Explanation Chapter 8

8.1 Which of the following actions contributes to the improvement of efficiency of Rankine cycle in a Thermal Power Plant? (multiple answers possible)
a) reheating of steam at intermediate stage
b) regeneration use of steam for heating Boiler feed water
c) use of high pressures
Ans: A,B,C. The regenerative features effectively raise the nominal cycle heat input temperature, by reducing the addition of heat from the Boiler/fuel source at the relatively low feedwater temperatures that would exist without regenerative feedwater heating.

8.2 In a regenerative Rankine cycle some steam is extracted from the turbine and is used to heat the water before it enters the boiler, although the extracted steam could have produced some work in the turbine. Is it smart to do this (and why)?
a) Yes
b) No
Ans: A. This is a smart thing to do because little work potential is lost, but a lot from the heat input is saved. The extracted steam has little work potential left, and most of its low temperature energy would be part of the heat rejected anyway. Therefore, by regeneration, a considerable amount of heat is saved by sacrificing little work output. This makes the efficiency of the system the highest.

8.3 A simple Rankine cycle is modified with regeneration. Assume the mass flow rate through the boiler and the temperature at the turbine inlet does not change. How does the heat input in the boiler change?
a) It increases
b) It decreases
c) It remains the same
Ans: B. As the feed water is preheated by steam extracted from the turbine less heat need to be supplied to the boiler.

8.4 A simple Rankine cycle is modified with regeneration. Assume the mass flow rate through the boiler does not change. How does the moisture content at the turbine exit change?
a) It increases
b) It decreases
c) It remains the same
Ans: C. The moisture content at the turbine exit is not influenced by the mass flow. It only depends on the properties of the fluid at the turbine exit (pressure, temperature).

8.5 Mass Flow 1 enters a closed feedwater heater as a saturated vapor at a pressure of 600 kPa. It leaves as a saturated liquid. Mass Flow 2 is heated. This stream has a pressure of 5 MPa and enters with an enthalpy of 341 kJ/kg.
What are approximately the maximum enthalpy and temperature of the second stream after leaving the closed feedwater heater?

a) T = 81.32°C and h = 341 kJ/kg
b) T = 158.83 °C and h = 670.38 kJ/kg
c) T = 211.39 °C and h = 912.45 kJ/kg
d) T = 263.94 °C and h = 1154.5 kJ/kg
e) You can’t tell with the given information

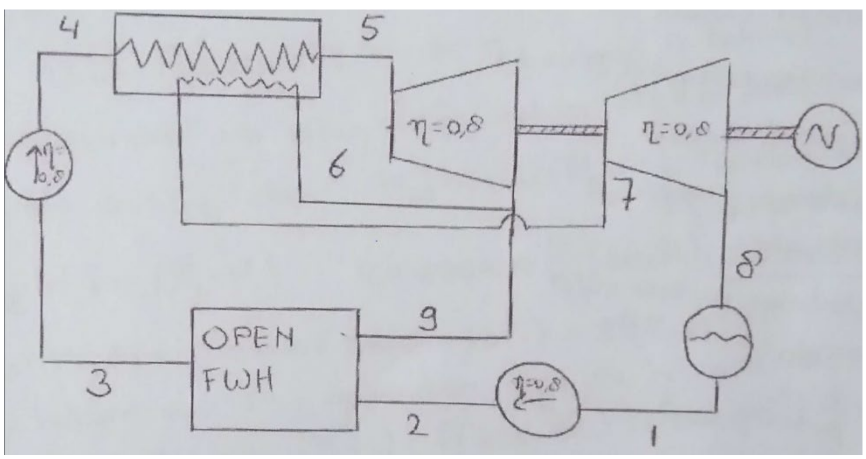
Ans: B. The maximum temperature to which the steam can be heated is 158.83 °C as this is the temperature of the heating steam.

8.6 A simple Rankine cycle is modified with regeneration. Assume the mass flow rate through the boiler does not change. How does the turbine work output change?

a) It increases
b) It decreases
c) It remains the same

Ans: B. The steam that is used for the feed water heating is extracted from the turbine and cannot produce work anymore in the turbine.

8.7 Consider the regenerative reheat cycle given in the figure. The enthalpy value for each point is given in kJ/kg. Determine the thermal efficiency of this cycle.



Point 1: 192 kJ/kg
Point 2: 193 kJ/kg
Point 3: 721 kJ/kg
Point 4: 734 kJ/kg
Point 5: 3502 kJ/kg
Point 6: 2940 kJ/kg
Point 7: 3480 kJ/kg
Point 8: 2696 kJ/kg
Point 9: 2940 kJ/kg

a) 37%: right answer
b) 43%: you forgot the reheater
c) 40%: you didn't consider the different mass flows
d) 48%: you didn't consider the different mass flows and forgot the reheater
e) 49%: you didn't consider the different mass flows and forgot the reheater as well as the pumps

Main mass flow $\rightarrow \dot{m}$
Flow at point 9 $\rightarrow \dot{m}_a$
Flow at point 2 $\rightarrow \dot{m}_b$

