# Chapter 4 - Energy Analysis for a Control Volume

Lecture 28

Section 4.4

MEMS 0051 Introduction to Thermodynamics

Mechanical Engineering and Materials Science Department
University of Pittsburgh



# Student Learning Objectives



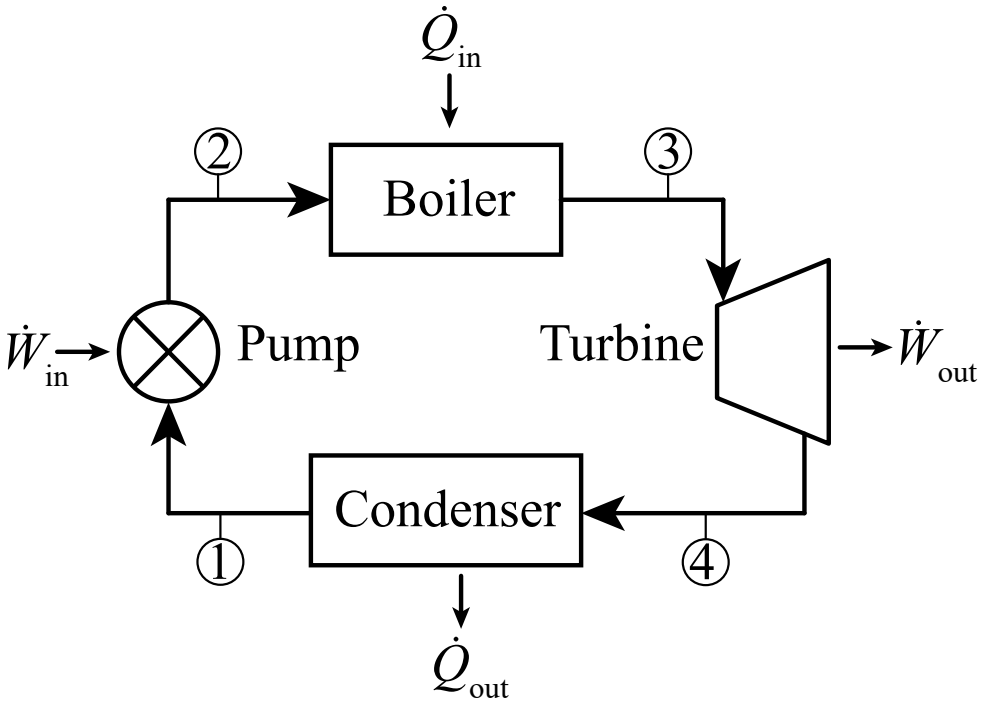
At the end of the lecture, students should be able to:

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

# 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

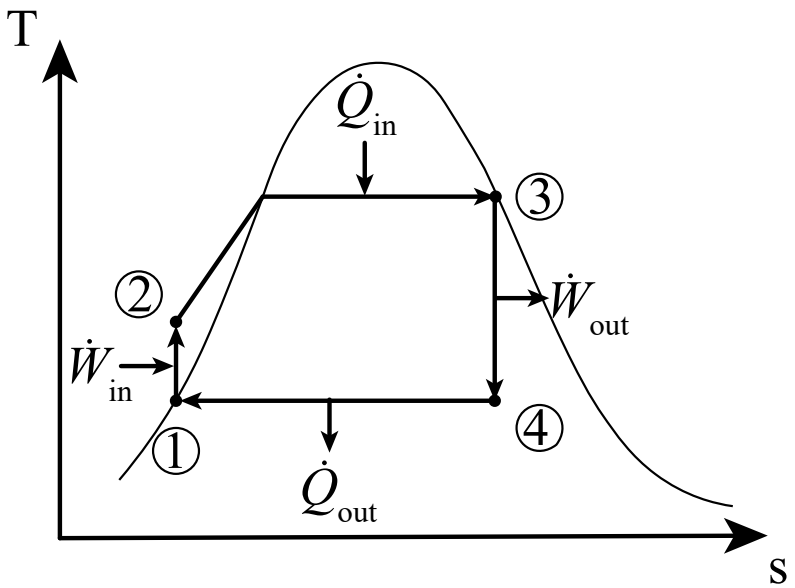


- For the ideal Rankine cycle, we assume the following:
- (1) → (2) is an isentropic compression process through the pump
- (2) → (3) is an isobaric heat addition process through the boiler
- (3) → (4) is an isentropic expansion process through the turbine
- (4) → (1) is an isobaric heat rejection process through the condenser

# Ideal Rankine Cycle $T$-$s$ diagram



- Consider a Rankine cycle that accepts saturated liquid water into to the pump at 100 [kPa] and inputs saturated vapor at 1,000 [kPa] into the turbine. How would these four individual processes appear on a $T$-$s$ diagram?



# Rankine Cycle - Pump and Boiler



- Considering the Conservation of Energy equation, what is the equation describing the pump work, neglecting KE and PE?

- Considering the Conservation of Energy equation, what is the equation describing the heat into the boiler, neglecting KE and PE?

# Rankine Cycle - Turbine and Condenser



- Considering the Conservation of Energy equation, what is the equation describing the turbine work, neglecting KE and PE?

- Considering the Conservation of Energy equation, what is the equation describing the heat rejected from the condenser, neglecting KE and PE?

# Example #1



- Steam, as a saturated vapor, enters the turbine at 8 [MPa] 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 turbine)
  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



# Example #1



# Example #1



# Example #1



# Example #1



# 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
  - The Rankine cycle is the most basic closed-loop power generation cycle, in where a pump circulates the working fluid through a boiler, which then provides steam to a turbine, which then rejects high-quality yet low-pressure mixture to a condenser.

# Suggested Problems

- 4.118, 4.119, 4.120, 4.123, 4.124, 4.125