40/40

Name: Nasser Abbasi

Course: MAE 91

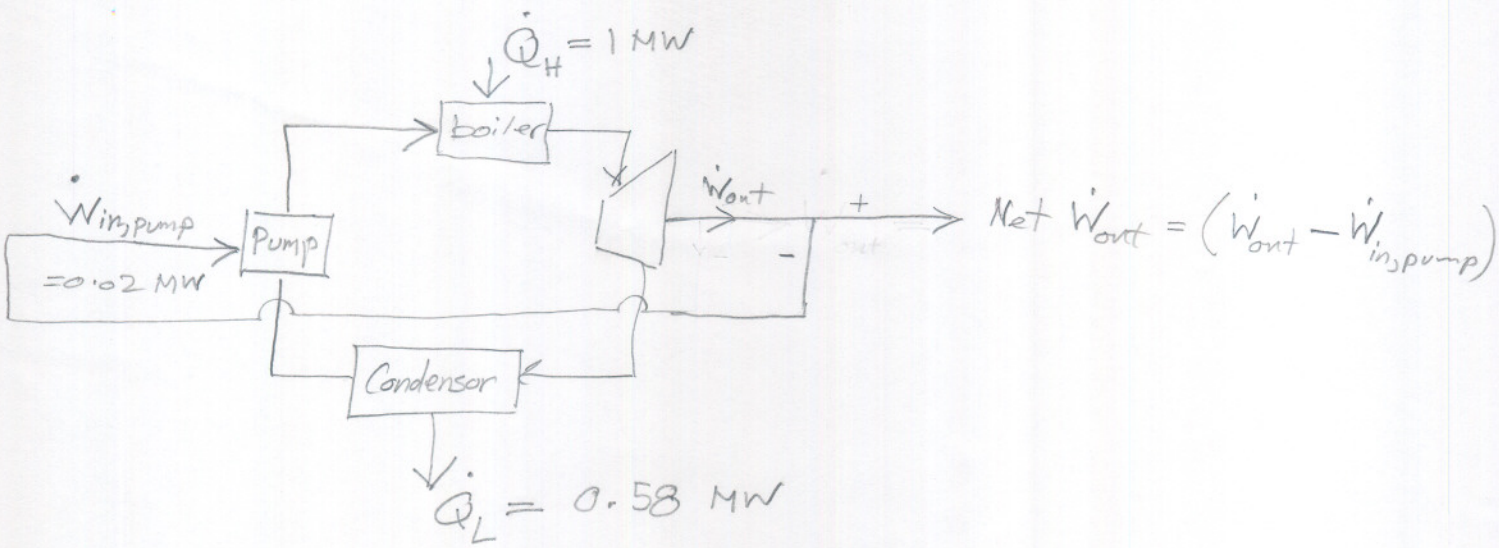
Set : #5

date : August 3, 2004

Problem 7.26 10/10

statment

Given the following steam plant



find plant thermal efficiency η.

if everything is reversed, find COF or β of new system as a refrigerator?

Assumption

Work to drive the pump is "charged" against plant output. No change in final answer if we assume power to run pump is from external source. we have to pay for power to run pump from somewhere anyway.

Laws

thermal efficiency $\eta = \dfrac{\text{Net Work output from plant}}{\text{Total heat energy input}}$

$COF = \beta = \dfrac{\text{Total Heat energy removed from refrigerator}}{\text{Net Work used}}$

Energy eqution for plant: $\boxed{\dot{Q}_H + \dot{W}_{in,pump} = \dot{W}_{out} + \dot{Q}_L}$ →

ie $\boxed{\dot{W}_{net\ output} = \dot{Q}_H - \dot{Q}_L}$

Net power output

Step ②

$$\eta = \frac{(\dot{W}_{out} - \dot{W}_{in,pump})}{\dot{Q}_H}$$

but $\dot{W}_{out} = \dot{Q}_H + \dot{W}_{in,pump} - \dot{Q}_L$ (from plant energy eq.)

