


ENVC 24 : Energy and Environment

Part-2 : Nuclear Energy & Bioenergy

Vermont, USA

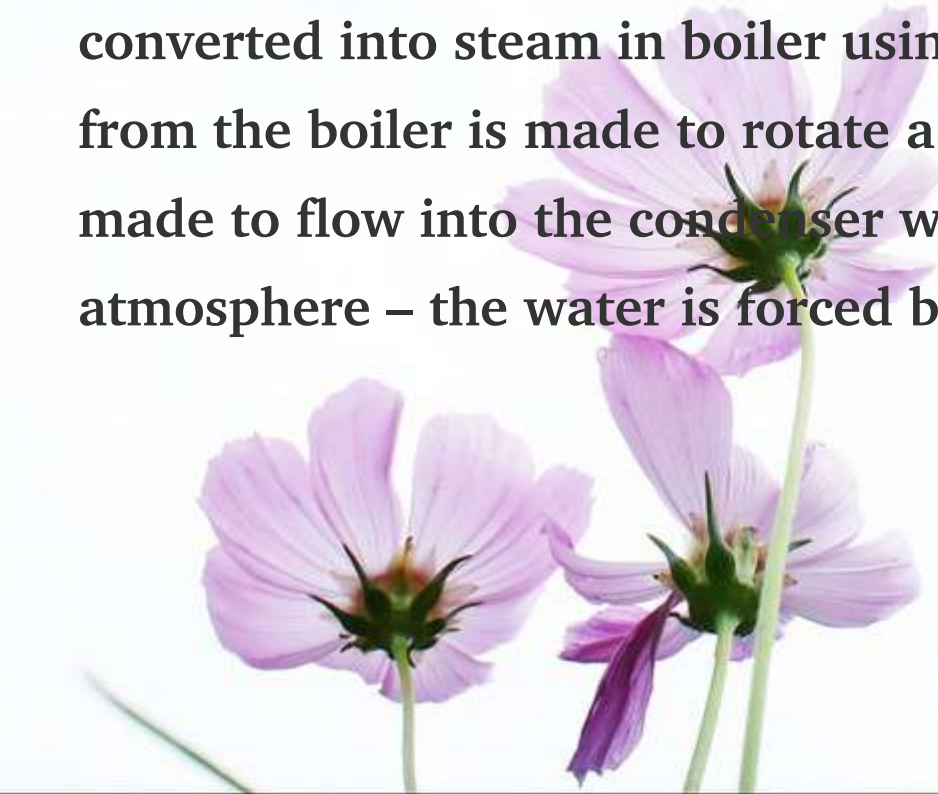
Cattenom, France

Trombay, India

AKB

Conventional energy sources

- In Thermal power plant, work is available from mechanical energy released by fuel burning in a Thermodynamic cycle, which using electrical generator is converted. Depending on nature of working fluid, thermal power point are classified as (a) Gas power cycle (GPC), (b) Vapour power cycle (VPC).
- Working fluid in GPC is mixture of air & gaseous combusted fuel product. In VPC, condensible vapour existing in liquid phase is the working fluid. Water is converted into steam in boiler using heat derived from coal. Steam flowing out from the boiler is made to rotate a turbine (imparting work), the steam is then made to flow into the condenser where water is regained giving out heat to the atmosphere – the water is forced back into the boiler with a feed pump.



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Thermodynamics of Engines

- Heat engines convert energy into work.

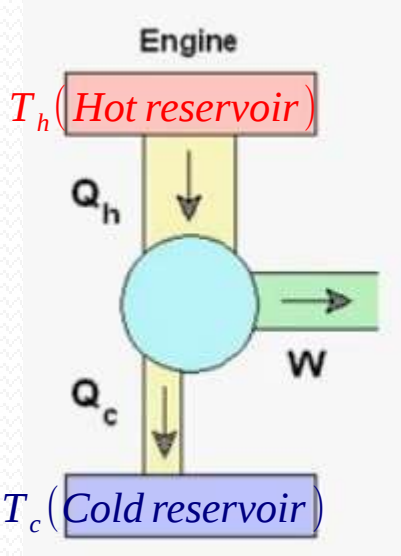
$$\text{Efficiency } \eta = \frac{\text{Work Done}}{\text{Heat Absorbed}} = \frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h} = \frac{T_h - T_c}{T_h} \text{(Carnot)}.$$

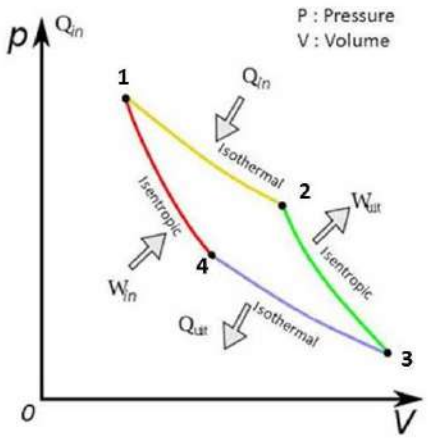
Carnot cycle : 1 → 2 reversible isothermal process : $PV = RT = \text{constant}$.

