Stirling Engines

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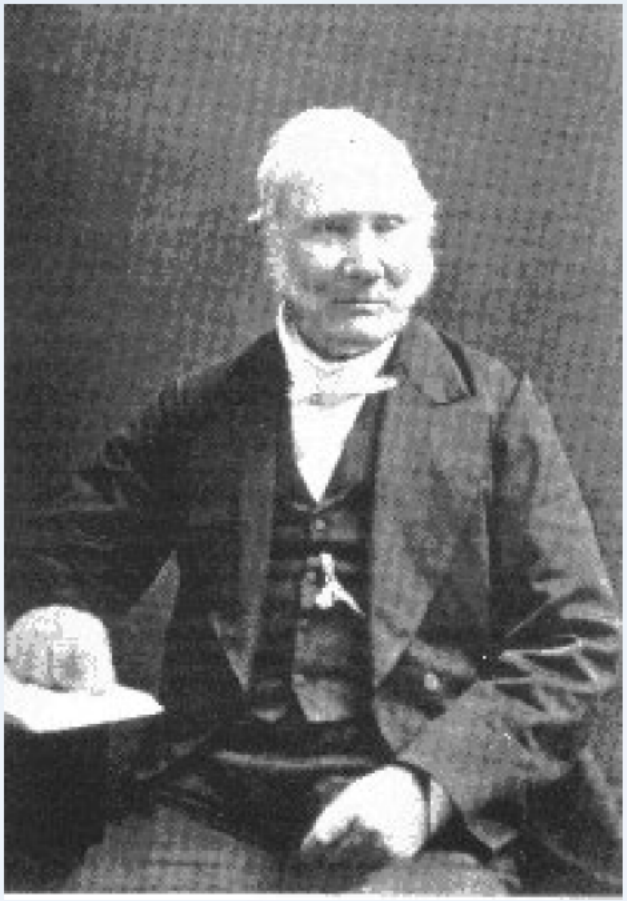
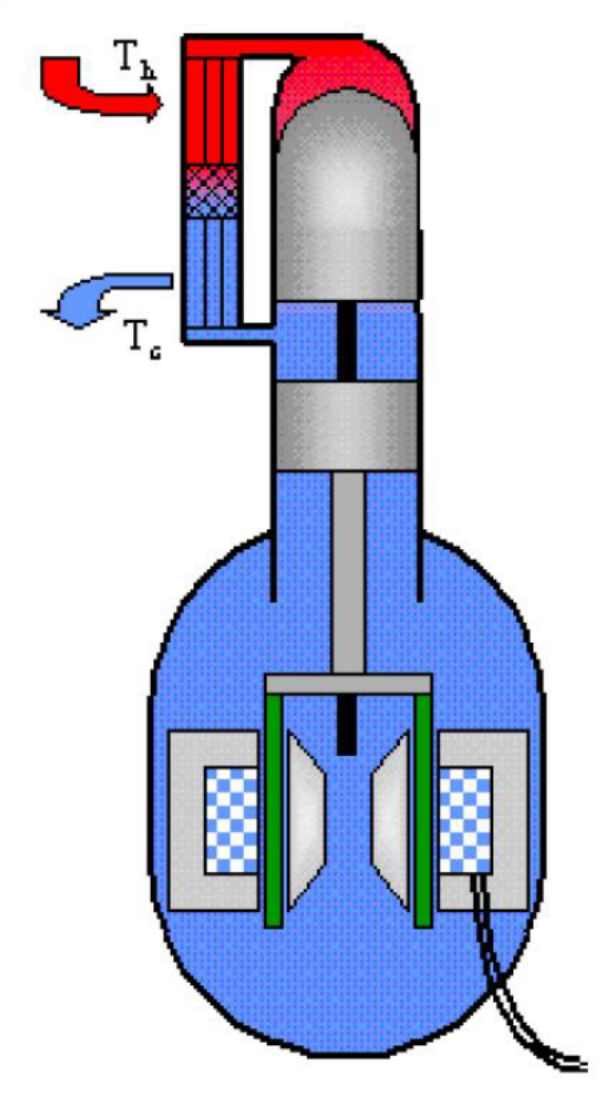
History

