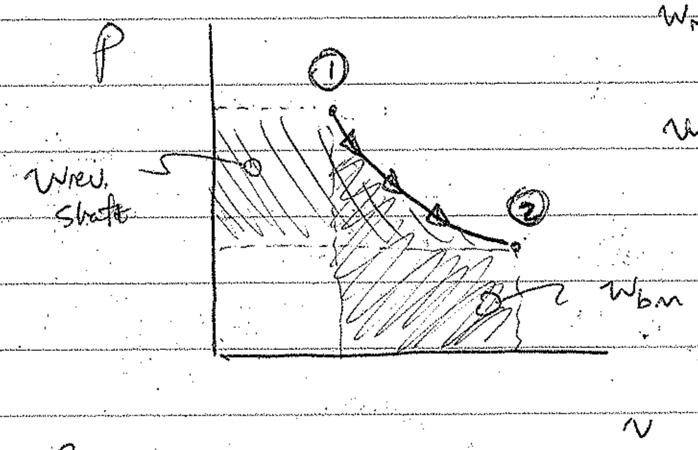
Ch. 11 Power & Refrigeration Systems

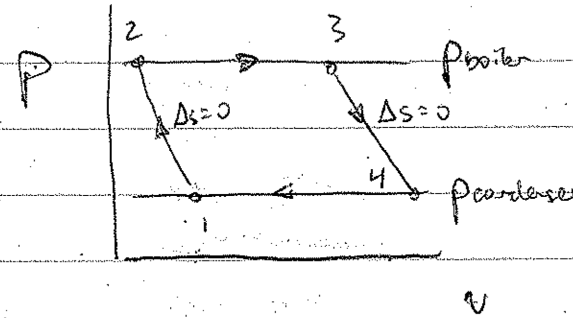
11.1 Power Systems

$w_{rev.\,shaft} = -\int v\,dp$ $dp \to 0,\ w \to 0$

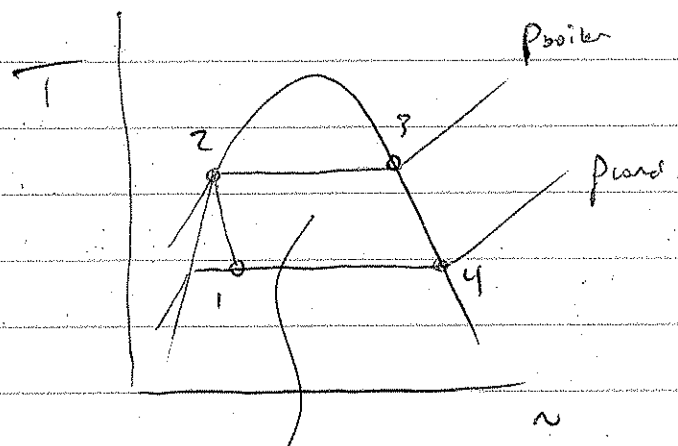
$w_{\substack{boundary\\movement}} = \int p\,dv$ $dv \to 0,\ w \to 0$



Reversible
Cycle:
- ① → ② pump / isentropic, $\Delta p > 0$, work in
- ② → ③ boiler / $\Delta p = 0$, Q_H
- ③ → ④ turbine / isentropic, $\Delta p < 0$, work out
- ④ → ① condenser / $\Delta p = 0$, Q_L



Note:

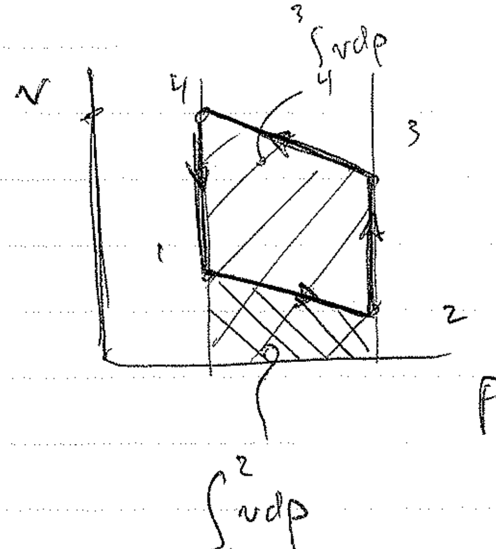


would be Carnot, since Q_H & Q_L would take place at T = const.

