UNIT-3

RANKINE WITH FEED WATER HEATING

Recap

- Concept and analysis of reheeating- and regeneration rankine cycle.
- Application of Reh-Reg rankine cycle.

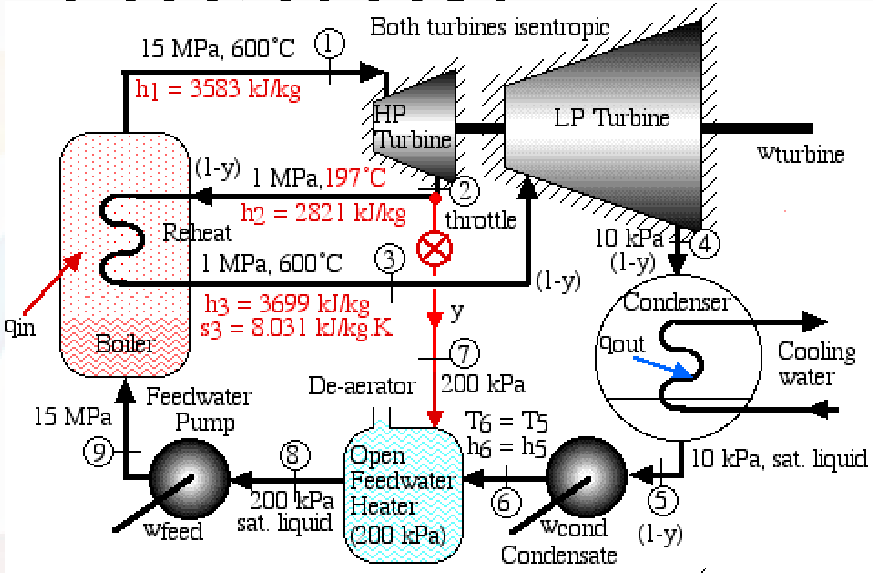
- **LEARNING OBJECTIVE OF LECTURE**

Students will be able to learn thermodynamics of feed water heating for regeneration purpose and its effect on rankine cycle performance..

Feedwater Heaters

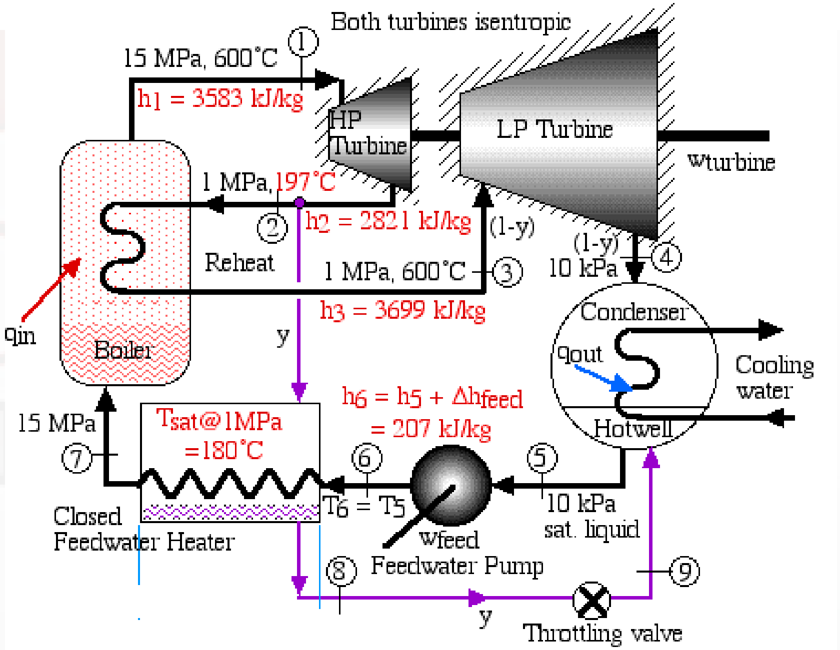
OPEN HEATERS

1. **The extracted steam mixes with feedwater** and both fluid leave at common temperature.
2. The advantages: lower cost, simplicity, and high heat transfer.
3. The disadvantage: more pumps.