so
$$\boxed{\eta = \frac{\dot{Q}_H - \dot{Q}_L}{\dot{Q}_H}} \quad \text{— ①}$$

$$\beta = \frac{\dot{Q}_L}{\dot{W}_{out} - \dot{W}_{in,pump}} = \boxed{\frac{\dot{Q}_L}{\dot{Q}_H - \dot{Q}_L}} \quad \text{— ②}$$

Numerical

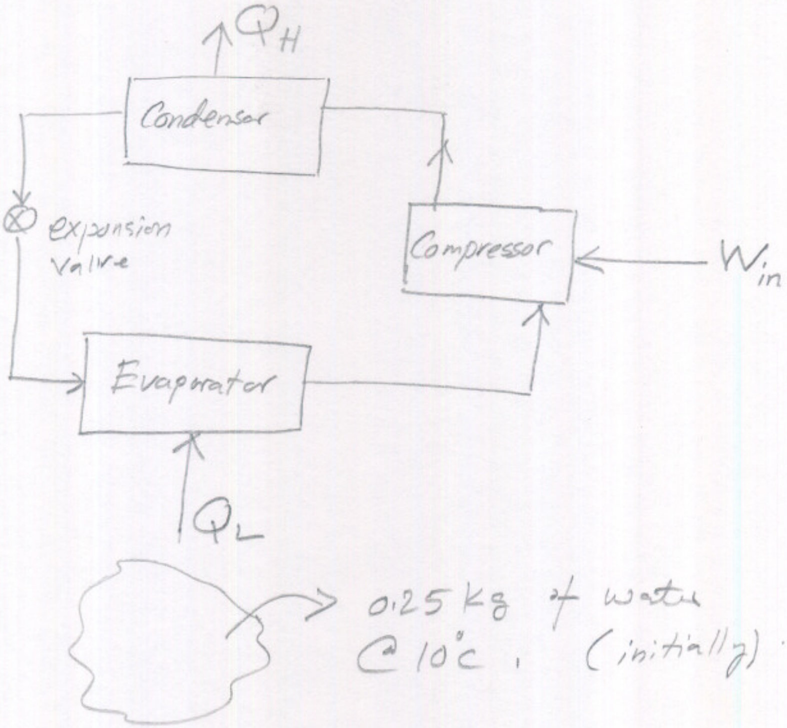
from ①, $\eta = \frac{1 - 0.58}{1} = \boxed{0.42}$

from ② $\beta = \frac{0.58}{1 - 0.58} = \frac{.58}{.42} = \boxed{1.3809}$

problem 7.30 8/10

statment

$\beta = 3.5$



given that compresser runs at 750 W, find W_{in} needed to cool down the water from 10°C to become ice. also find time it takes.

Assumptions

all power is used for cooling water to ice.

Laws

$U_2 - U_1 = {}_1Q_2 - {}_1W_2$ energy eq needed for cooling water to ice. as 1st Law thermodynamics for control mass.

$\beta = \frac{Q_L}{W_{in}}$

time $= \frac{W}{\dot{W}}$ or $\frac{\text{work}}{\text{power}}$

using refrigerator equation:

$$\beta = \frac{Q_L}{W_{in}} \Rightarrow \boxed{W_{in} = \frac{Q_L}{\beta}} \quad \text{——— (1)}$$

β is given, so need to find Q_L.

Q_L is amount of heat energy removed from water to convert it to ice.

water @ 10°C —— Remove heat at constant P ——> ice @ T = 0.01°C

state (1) state (2) ice phase.

notice $_1W_2 = 0$ since no work done here.

Since mass is same in state (1) and (2), then only thing that change is the internal energy.

$$\boxed{{}_1Q_2 = Q_L = m(u_2 - u_1)} \quad \text{~~(= m(h_2 - h_1))~~ O.K.} \quad \text{——— (2)}$$

m → given

u_1 → Table B.1.1 using (T = 10°C), use u_f value.

u_2 → Table B.1.5 (saturated solid-vapor phase), using (T = 0.01°C) use u_f value.

now that Q_L is found, use eq (1) to find W_{in}.

but $$\boxed{\text{time} = \frac{W \ (J)}{\dot{W} \ (J/s)}} \quad \text{——— (3)}$$

W → calculated above.

