# ME 306

## Rankine Cycle Tutorial Sheet

Q1. Consider a 210-MW steam power plant that operates on a simple ideal Rankine cycle. Steam enters the turbine at 10 MPa and 500°C and is cooled in the condenser at a pressure of 10 kPa. Show the cycle on a T-s diagram with respect to saturation lines, and determine:

(a) the quality of the steam at the turbine exit
(b) the thermal efficiency of the cycle
(c) the mass flow rate of the steam.

Q2. A Rankine cycle using water as the working fluid operates between the pressure limits of 15 MPa in the boiler and 100 kPa in the condenser. Saturated steam enters the turbine. Irreversibilities in the turbine cause the steam quality at the outlet of the turbine to be 70 percent. Determine:

(a) The isentropic efficiency of the turbine and
(b) the thermal efficiency of the cycle.

Q3. Consider a Rankine cycle with saturated steam. Undertake a study of such a plant with steam entering the turbine is dry and saturated at (a) 10 bar, (b) 30 bar, (c) 50 bar. In each case, compute efficiency, and dryness fraction of steam at the exit of turbine. Compare and comment. Assume that the condenser is at 0.06 bar in all cases.

Q4. Consider a superheated steam plant working at 120 bar, with the condenser at 0.06 bar. Study the effect of superheating by determination of performance at 400°C, 500°C and 600°C.

Q5. A steam plant works on the Rankine cycle with reheat. Steam enters the high-pressure turbine at 10 MPa and 500°C and the low-pressure turbine at 1 MPa and 500°C. Steam leaves the condenser as a saturated liquid at a pressure of 10 kPa. Show the cycle on a T-s diagram with respect to saturation lines, and determine (a) work done in HP and LP turbines, (b) heat added in the boiler, (c) heat added in the reheater, (d) pump work, and (e) efficiency.

Q6. A steam power plant operates on an ideal Rankine cycle with two stages of reheat and has a net power output of 75 MW. Steam enters all three stages of the turbine at 540°C. The maximum pressure in the cycle is 10 MPa, and the minimum pressure is 30 kPa. Steam is reheated at 4 MPa the first time and at 2 MPa the second time. Show the cycle on a T-s diagram with respect to saturation lines, and determine:

(a) the total heat input
(b) net-work output
(c) thermal efficiency of the cycle
(d) mass flow rate of the steam

Q7. A steam power plant operates on an ideal regenerative Rankine cycle. Steam enters the turbine at 6 MPa and 450°C and is condensed in the condenser at 20 kPa. Steam is extracted from the turbine at 0.4 MPa to heat the feedwater in an open feedwater heater. Water leaves the feedwater heater as a saturated liquid.

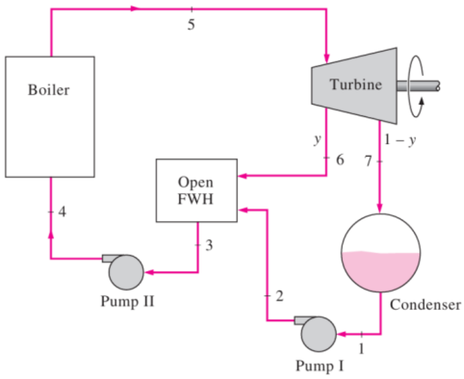


Fig: An ideal regenerative Rankine cycle with an open feedwater heater

Show the cycle on a T-s diagram, and determine:

(a) the fraction of steam extracted
(b) heat added in the boiler per kg of steam flowing through the boiler
(c) the net-work output per kg of steam flowing through the boiler
(d) efficiency of the cycle
(e) Calculate (b), (c) and (d) for an ideal Rankine cycle (without regeneration) working on the same parameters. Compare and comment.

Q8. Repeat Question 7 (a) to (d), by replacing the open feedwater heater with a closed feedwater heater. Assume that the feed water leaves the heater at the condensation temperature of the extracted steam and that the extracted steam leaves the heater as a saturated liquid and is pumped to the line carrying the feedwater. (Hint: Assume h $\approx$ f(T) for subcooled region, $T_3 = T_9$).

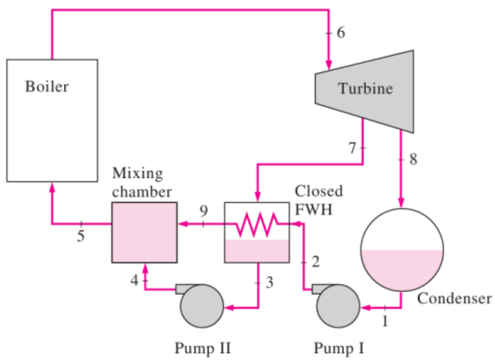


Fig: An ideal regenerative Rankine cycle with a closed feedwater heater

Q9. Consider an ideal steam regenerative Rankine cycle with two feedwater heaters, one closed and one open. Steam enters the turbine at 10 MPa and 600°C and exhausts to the condenser at 10 kPa. Steam is extracted from the turbine at 1 MPa for the closed feedwater heater and at 0.6 MPa for the open one. The feedwater is heated to the condensation temperature of the extracted steam in the closed feedwater heater. The extracted steam leaves the closed feedwater heater as a saturated liquid, which is subsequently throttled to the open feedwater heater. (Hint: Assume h $\approx$ f(T) for subcooled region, $T_5 = T_6$).

Show the cycle on a T-s diagram with respect to saturation lines, and determine

(a) the fraction of steam extracted to the closed feedwater heater 'y' as shown in the figure
(b) the fraction of steam extracted to the open feedwater heater 'z' as shown in the figure

(c) efficiency of the cycle

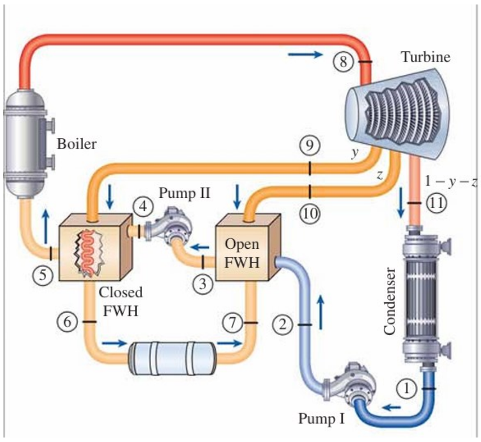


Fig: Ideal regenerative Rankine cycle with two feedwater heaters

Q10. Consider an ideal reheat–regenerative Rankine cycle with one open feedwater heater. Steam enters the high-pressure turbine at 3.0 MPa, 400°C, and is extracted to an open feedwater heater at 0.7 MPa with exit as saturated liquid. The remainder of the steam is reheated to 400°C at this pressure, 0.7 MPa, and is fed to the low-pressure turbine. The condenser pressure is 10 kPa. Determine:

(a) the fraction of steam extracted
(b) heat added in the boiler per kg of steam flowing through the boiler
(c) the net-work output per kg of steam flowing through the boiler
(d) efficiency of the cycle

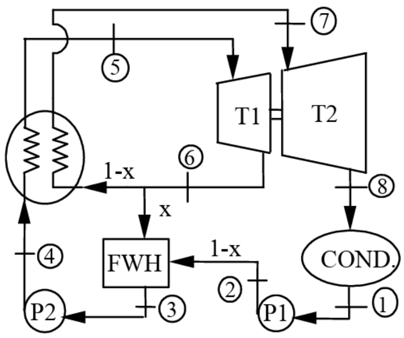


Fig: An ideal reheat–regenerative Rankine cycle with one open feedwater heater