Chapter 2

Energy and the
First Law of Thermodynamics
Continued-4

Thermodynamic Cycles

- A *thermodynamic cycle* is a sequence of processes that begins and ends at the same state.
- Examples of thermodynamic cycles include
  - **Power cycles** that develop a net energy transfer by work in the form of electricity using an energy input by heat transfer from hot combustion gases.

Thermodynamic Cycles

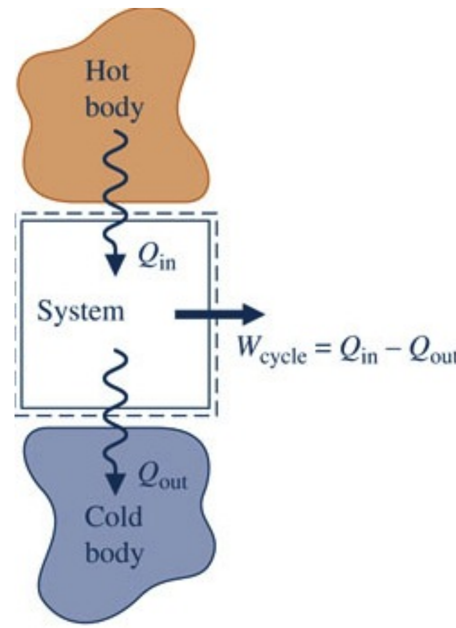
- ►A *thermodynamic cycle* is a sequence of processes that begins and ends at the same state.
- ►Examples of thermodynamic cycles include
  - ►**Power cycles** that develop a net energy transfer by work in the form of electricity using an energy input by heat transfer from hot combustion gases.
  - ►**Refrigeration cycles** that provide cooling for a refrigerated space using an energy input by work in the form of electricity.

Thermodynamic Cycles

- A *thermodynamic cycle* is a sequence of processes that begins and ends at the same state.
- Examples of thermodynamic cycles include
  - **Power cycles** that develop a net energy transfer by work in the form of electricity using an energy input by heat transfer from hot combustion gases.
  - **Refrigeration cycles** that provide cooling for a refrigerated space using an energy input by work in the form of electricity.
  - **Heat pump cycles** that provide heating to a dwelling using an energy input by work in the form of electricity.

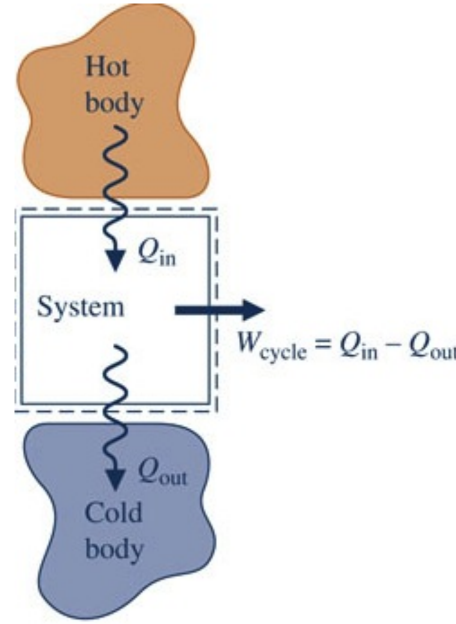
Power Cycle

►A system undergoing a power cycle is shown at right.



Power Cycle

► A system undergoing a power cycle is shown at right.



http://www.turbinesinfo.com/what-is-a-turbine/

Pelton Turbine

Pelton Turbine

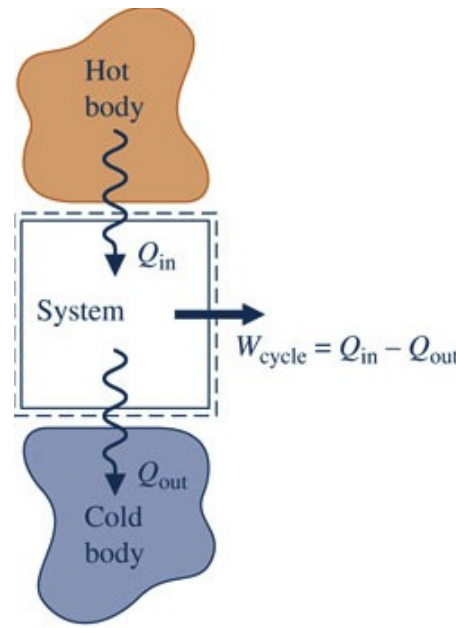
The Pelton wheel is among the most efficient types of water turbines. It was invented by Lester Allan Pelton (1829–1908) in the 1870s, and is an impulse machine, meaning that it uses the principle of Newton's second law to extract energy from a jet of fluid.

- At least one jet of water strike the buckets at atmospheric pressure.
- Maximum jet diameter about 1/3 bucket width.
- More jets increase flow and are used at low head.