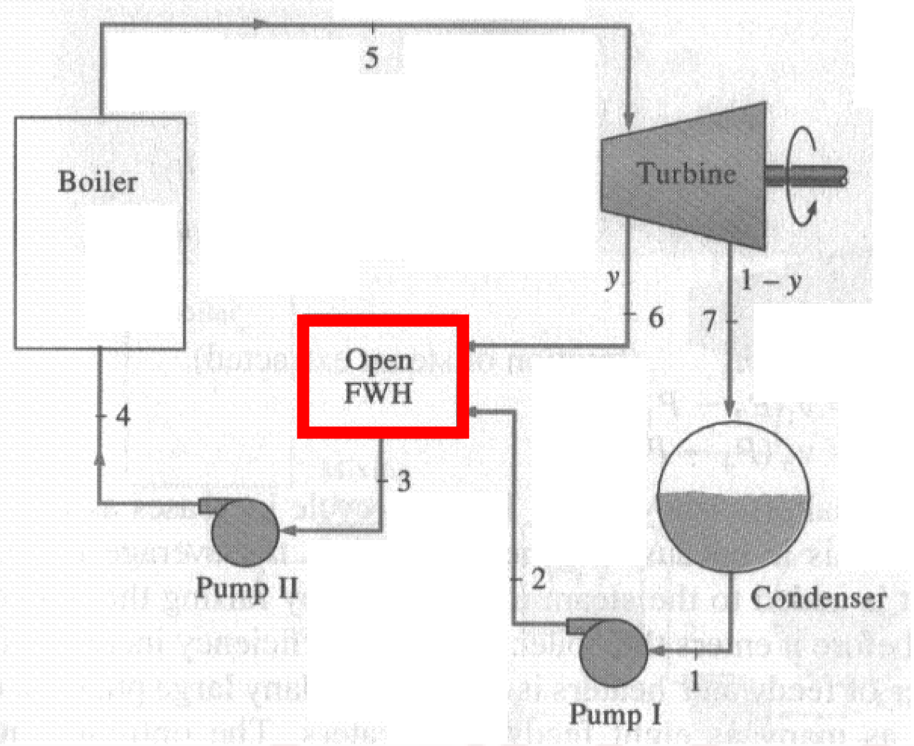
CLOSED HEATERS

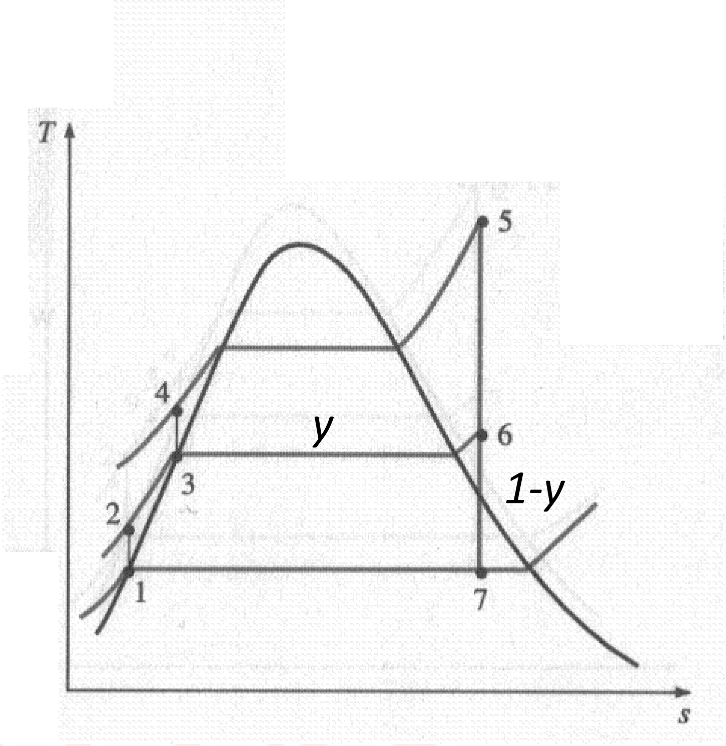
1. **Extracted steam and feedwater are kept separately**.
2. Closed heaters are shell-and-tube heat exchangers.
3. The advantages: no extra pump.
4. The disadvantage: complex, higher cost, lower heat transfer capacity.