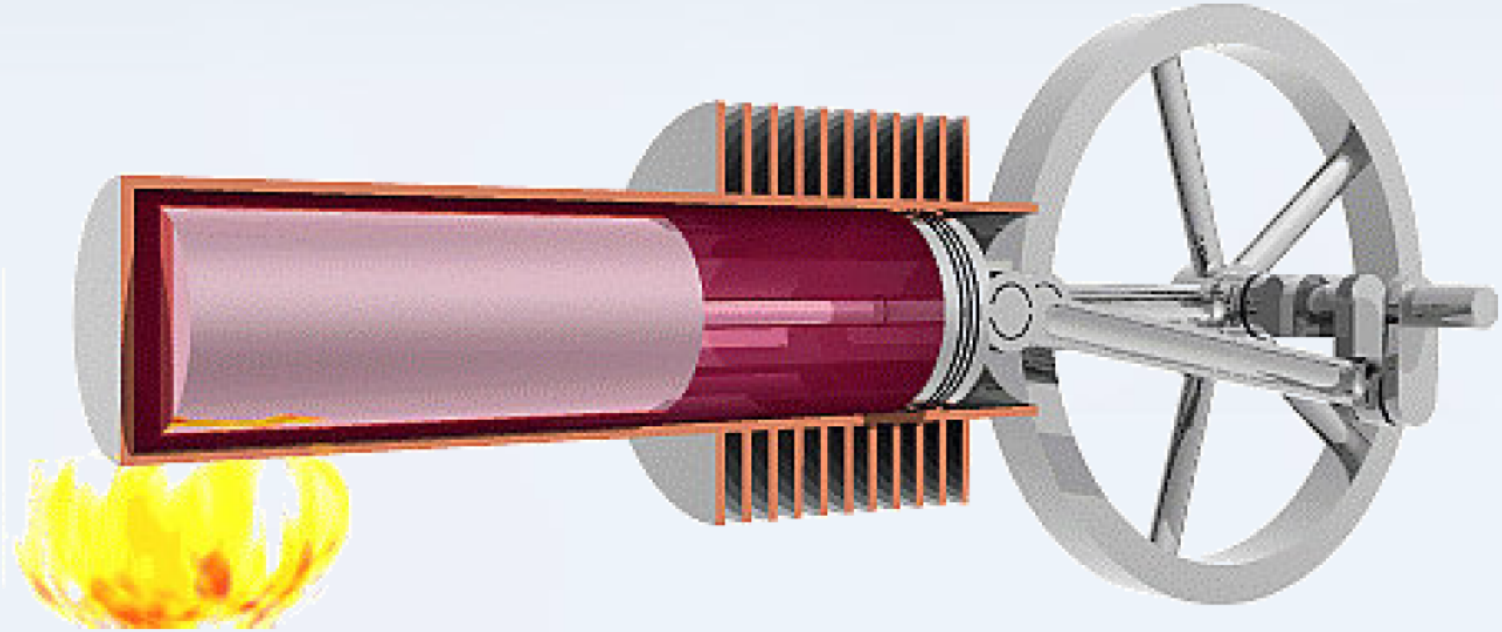
- Invented in 1816 by Robert Stirling
- Rival to Steam Engine
- Originally called the “Economiser”
- Overshadowed by Steam Engine and Internal Combustion Engine



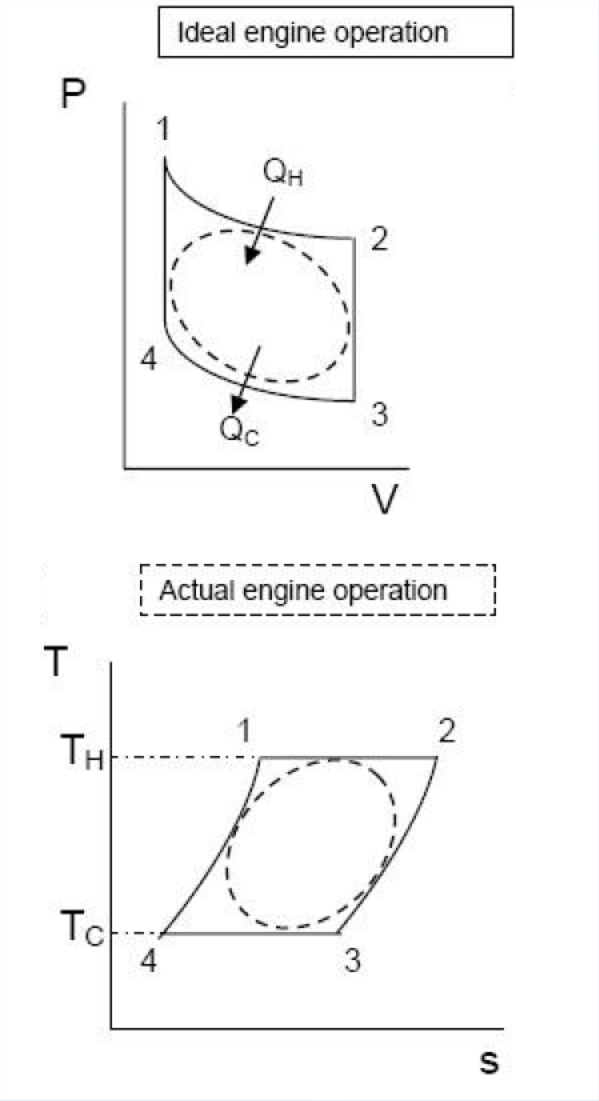
Main Components



- External Combustion
- Hot Region (heat addition)
- Cold Region (heat rejection)
- Regenerator



