T_{eff})_{total} = \Delta T_{ov} - \Sigma BPE = 50.191 - 10.685 = 39.506°C$$

$$(\Delta T_{eff})_1 + (\Delta T_{eff})_2 = 39.506 \quad --- ⑦$$

Assuming equal rate of heat transfer and area of heat transfer in effects 1 & 2,

$$U_1(\Delta T_{eff})_1 = U_2(\Delta T_{eff})_2 \quad --- ⑧$$

Solving (7) & (8),

$(\Delta T_{eff})_1 = 13.72\,^\circ C \qquad (\Delta T_{eff})_2 = 25.79\,^\circ C$

$(\Delta T_{eff})_1 = 13.72 = T_{S+} - T_S(P_1) - BPE(x_1)$

$T_1 = T_S(P_1) + BPE(x_1) = 85.89\,^\circ C$

$\therefore \; T_S(P_1) = 83.39\,^\circ C$

$P_1 = 0.0535\,MPa$ ---- from steam table.

for effect-1,

$P_1 = 0.0535\,MPa \qquad T_f = 35\,^\circ C \qquad L_1 = 9.26\,kg/s$

$T_S(P_1) = 88.89\,^\circ C \qquad T_1 = 85.89\,^\circ C \qquad V_1 = 4.63\,kg/s$

Enthalpy balance,

$T_{ref} = T_1$

$$Sh_g + Fc_p(T_f - T_1) = Sh_f + V_1 h_{V_1} + \cancel{L_1 c_p (T_1 - T_1)}^{\,0}$$

$$S\lambda + Fc_p(T_f - T_1) = \cancel{Sh_f} + V_1 h_{V_1}$$

$$2257.45 + 13.89 \times (4.18 + 2.42 \times 0.2) \times (35 - 85.89) = 4.63 \times 2652.6$$

------ λ, h_{V_1} taken from steam table.

Solving for S we get,

$S = 6.9\,kg/sec$.

Calculating A_1 & A_2,

$$A_1 = \frac{S\lambda_S}{U_1 (\Delta T_{eff})_1} = \frac{6.9 \times 2257.4}{2.350 \times 13.72} = 483.098\,m^2$$

$$A_2 = \frac{V_1 (h_{V_1} - h_{con_2})}{U_2 (\Delta T_{eff})_2} = \frac{4.63\,(2652.6 - 345)}{1.25 \times 25.79} = 331.421\,m^2$$

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

$$\left|\frac{A_1 - \frac{(A_1+A_2)}{2}}{}\right| \times 100 > 5\%$$

$\therefore$ $(\Delta T_{eff})_1$ & $(\Delta T_{eff})_2$ needs to be recalculated,

$$\sum \frac{q_i}{U_i} = \frac{q_1}{U_1} + \frac{q_2}{U_2} = \frac{S\lambda_S}{U_1} + \frac{V_1(h_{V_1} - h_{10m_2})}{U_2} = 15175.46$$

$$(\Delta T_{eff})_{1new} = \frac{(\Delta T_{eff})_{tot} \times \frac{q_1}{U_1}}{15175.46} = 17.25°C$$

$$(\Delta T_{eff})_{2new} = \frac{(\Delta T_{eff})_{tot} \times \frac{q_2}{U_2}}{15175.46} = 22.25°C$$

$$(\Delta T_{eff})_{1new} = T_{steam} - T_1$$

$$\boxed{T_1 = 99.606 - 17.25 = 82.356°C}$$

$$T_1 = T_S(P_1) + BPE(x_1)$$

$$\boxed{T_S(P_1) = 82.356 - 2.5 = 79.856}$$

enthalpy balance 1,

$$S\lambda + F(C_{PW} + 0.2C_{PG})(T_f - T_1) = V_1 \times h_{V_1}$$

$$h_{V_1} = h(T_1, P_1)$$

$$2257.45 + 13.89(4.18 + 0.2 \times 2.42)(35 - 82.356) = V_1 \times 2647$$

--- values taken from steam table.

$$2257.45 - 3069.85 = 2647 V_1 \quad \text{---} \; (9)$$

P.R.E.

energy balance of effect-2,

$$T_{ref} = T_1$$

$$V_1 h_{V_1} + L_1 C_p (\cancel{T_1 - T_1})^{0} = V_1 h_{con2} + L_2 C_p (T_2 - T_1) + V_2 h_{V_2}$$

$$h_{con_2} = h(P_2, T_S(P_2))$$

$$2647 V_1 = V_1 \times 206.91 + 4.63(4.18 + 0.6 \times 2.42)(57.6 - 82.356) + 2606.6 V_2$$

$$2440.1 V_1 = 2606.6 V_2 - 646.54 \quad \text{----} \quad (10)$$

$$V_1 + V_2 = 9.26 \quad \text{---} \quad (11)$$

solving (9) - (11),

$V_1 = 4.65$ kg/sec

$V_2 = 4.6$ kg/sec

$S = 6.82$ kg/sec

$$q_1 = S\lambda_S$$

$$A_1 = \frac{q_1}{U_1 (\Delta T_{eff})_{1new}} = \frac{2257.4 \times 6.82}{2.35 \times 17.25} = 379.78 m^2$$

$$q_2 = V_1 (h_{V_1} - h_{con_2}).$$

$$A_2 = \frac{q_2}{U_2 (\Delta T_{eff})_{2new}} = \frac{2440.1 \times 4.65}{1.25 \times 22.25} = 407.96 m^2$$

$$\left| A_1 - \left(\frac{A_1 + A_2}{2}\right) \right| \times 100 \quad \& \quad \left| A_2 - \left(\frac{A_1 + A_2}{2}\right) \right| \times 100 \leq 5\%$$

$\therefore$ $A_1 = 379.78 m^2$ $\quad$ $A_2 = 407.96 m^2$

$V_1 = 4.65$; $V_2 = 4.6$; $S = 6.82$ kg/sec

P.T.O. →

$\cancel{A}_1 = V_2 + L_2 = 4.6 + 4.63 = 9.23$

$\boxed{L_1 = 9.23\ kg/sec}$

$\boxed{x_1 = \frac{2.78}{9.23} = 0.301}$

$\boxed{\begin{array}{l} P_1 = 0.046\ MPa \\ T_1 = 82.356\ ^\circ C \end{array}}$