http://www.ohio.edu/mechanical/thermo/Applied/Chapt.7_11/Chapter8b.html

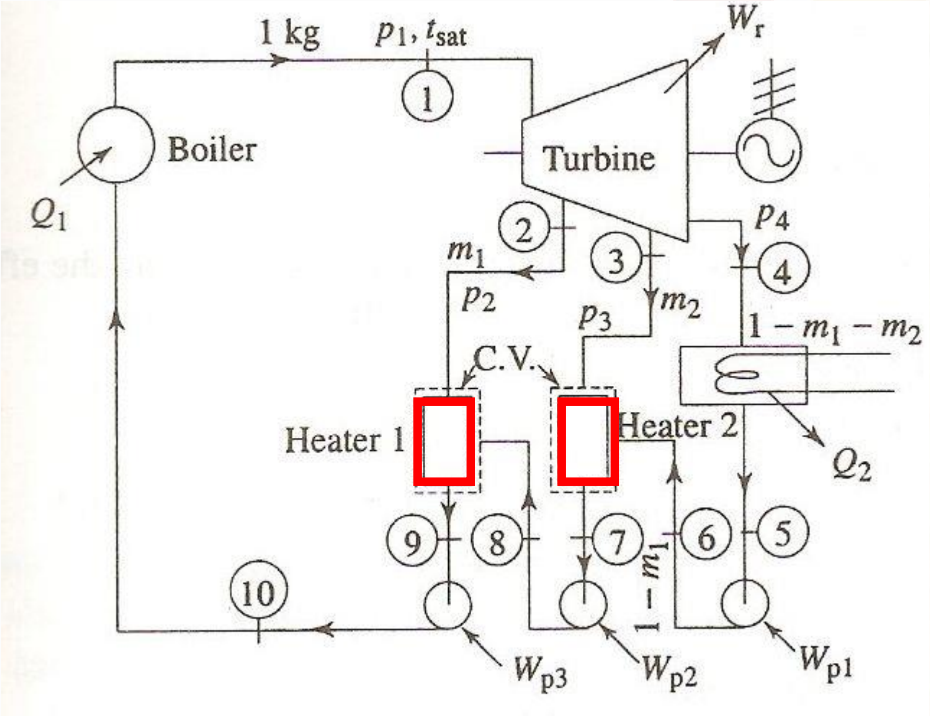
OPEN Feedwater Heaters



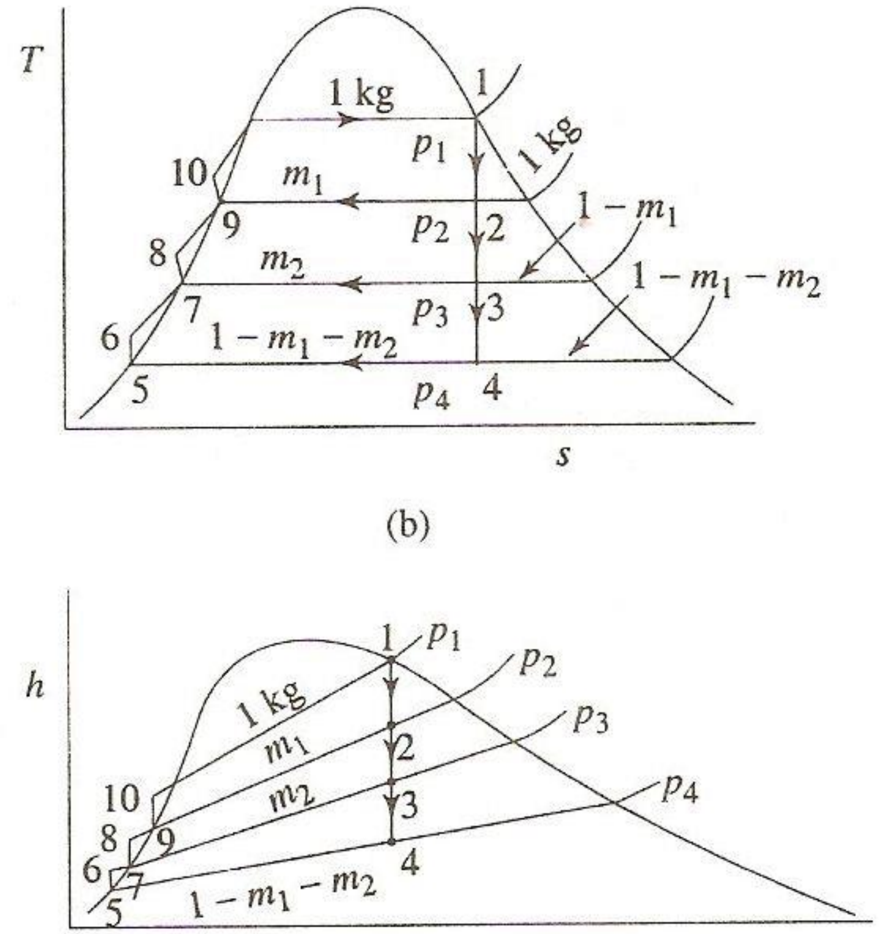


- Mixing chamber: steam extracted from the turbine mixes with the feedwater from the pump.
- The mixture leaves the heater (3) as saturated liquid at the heater pressure.
- Heat of *y* at OFWH (6-3) at constant pressure increases feedwater temperature (2-3)

Two OPEN Feedwater Heaters: Diagram



(a)

