Chapter 9 - Power and Refrigeration Systems - With Phase Change

Lecture 29
Sections 9.3-9.4

MEMS 0051 Introduction to Thermodynamics

Mechanical Engineering and Materials Science Department
University of Pittsburgh

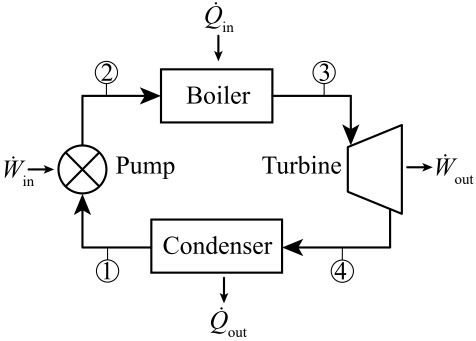
Student Learning Objectives

At the end of the lecture, students should be able to:

- Apply the Conservation of Energy and Conservation of Mass to basic power cycles, i.e. the Rankine cycle, using superheat and reheat

Rankine cycle

- The Rankine Cycle is the back-bone of land-based power generation and reflects the most basic heat engine

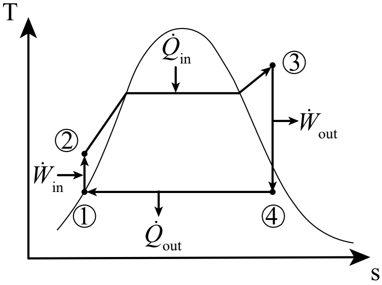


Ideal Rankine Cycle Processes

- Recall for the ideal Rankine cycle, we assume the following:
- 1 $\rightarrow$ 2 is an isentropic compression process through the pump
- 2 $\rightarrow$ 3 is an isobaric heat addition process through the boiler
- 3 $\rightarrow$ 4 is an isentropic expansion process through the turbine
- 4 $\rightarrow$ 1 is an isobaric heat rejection process through the condenser

Rankine Cycle Superheat T-s diagram

- What happens when the system is superheated?



Example #1

- Steam enters the turbine at 8 [MPa] and 480 °C and saturated liquid exits the condenser at 8 [kPa]. The net power produced is 100 [MW]. Determine:
  1. The thermal efficiency (net work per heat input)
  2. The backwork ratio (work of the pump per compressor)
  3. The mass flow rate of steam
  4. The rate of heat supplied to the boiler
  5. The rate of heat rejected from the condenser

Example #1

Example #1

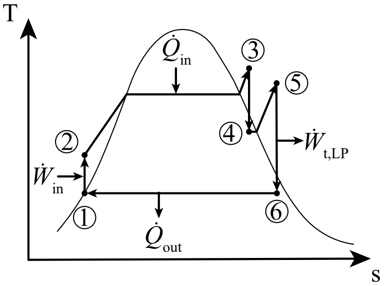
Example #1

Example #1

Example #1

Rankine Cycle Super- & Reheat T-s diagram

- What happens when the system is superheated and reheated?



Example #2

- Steam enters the turbine at 8 [MPa] and 480 °C and expands to 700 [kPa]. It is then reheated to 440 °C before entering a second turbine, where it expands to 8 [kPa]. Saturated liquid exits the condenser at 8 [kPa]. The net power produced is 100 [MW]. Determine:
  1. The thermal efficiency (net work per heat input)
  2. The backwork ratio (work of the pump per compressor)
  3. The mass flow rate of steam
  4. The rate of heat supplied to the boiler
  5. The rate of heat rejected from the condenser

Example #2

Example #2

Example #2

Example #2

Example #2

Example #2

Example #2

Student Learning Objectives

At the end of the lecture, students should be able to:

- Apply the Conservation of Energy and Conservation of Mass to basic power cycles, i.e. the Rankine cycle
  - Superheat the steam before allowing it to enter the turbine, although requiring more heat input, increases the power output substantially, and thereby increase the thermal efficiency of the cycle.
  - Superheat and reheating the steam before allowing it to enter the turbine, although requiring more heat input, increases the power output substantially, and thereby increase the thermal efficiency of the cycle, even more than reheating.

Suggested Problems

- 9.13-9.39