Tomoki Koike | HW 16 | 3175 | 1

(i) GIVEN

reservoir → pump → storage tank system

» $p_1 = 1$ bar, $T_1 = 15°C$, $\dot{m}_1 = 1.5$ kg/s

» $p_2 = 3$ bar $T_2 \approx 15°C$ (since $T \approx$ const.)

» $\Delta KE = 0$

» $\dot{Q} = 0$, $g = 9.81$ m/s²

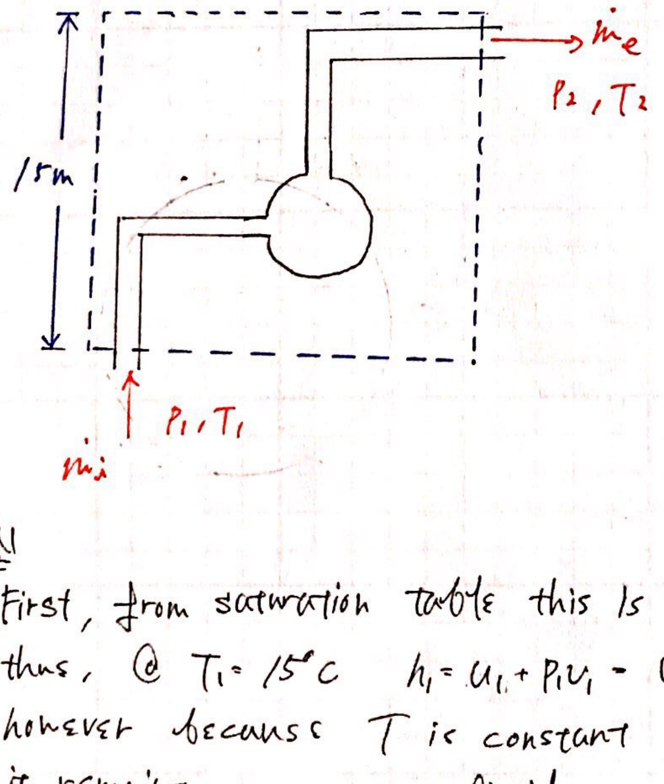
» $h = 15m$ (from reservoir to tank)

FIND power $\dot{W}$ required by pump, in kW

ASSUMP
- open sys.
- SSSF
- uniform flow
- $\Delta KE = 0$
- $\dot{Q} = 0$
- $T \approx$ const.

EQN
- $\cancel{\frac{dm}{dt}}\Big|_{sys}^{0} = \sum \dot{m}_i - \sum \dot{m}_e$
- $\cancel{\frac{dE}{dt}}\Big|_{sys}^{0} = \cancel{\dot{Q}}^{0} - \dot{W} + \sum_i \dot{m}(h+pe+\cancel{ke}^{0}) - \sum_e \dot{m}(h+pe+\cancel{ke}^{0})$
- $pe = gh$

EFD



SOLN

First, from saturation table this is a compressed liquid

thus, @ $T_1 = 15°C$ $h_1 = u_1 + p_1 v_1 = u_{f1} + p_1 v_{f1}$

however because T is constant and throughout the system it remains a compress liquid so

$$h_2 = u_2 + p_2 v_2 = u_{f1} + p_2 v_{f1}$$

where $v_{f1} = 0.001009\ \frac{m^3}{kg}$

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now $\dot{m} = \dot{m}_i = \dot{m}_e = 1.5 \ kg/s$

and

$$pe_1 = g \cdot 0 = 0$$

$$pe_2 = gh = (9.81 \ \frac{m}{s^2})(15 m) = 147.15 \ \frac{m^2}{s^2}$$

therefore

$$0 = -\dot{W} + \dot{m}(u_{f1} + p_1 v_{f1} + pe_1) - \dot{m}(u_{f1} + p_2 v_{f2} + pe_2)$$

$$\dot{W} = \dot{m} v_{f1}(p_1 - p_2) - \dot{m} pe_2$$

$$= (-300.27 - 147.15) W$$

$$\approx -520.9 \ W$$

$$= -0.5209 \ kW$$

$$\boxed{\dot{W} = -0.521 \ kW}$$

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(ii) GIVEN

Steady State Condenser (Sat. vap → Sat. liquid)

>> Sat. vap → Sat. liquid

* $\dot{m}_1 = 2\times10^5$ kg/h , $P_1 = 0.1$ bar , $P_2 = 0.1$ bar

>> river water

* up-stream vol-flow-rate $\equiv \dot{V}_3 = 2\times10^5$ m³/h $T_3 = 15°C$

FIND

(a) river-water temp. rise ΔT, in °C.

(b) comment on industrial impact of industrial plant.