$\dot{W}$ → given for compressor

So time is found. ——→

Numerical.

from eq ②

$Q_L = m(u_2 - u_1)$.

$u_1 = 41.99$ KJ/Kg (Table B.1.1, at T=10°c, use u_f).

$u_2 = -333.40$ KJ/Kg (Table B.1.5, T=0.01°c, using u_f).

$m = .25$ Kg (given).

so $\boxed{Q_L = -93.8475 \text{ KJ}}$

from eq. ①

$$W_{in} = \frac{Q_L}{\beta} = \frac{93.8475}{3.5} = \boxed{26.8135 \text{ KJ}}$$

note from point of View of water, heat energy is negative, since it is "Leaving". but from point of View of refrigator system, i.e evaporator Box, this energy is entering the system, that is why I used just the absolute value of Q_L in eq ①.

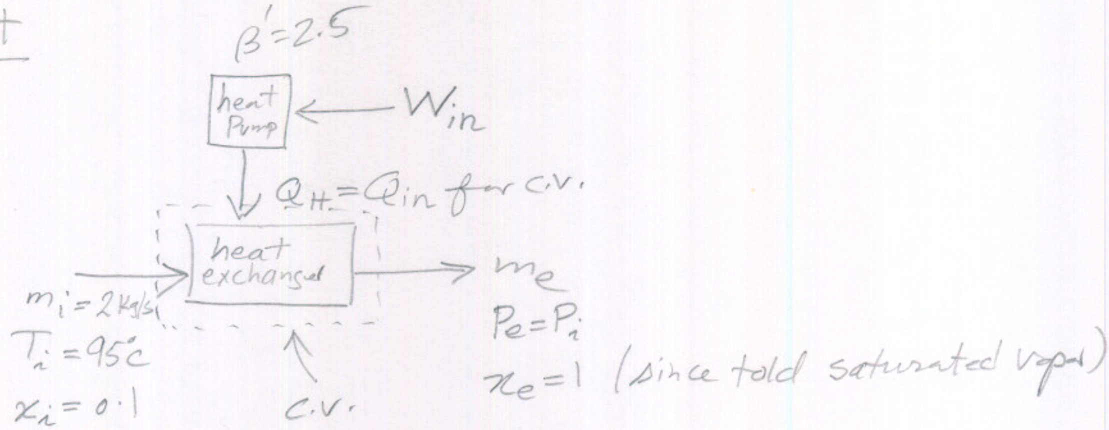
to find time, from eq ③

$$time = \frac{W_{in}}{\dot{W}_{compressor}} = \frac{26.8135 \times 10^3 \text{ (J)}}{750 \text{ (W)}} = \boxed{35.75 \text{ seconds}}$$

Problem 7.32

P/10

statment



R-12 at 95°C, $x = 0.1$, flows in at 2 kg/s, brought to saturated vapor in heat exchanger. $\dot{Q}_{in}$ is supplied by a heat pump $\beta' = 2.5$.

Find $\dot{W}_{in}$.

Assumptions

steady state for heat exchanger.

Laws

$$\beta' = \frac{Q_H}{W_{in}} = \frac{\dot{Q}_H}{\dot{W}_{in}}$$

Control volume 1st Law of thermodynamics

R-12 steam tables.

continuity equation $\dot{m}_i = \dot{m}_e$

Steps

need to find $\dot{Q}_{in}$ for heat exchanger.

this is the same as $\dot{Q}_H$.

use 1st Law on C.V. to find $\dot{Q}_{in}$, then

use $\dot{W}_{in} = \frac{\dot{Q}_H}{\beta'}$ to find $\dot{W}_{in}$ →

Looking at C.V.

$$\dot{Q}_{in} + \cancel{\dot{W}_{in}} + \dot{m}_i(\cancel{KE}+\cancel{PE}+h)_i = \cancel{\dot{Q}_{out}} + \cancel{\dot{W}_{out}} + \dot{m}_e(\cancel{PE}+\cancel{KE}+h)_e + \cancel{\frac{d}{dt}(E)_{cv}}$$

$$\Rightarrow \boxed{\dot{Q}_{in} + \dot{m}_i h_i = \dot{m}_e h_e}$$

so $\boxed{\dot{Q}_{in} = \dot{m}(h_e - h_i)}$ ——— ① since $\dot{m}_i = \dot{m}_e$ ∵ steady state.