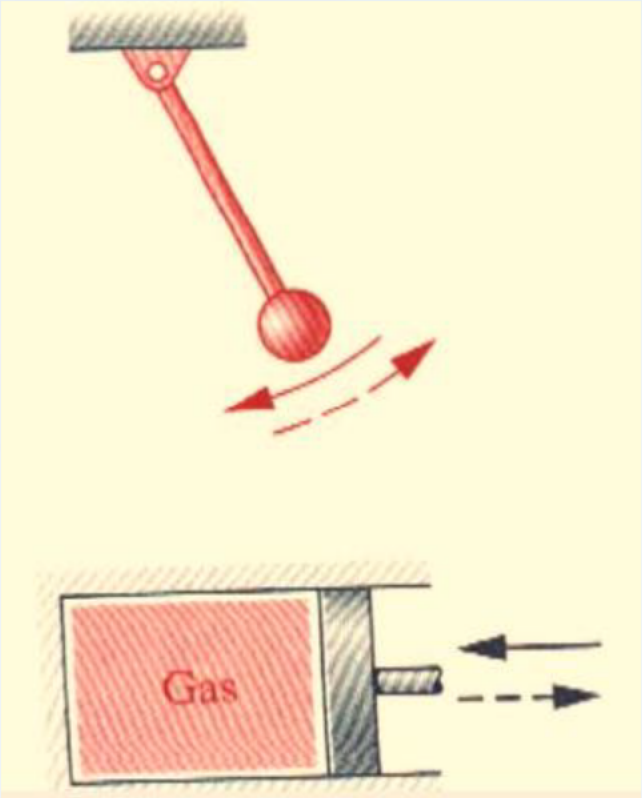
Stirling Cycle



- Four Components
  - (1-2): Isothermal Expansion
  - (2-3): Constant Volume Cooling
  - (3-4): Isothermal Compression
  - (4-1): Constant Volume Heating
- Counter-clockwise is refrigeration cycle
- Reversible Process
  - System+surroundings can return to previous state

Reversible Process

- All actual processes are irreversible (estimate)
- Friction (irreversible)



Efficiency

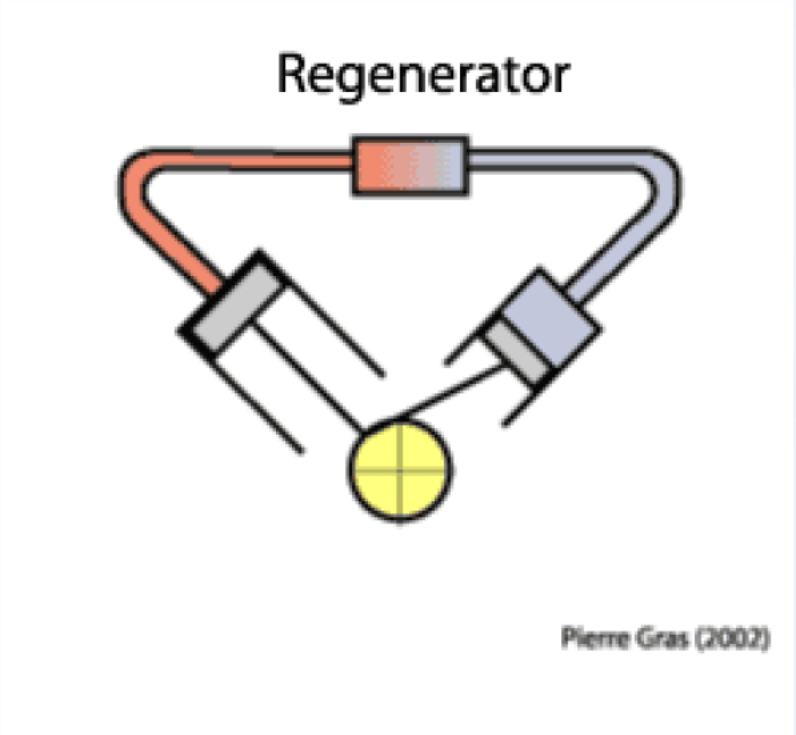
$$\eta = \frac{W}{Q_H} = 1 - \frac{T_C}{T_H}$$