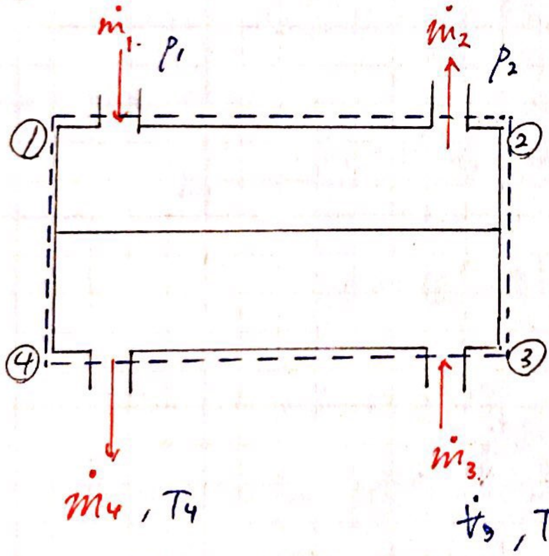
ASSUMP

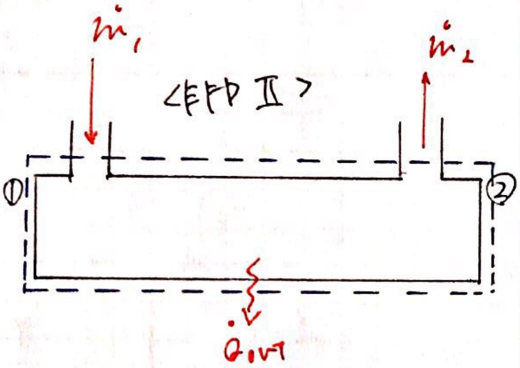
- open sys.
- SSSF
- uniform flow
- $\Delta PE = \Delta KE = 0$
- $\dot{W} = 0$

EQN

- $\cancelto{0}{\frac{dm}{dt}\Big|_{sys}} = \sum \dot{m}_i - \sum \dot{m}_e$
- $\cancelto{0}{\frac{dE}{dt}\Big|_{sys}} = \dot{Q} - \cancelto{0}{\dot{W}} + \sum_i \dot{m}(h + \cancelto{0}{pe} + \cancelto{0}{ke}) - \sum_e \dot{m}(h + \cancelto{0}{pe} + \cancelto{0}{ke})$

EFD





SOLN

at inlet ①, sat. vap of $P_1 = 0.1$ bar is entering,
from saturation table $h_1 = 2582.4$ kJ/kg

at outlet ②, sat. liquid of $P_2 = 0.1$ bar is exiting
from table

$h_2 = 188.43$ kJ/kg

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then, considering mass flow conservation

for <EFD II> $\cancelto{0}{\left.\frac{dE}{dt}\right|_{sys\,II}} = \dot{Q} - \cancelto{0}{\dot{W}} + \sum_i \dot{m}(h + \cancelto{0}{pe} + \cancelto{0}{ke}) - \sum_e \dot{m}(h + \cancelto{0}{pe} + \cancelto{0}{ke})$

however, for <EFD I>

$$\cancelto{0}{\left.\frac{dE}{dt}\right|_{sys\,I}} = \cancelto{0}{\dot{Q}} - \cancelto{0}{\dot{W}} + \sum_i \dot{m}(h + \cancelto{0}{pe} + \cancelto{0}{ke}) - \sum_e \dot{m}(h + \cancelto{0}{pe} + \cancelto{0}{ke})$$

so from <EFD I>

$$0 = \dot{m}_1 h_1 + \dot{m}_3 h_3 - \dot{m}_2 h_2 - \dot{m}_4 h_4 \quad \cdots (*1)$$

now we must find out h_3, h_4, $\dot{m}_3$

because $\dot{m}_1 = \dot{m}_2$, $\dot{m}_3 = \dot{m}_4$

and $\dot{m}_3 = \dfrac{\dot{V}_3}{v_3}$

from saturated table $v_3 \approx v_f(T_3) = 0.0010009 \ m^3/kg$

$$\dot{m}_3 = \left(\frac{2\times10^5 \ m^3}{h}\right)\left(\frac{kg}{0.0010009 \ m^3}\right) \simeq 1.9982\times10^8 \ \frac{kg}{h}$$

and $h_3 \approx h_f(T_3) = 62.981 \ kJ/kg$

thus, from (*1)

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

$$= \left(\frac{2\times10^5 \ kg}{h}\right)\frac{\left[(2582.4 - 188.43) \ kJ/kg\right]}{1.9982\times10^8 \ kg/h} + 62.981 \ kJ/kg$$

$$\cong 65.377 \ kJ/kg$$

from the saturation table using interpolation of data

between $T_3 = T_\alpha = 15°C$ and $T_\beta = 16°C$

$$h_\alpha = 62.981 \ kJ/kg \quad \text{and} \quad h_\beta = 67.170 \ kJ/kg$$

$$h_4 = (T_4 - T_3)\left(\frac{h_\beta - h_\alpha}{T_\beta - T_\alpha}\right) + h_\alpha$$

since $T_4 - T_3 = \Delta T$

$$\Delta T = (h_4 - h_\alpha)\frac{(T_\beta - T_\alpha)}{(h_\beta - h_\alpha)} = \left[(65.377 - 62.981)\frac{kJ}{kg}\right]\frac{(16 - 15)°C}{(67.170 - 62.981) \ kJ/kg}$$

$\Delta T \cong 0.5719\ ^\circ C$

$\boxed{\Delta T = 0.572}$

(b)

By the rise of water temperature caused by the industrial plant will lead to the deoxidation of the river. This is because at higher temperatures oxygen will less likely dissolve in water.

This threats the fish, planktons, and other creatures habitating the river, which ultimately will kill them and collapse the ecosystem of the river.

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