For the cycle:

$$w_{net} = -\int_1^2 v\,dp - \cancel{\int_2^3 v\,dp} - \int_3^4 v\,dp - \cancel{\int_4^1 v\,dp}$$

$$= -\int_1^2 v\,dp + \int_4^3 v\,dp$$



replot it

$w_{net} = \int_4^3 v\,dp - \int_1^2 v\,dp$

net area enclosed

same is true for piston-cylinder closed system.

11.2 Rankine Cycle (could be something besides steam)

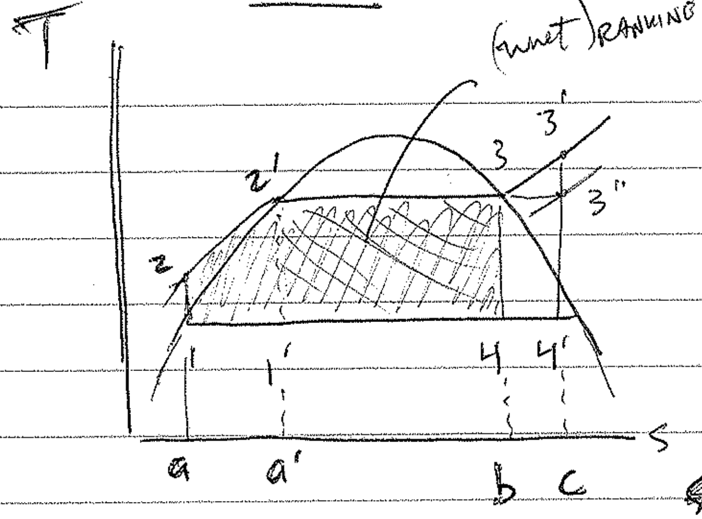
1 → 2 pump / liquid

2 → 3 boiler / liq. → SH vapor

3 → 4 turb / SH vap → sat. mix

4 → 1 cond. / sat. mix → cond. liq.

Ideal



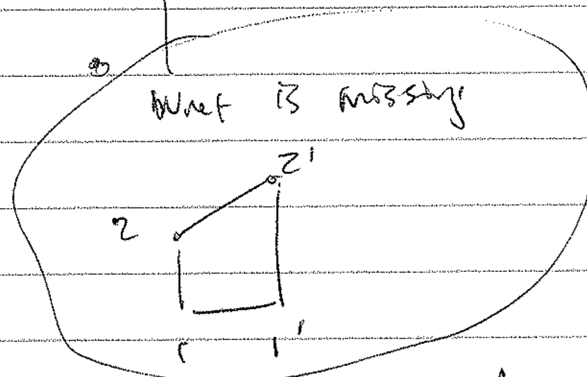
For Rankine (w/out superheat)

$q_H = a-2-2'-3-b-a$

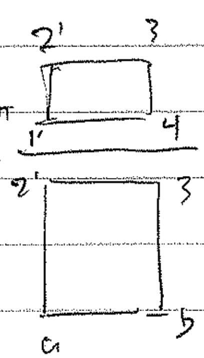
$q_H - q_L = 1-2-2'-3-b-a = w_{net}$

Carnot

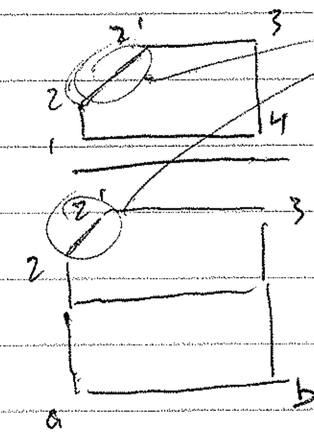
$q_H^C = a'-2'-3-b < q_H^R$



$\eta^{CARNOT} =$



$\eta^{RANKINE} =$



Always get lower

$\eta^{RANKINE} < \eta^{CARNOT}$

Real Carnot does not work practically

① 1' is sat. mix. – cannot actually pump this efficiently

② Cannot expand Carnot Cycle to super heat conditions easily! (i.e. go from 3 → 3")