- Carnot cycle efficiency
- Reduced Emissions
  - External Combustion
  - Energy transferred separate from working fluid
- Same as Ericsson Cycle

Regenerator

- Heat Exchanger
- Between Hot/Cold fluid
- Uses energy from hot exhaust gas (turbine)

$$\eta_{reg} = \frac{h_x - h_2}{h_4 - h_2}$$



Advantages

- High efficiency (Carnot efficiency)
- Does not depend on type of heat source
- Easy to build
- Quiet
- No internal combustion
- Environmental Impact (pollution)
- Reliable/Easy to maintain
- Gases remain inside

Disadvantages

- Low specific power (power per unit mass)
- Needs warm up period (time to get heated up)
- Difficult to adjust power output (tends to be constant)
- Needs higher temperature differential for more power (heat exchanger)
- Low molecular weight gases tend to work best
- Moving parts
- Relatively expensive to build

http://www.youtube.com/watch?v=UvrBzwBIFhM

Applications

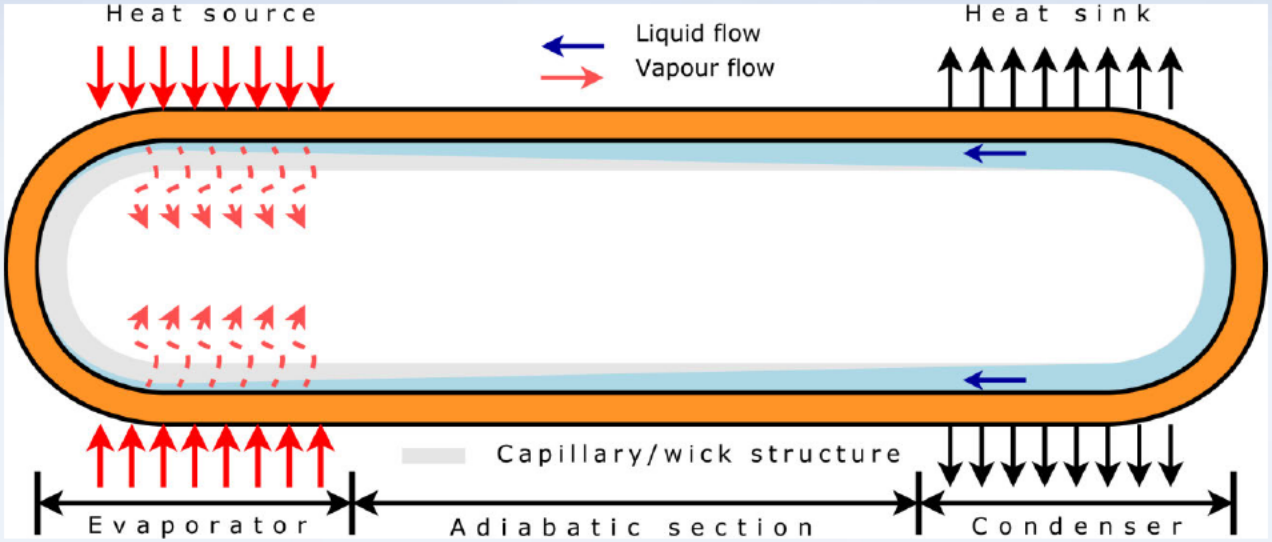
- Submarines
- “Stirling Coolers” (Input: mechanial work, Output: cold temperature due to reversible process)
- Space exploration probes

Use at NASA

- Deep-space exploration
- Uranium battery provides heat input (solar power unreliable)
- Stirling engines used
- Radiation as means of heat rejection

http://www.wired.com/wiredscience/2012/11/radioactive-stirling-engine-exploration/

Heat Pipe



- **Adiabatic section**: insignificant temperature drop
- **Condenser**: heat is rejected
- **Wick**: pumps fluid from condenser to evaporator
- **Evaporator**: heat enters, vaporizing fluid

References

- T. Finkelstein; A.J. Organ (2001), Chapters 2&3
- A.J. Organ (1997)
- Moran MJ, Shapiro HN. *Fundamentals of Engineering Thermodynamics*. 6th Ed. Hoboken, NJ: Wiley; 2008.
- http://en.wikipedia.org/wiki/Stirling_engine
- http://www.wired.com/wiredscience/2012/11/radioactive-stirling-engine-exploration/