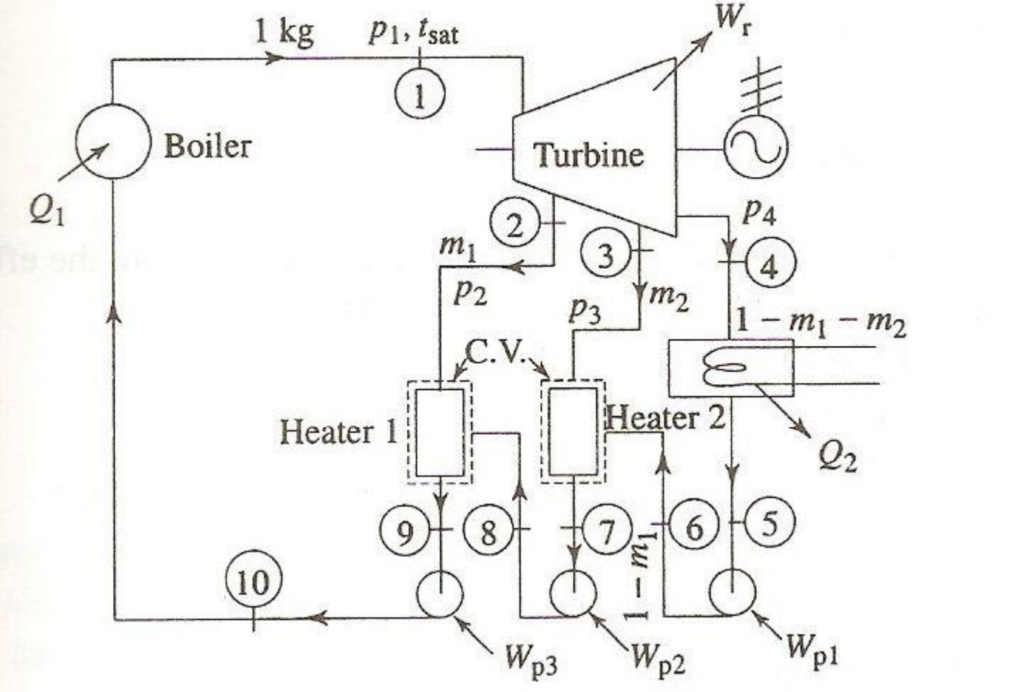


(b)

(c)

- Steam extract for each pressure stage (m1, m2).
- A pump is needed for each stage to flow low pressure fluid to higher pressure heater.

Two OPEN Feedwater Heaters: Efficiency



(a)

$$\eta_{th} = \frac{W_{net}}{Q_1} = \frac{W_T - W_P}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$W_T = 1(h_1 - h_2) + (1 - m_1)(h_2 - h_3) + (1 - m_1 - m_2)(h_3 - h_4)$$