decreasing pressure means we would do work while heating!

11.3

Effect of Press. & Temp. on Rankine

Ⓐ Lower exhaust pressure

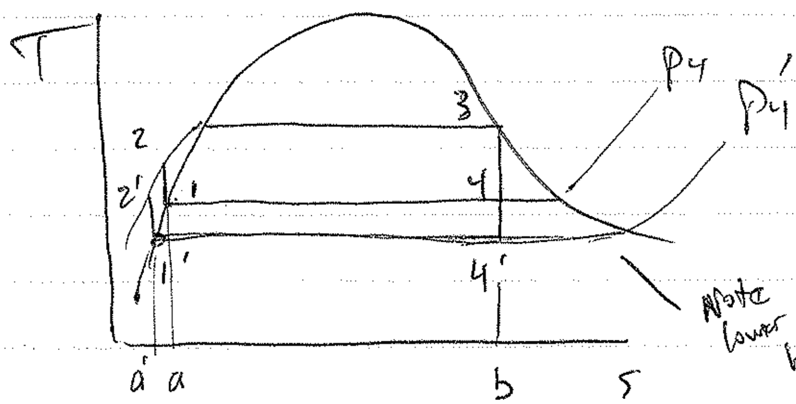


FIG. 11.4

Note lower temp heat rejection here!

$(q_H)_{ADDED} = a' - 2' - 2 - a - a'$

$(w_{net})_{ADDED} = 1 - 4 - 4' - 1' - 2' - 2 - 1$ Shaded in book

similar areas

$$\eta_{\text{lower press}} = \frac{w_{net} + (w_{net})_{ADDED}}{q_H + (q_H)_{ADDED}} \qquad \frac{x+c}{y+c}$$

improves efficiency!

Examples

30% ↑

$\frac{3+1}{10+1} = \frac{4}{11} = 0.363$

45% compar

$\frac{4+1}{10+1} = \frac{5}{11} = 0.4545$

(B) Superheat in Boiler - 11.5

$$\eta = \frac{w_{net}}{q_H} = \frac{\overbrace{(1-2-3-4-1) + (3-3'-4'-4-3)}^{\text{SH effect}}}{(a-1-2-3-4-b-a) + (a-1-2-3-3'-4'-b'-a)}$$

For 40% w/ no SH

$$\eta = \frac{4}{10} \qquad \eta_{SH} = \frac{4+1}{10+2} = \frac{5}{12} = 0.42$$

improves effic.

note, ave. temp. of heat add. is increased.

(C) Max. press. of steam - 11.6

3' same temp as 3, but higher pressure ...

lowers the quality

net work is about the same, but less heat is rejected ...

better efficiency

Summary

(1) Lower press. in condenser &

(2) Increase press. in boiler

(3) Superheat the steam

11.4 Reheating

↳ want high press. in boiler, but this causes ~~big~~ lower quality at turb. exit.

↳ Fig. 11.9

1-2-3-4-5-6-1

Note cannot just do 3-3'
because T is too high for metals
in boiler & turbine

11.5 Regeneration

pre-heat feed-water to boiler
so ave. temp. is higher

↓

use turbine vapor to do this...

↓

Feedwater heaters

See. Fig 11.12 → extraction rate into is just enough so that 3 is sat. liq.

allows higher press. heat add. → T_3 is inlet to boiler rather than T_2