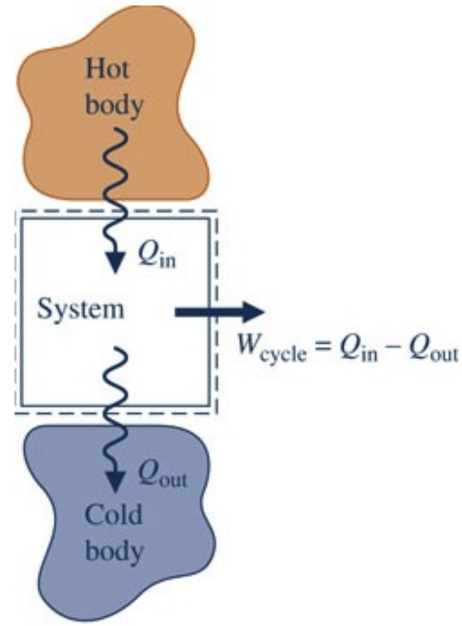
Power Cycle

► A system undergoing a power cycle is shown at right.

► The energy transfers by heat and work shown on the figure are each positive in the direction of the accompanying arrow. This convention is commonly used for analysis of thermodynamic cycles.



Power Cycle



► A system undergoing a power cycle is shown at right.

► The energy transfers by heat and work shown on the figure are each positive in the direction of the accompanying arrow. This convention is commonly used for analysis of thermodynamic cycles.

► W_{cycle} is the **net energy transfer by work** from the system per cycle of operation – in the form of electricity, typically.

► Q_{in} is the **heat transfer of energy to the system** per cycle from the hot body – drawn from hot gases of combustion or solar radiation, for instance.

► Q_{out} is the **heat transfer of energy from the system** per cycle to the cold body – discharged to the surrounding atmosphere or nearby lake or river, for example.

Power Cycle

►Applying the closed system energy balance to each cycle of operation,

$$\Delta E_{\text{cycle}} = Q_{\text{cycle}} - W_{\text{cycle}} \qquad \textbf{(Eq. 2.39)}$$

Power Cycle

► Applying the closed system energy balance to each cycle of operation,

$$\Delta E_{\text{cycle}} = Q_{\text{cycle}} - W_{\text{cycle}} \qquad \textbf{(Eq. 2.39)}$$

► Since the system returns to its initial state after each cycle, there is no net change in its energy: $\boldsymbol{\Delta E_{\text{cycle}} = 0}$, and the energy balance reduces to give

$$W_{\text{cycle}} = Q_{\text{in}} - Q_{\text{out}} \qquad \textbf{(Eq. 2.41)}$$

► In words, the ***net*** energy transfer by work from the system equals the ***net*** energy transfer by heat to the system, each per cycle of operation.

Power Cycle

►The performance of a system undergoing a power cycle is evaluated on an energy basis in terms of the extent to which the energy added by heat, Q_{in}, is converted to a net work output, W_{cycle}. This is represented by the ratio

$$\eta = \frac{W_{cycle}}{Q_{in}} \quad \text{(power cycle)} \qquad \textbf{(Eq. 2.42)}$$

called the thermal efficiency.

Power Cycle

► The performance of a system undergoing a power cycle is evaluated on an energy basis in terms of the extent to which the energy added by heat, Q_{in}, is converted to a net work output, W_{cycle}. This is represented by the ratio

$$\eta = \frac{W_{cycle}}{Q_{in}} \quad \text{(power cycle)} \qquad \textbf{(Eq. 2.42)}$$

called the thermal efficiency.

► Introducing **Eq. 2.41**, an alternative form is obtained

$$\eta = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}} \quad \text{(power cycle)} \qquad \textbf{(Eq. 2.43)}$$

Power Cycle

►Using the second law of thermodynamics (Chapter 5), we will show that the value of thermal efficiency must be less than unity: **η < 1 (< 100%)**. That is, only a portion of the energy added by heat, Q_{in}, can be obtained as work. The remainder, Q_{out}, is discharged.

Power Cycle

►Using the second law of thermodynamics (Chapter 5), we will show that the value of thermal efficiency must be less than unity: η **< 1 (< 100%)**. That is, only a portion of the energy added by heat, Q_{in}, can be obtained as work. The remainder, Q_{out}, is discharged.

Example: A system undergoes a power cycle while receiving 1000 kJ by heat transfer from hot combustion gases at a temperature of 500 K and discharging 600 kJ by heat transfer to the atmosphere at 300 K. Taking the combustion gases and atmosphere as the hot and cold bodies, respectively, determine for the cycle, the net work developed, in kJ, and the thermal efficiency.

Power Cycle

►Using the second law of thermodynamics (Chapter 5), we will show that the value of thermal efficiency must be less than unity: $\eta < 1$ (< 100%). That is, only a portion of the energy added by heat, Q_{in}, can be obtained as work. The remainder, Q_{out}, is discharged.

Example: A system undergoes a power cycle while receiving 1000 kJ by heat transfer from hot combustion gases at a temperature of 500 K and discharging 600 kJ by heat transfer to the atmosphere at 300 K. Taking the combustion gases and atmosphere as the hot and cold bodies, respectively, determine for the cycle, the net work developed, in kJ, and the thermal efficiency.

►Substituting into **Eq. 2.41**, W_{cycle} = 1000 kJ – 600 kJ = 400 kJ.

►Then, with **Eq. 2.42**, η = 400 kJ/1000 kJ = 0.4 (40%). Note the thermal efficiency is commonly reported on a percent basis.