$\dot{m}$ → given

h_i → Find using table B.3.1 (saturated R-12) using (T_i):
Find $h_f, h_{fg} \Rightarrow \boxed{h_i = h_f + x_i h_{fg}}$ ——— ②

h_e → Find using table B.3.1., use T_i, look up h_g

now that $\dot{Q}_{in}$ is found, $\boxed{\dot{W}_{in} = \frac{\dot{Q}_H}{\beta'}}$ ——— ③

Numerical

From Table B.3.1

$h_{f @ T=95°c} = 140.23$ KJ/Kg.

$h_{fg @ T=95°c} = 71.1$ KJ/Kg.

$h_{g @ T=95°c} = 211.94$ KJ/Kg $= h_e$

so from eq ②, $h_i = 140.23 + (0.1)(71.1) = \boxed{147.34 \text{ KJ/Kg}}$

from eq ① $\dot{Q}_{in} = \dot{m}(h_e - h_i) = 2(\text{Kg/s})(211.94 - 147.34) = \boxed{129.2 \text{ KW}}$

from eq ③ $\dot{W}_{in} = \frac{\dot{Q}_H}{\beta'} = \frac{129.2 \text{ KW}}{2.5} = \boxed{51.68 \text{ KW}}$

Problem 7.39 10/10

Statment

Consider following four cases of heat engines:

a. $\dot{Q}_H = 6KW$, $\dot{Q}_L = 4KW$ $\dot{W} = 2KW$

b. $\dot{Q}_H = 6KW$ $\dot{Q}_L = 0 KW$ $\dot{W} = 6KW$

c. $\dot{Q}_H = 6KW$ $\dot{Q}_L = 2KW$ $\dot{W} = 5KW$

d. $\dot{Q}_H = 6KW$ $\dot{Q}_L = 6KW$ $\dot{W} = 0KW$

and Find if any of those are PMM of first or second Kind.

Assumptions

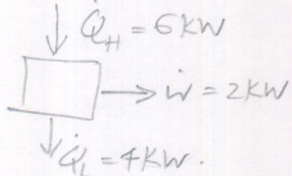
Laws

use These rules to decide: IF $\dot{Q}_H = \dot{W}$ Then PMM 2nd Kind.
IF $\dot{Q}_H < \dot{W} + \dot{Q}_L$ Then PMM 1st Kind.

- PMM of 1st Kind would violate 1st Law, i.e it will create more work + energy than energy used.
- PMM of 2nd Kind would violate 2nd Law. i.e it will generate all energy consumed to work with no waste.
- heat engine: uses heat energy to produce work.

steps.

a)



$\Rightarrow$ Since $\dot{Q}_H = \dot{W} + \dot{Q}_L \Rightarrow$ OK 1st Law.
since $\dot{Q}_H > \dot{W} \Rightarrow$ OK 2nd Law.

b) since all heat energy in was converted to work with no loss $\Rightarrow$ Violate 2nd Law. $\Rightarrow$ PMM 2nd Kind.
OK for 1st Law

c) sine $\dot{Q}_L + \dot{W} > \dot{Q}_H \Rightarrow$ energy was generated.
$\Rightarrow$ PMM 1st Kind.
but OK for 2nd Law

d) since $\dot{Q}_L + \dot{W} = \dot{Q}_H \Rightarrow$ OK for 1st Law.
since $\dot{Q}_H > \dot{W} \Rightarrow$ ok also for 2nd Law