$$W_P = (1 - m_1 - m_2)(h_6 - h_5) + (1 - m_1)(h_8 - h_7) + 1(h_{10} - h_9)$$

$$Q_1 = 1(h_1 - h_{10})$$

$$Q_2 = (1 - m_1 - m_2)(h_4 - h_5)$$

Two OPEN Feedwater Heaters: Energy balance

FWH1

$$Inflow\,Energy = Outflow\,Energy$$

$$m_1 h_2 + (1 - m_1) h_8 = 1 h_9$$

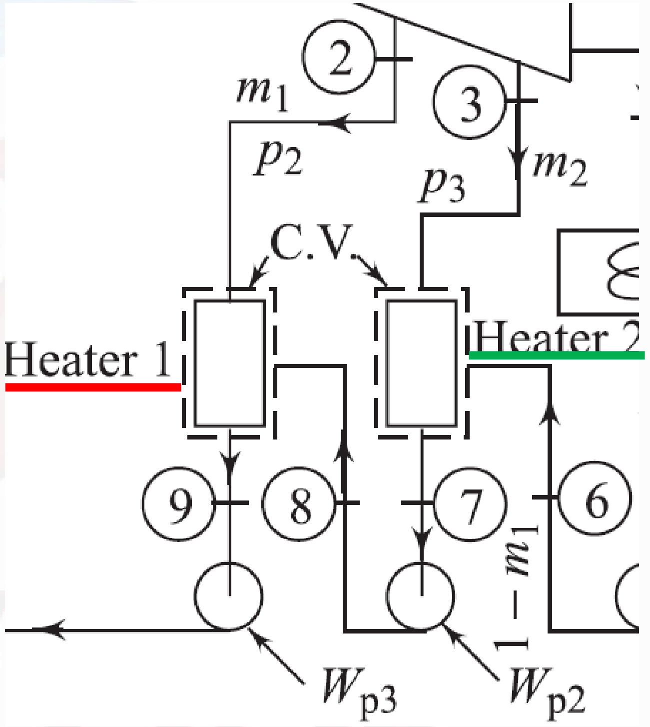
$$m_1 = \frac{h_9 - h_8}{h_2 - h_8}$$

FWH2

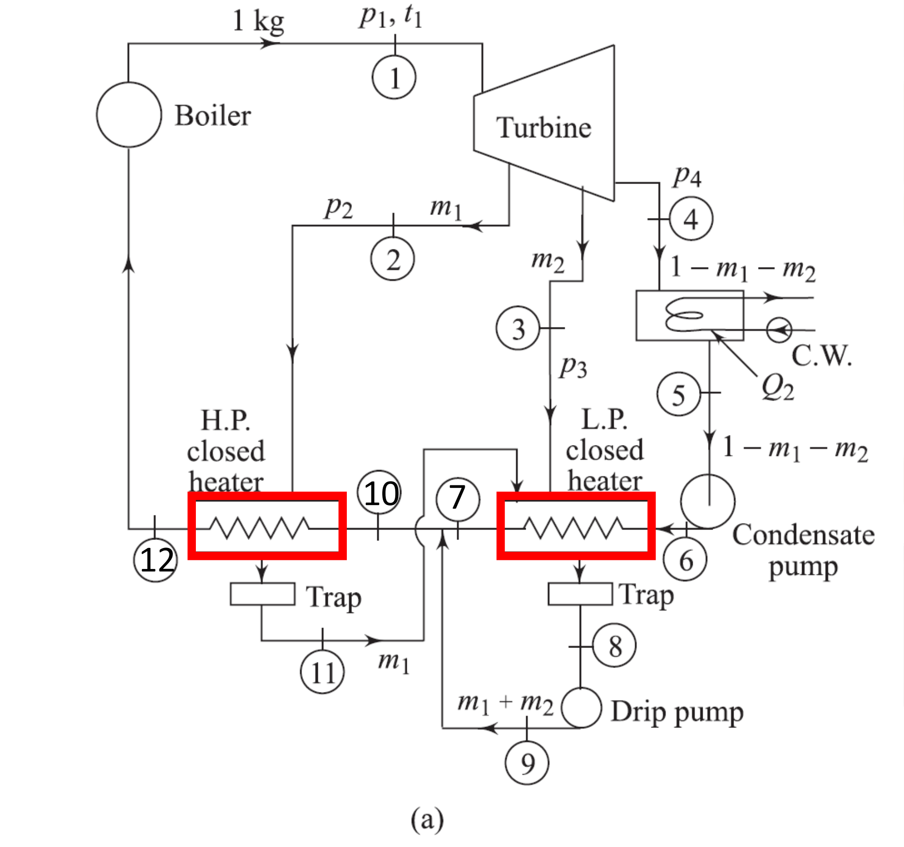
$$Inflow\,Energy = Outflow\,Energy$$

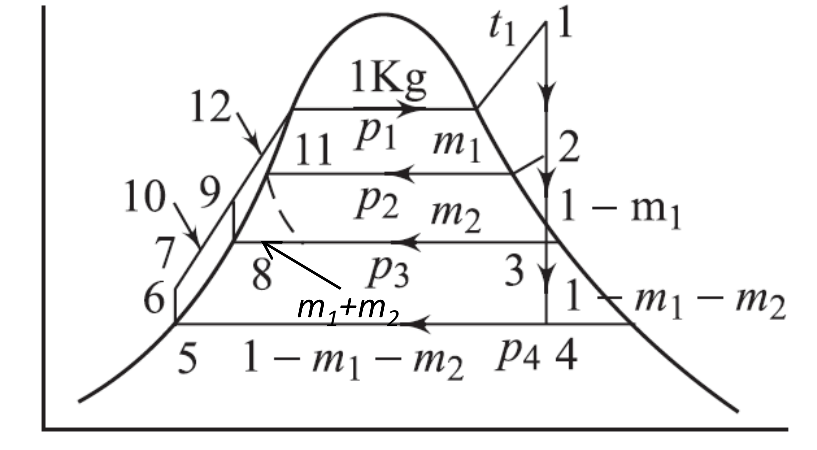
$$m_2 h_3 + (1 - m_1 - m_2) h_6 = (1 - m_1) h_7$$