Conservation of mass gives $\rightarrow \dot{m} = \dot{m}_a + \dot{m}_b$
Conservation of energy over the feedwater heater $\rightarrow \dot{m}h_3 = \dot{m}_a h_9 + \dot{m}_b h_2$
Combining the two conservation equations $\rightarrow \dot{m}_b = \dot{m}\left(\frac{h_9 - h_3}{h_9 - h_2}\right)$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}}$$

$$\dot{W}_{net} = \dot{W}_{HPT} + \dot{W}_{LPT} - \dot{W}_{pump1} - \dot{W}_{pump2} = \dot{m}(h_5 - h_6) + \dot{m}_b(h_7 - h_8) - \dot{m}_b(h_2 - h_1) - \dot{m}(h_4 - h_3) = \dot{m}(h_5 - h_6) + \dot{m}\left(\frac{h_9 - h_3}{h_9 - h_2}\right)[(h_7 - h_8) - (h_2 - h_1)] - \dot{m}(h_4 - h_3)$$

$$\dot{Q}_{in} = \dot{Q}_{boiler} + \dot{Q}_{reheating-boiler} = \dot{m}(h_5 - h_4) + \dot{m}_b(h_7 - h_6) = \dot{m}(h_5 - h_4) + \dot{m}\left(\frac{h_9 - h_3}{h_9 - h_2}\right)(h_7 - h_6)$$

Filling in $\rightarrow \eta_{th} = \dfrac{\dot{m}(h_5 - h_6) + \dot{m}\left(\frac{h_9 - h_3}{h_9 - h_2}\right)[(h_7 - h_8) - (h_2 - h_1)] - \dot{m}(h_4 - h_3)}{\dot{m}(h_5 - h_4) + \dot{m}\left(\frac{h_9 - h_3}{h_9 - h_2}\right)(h_7 - h_6)} = 0.37 \rightarrow 37\%$

43%: you forgot the reheater
40%: you didn't take into account the different mass flows
48%: you didn't take into account the different mass flows and forgot the reheater
49%: you didn't take into account the different mass flows and forgot the reheater as well as the pumps

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8.8 Consider a simple ideal Rankine cycle and an ideal Rankine cycle with two reheat stages. Both cycles operate between the same pressure limits. In the simple Rankine cycle, the maximum temperature is 600 degrees Celsius while in the reheat Rankine cycle the maximum temperature is 400 degrees Celsius. Which cycle will have higher thermal efficiency and why?
a) The simple Rankine cycle since the average temperature at which heat is added will be higher compared to the reheat Rankine cycle
b) The simple Rankine cycle since an ideal simple cycle has the Carnot efficiency
c) The simple Rankine Cycle since it requires less heat input
d) The reheat Rankine cycle since it has two turbines and produces more work
e) The reheat Rankine cycle since it has reheating which makes the cycle more efficient compared to a simple cycle
Ans: A. The thermal efficiency of the simple ideal Rankine cycle will be higher since the average temperature at which heat is added will be higher in this case.

8.9 Is there an optimal pressure for reheating the steam of a Rankine cycle and if yes, what determines this optimal pressure?
a) No
b) Yes, the optimal reheat pressure is determined by the reheat temperature
c) Yes, the optimal reheat pressure is determined by the moisture content of the steam at the exit of the low-pressure turbine
d) You cannot say this without knowing the properties of the cycle
Ans: B. The T-s diagram shows two reheat cases for the reheat Rankine cycle. In the first case there is expansion through the high-pressure turbine from 6000 kPa to 4000 kPa between states 1 and 2 with reheat at 4000 kPa to state 3 and finally expansion in the low-pressure turbine to state 4. In the second case there is expansion through the high-pressure turbine from 6000 kPa to 500 kPa between states 1 and 5 with reheat at 500 kPa to state 6 and finally expansion in the low-pressure turbine to state 7. Increasing the pressure for reheating increases the average temperature for heat addition and makes the energy of the steam more available for doing work, see the reheat process 2 to 3 versus the reheat process 5 to 6. Increasing the reheat pressure will increase the cycle efficiency. However, as the reheating pressure increases, the amount of condensation increases during the expansion process in the low-pressure turbine, state 4 versus state 7. An optimal pressure for reheating generally allows for the moisture content of the steam at the low-pressure turbine exit to be in the range of 10 to 15% and this corresponds to quality in the range of 85 to 90%.

8.10 Mass Flow 1 enters (1) a closed feedwater heater as a saturated vapor at a pressure of 600 kPa. It leaves (2) as a saturated liquid. Mass Flow 2 is heated. This stream has a pressure of 5 MPa and enters (3) with an enthalpy of 341 kJ/kg. It leaves (4) with the maximum achievable temperature.
What is the ratio between mass flow 1 and 2? Mass flow 2 / mass flow 1 = ?
You may find the following image helpful. 1, 2, 3 and 4 in the text are displayed in this image.
a) 0.16
b) 0.39
c) 2.56
d) 6.34
Ans: D. First, we calculate the energy balance over the heat exchanger:
$Q_{dot} = m_{dot_1} * (h_1 - h_2) = m_{dot_2} * (h\_4 - h\_3)$
We then rewrite to: $m_{dot\,2} = \frac{h_1 - h_2}{h_4 - h_3} * m_{dot_1}$
Looking up the corresponding h values gives:

$$h_1 = 2756\ kJ/kg$$
$$h_2 = 670\ kJ/kg$$
$$h_3 = 341\ kJ/kg$$
$$h_4 = 670\ kJ/kg$$

And finally, simply filling in the formula gives:

$$m_{dot_2} = \frac{2756 - 670}{670 - 341} = 6.34\, m_{dot_1}$$