$$m_2 = (1 - m_1) \frac{h_7 - h_6}{h_3 - h_6}$$



Two CLOSED Feedwater Heaters: Diagram





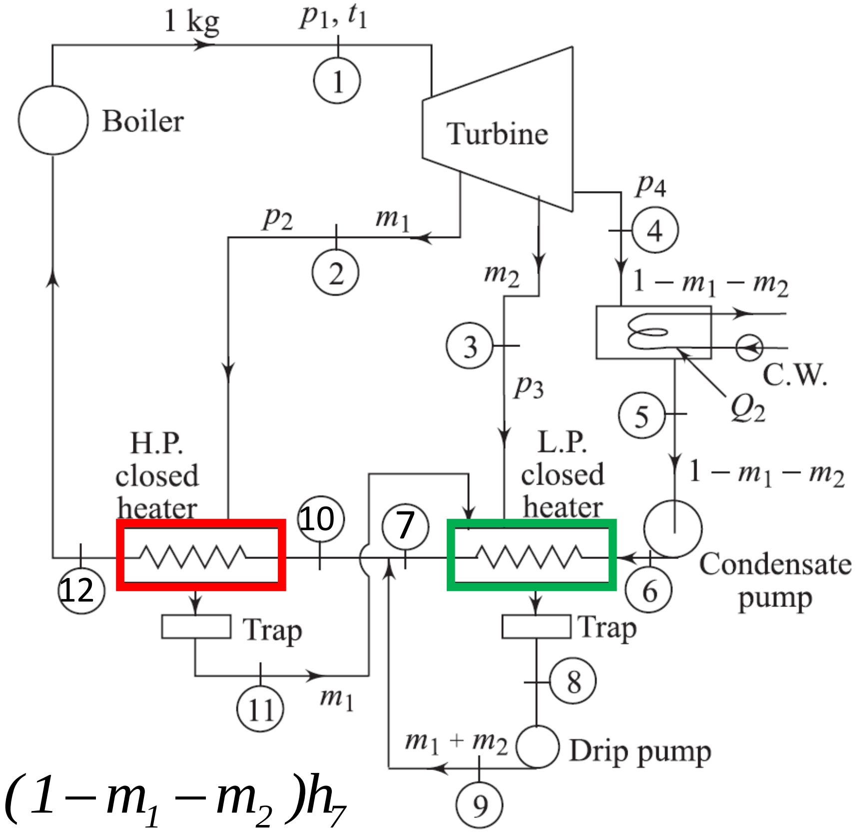
- Steam is extracted for each pressure stage (m1, m2).
- After condenser, pressure of (1-m1-m2) was increased to the highest pressure.
- After heat exchange at HP FWH, vapour in m1 is trapped and then it mixes with m2 at LP FWH.
- Next, vapor in m1 & m2 are trapped and finally pumped to the highest pressure.

FWH1

$$Inflow\ Energy = Outflow\ Energy$$

$$m_1 h_2 + h_{10} = m_1 h_{11} + h_{12}$$

$$m_1 = \frac{h_{12} - h_{10}}{h_2 - h_{11}}$$



(a)

FWH2

$$Inflow\ Energy = Outflow\ Energy$$

$$m_2 h_3 + (1 - m_1 - m_2) h_6 + m_1 h_{11} = (m_2 + m_1) h_8 + (1 - m_1 - m_2) h_7$$

$$m_2 = \frac{m_1 (h_6 - h_7 + h_8 - h_{11}) - h_6 + h_7}{h_3 - h_6 - h_7 - h_8}$$

References-

1-https://energyeducation.ca/encyclopedia/Rankine_cycle.
2-http://www.thermopedia.com/content/1072/
3-Çengel, Yunus A., and Michael A. Boles. Thermodynamics: An Engineering Approach. 7th ed. New York: McGraw-Hill, 2011. p. 299. Print.
4-N. A. Sinitsyn (2011). "Fluctuation Relation for Heat Engines". J. Phys. A: Math. Theor. 44 (40): 405001. arXiv:1111.7014. Bibcode:2011JPhA...44N5001S. doi:10.1088/1751-8113/44/40/405001. S2CID 119261929.
5-Carnot, Sadi, Reflections on the Motive Power of Fire