2 → 3 reversible adiabatic process : $PV^{\gamma} = \text{constant}$.

3 → 4 reversible *isothermal* process: $PV = RT = \text{constant}$.

4 → 1 reversible adibatic process : $PV^{\gamma} = \text{constant}$.





P-V Diagram of Carnot Cycle

indicator diagram

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Thermodynamics of Engines

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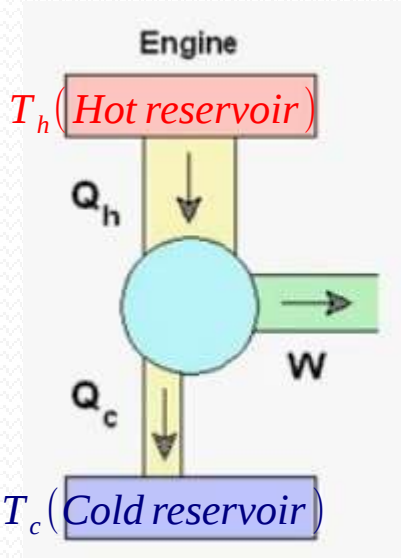
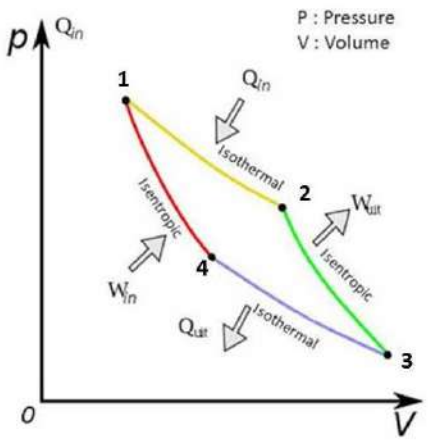
- Entropy $dS = \frac{dQ}{T}$ (as Q/T = constant, resulting to T.D. scale of temperature).





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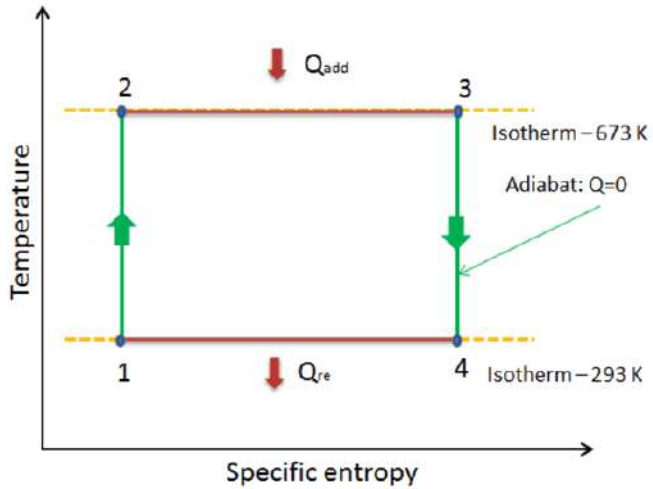

$$dS = \frac{dQ}{T}$$

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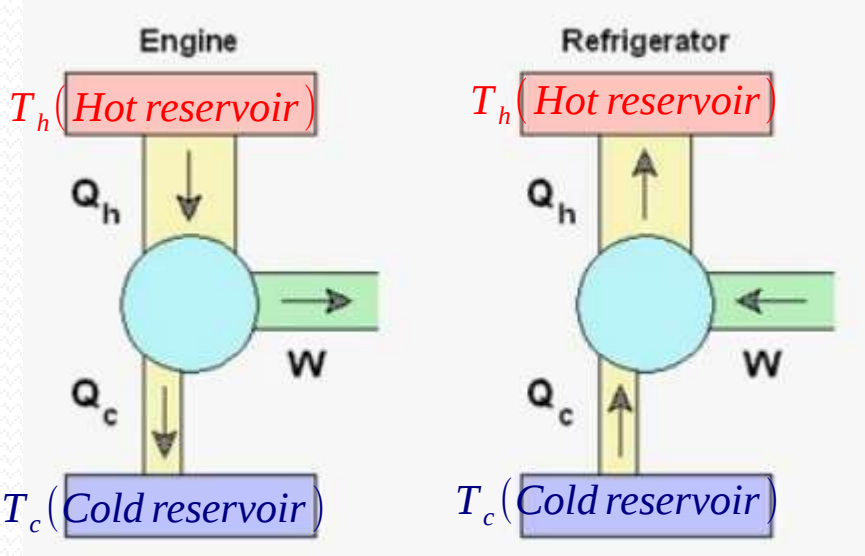
Thermodynamics of Engines

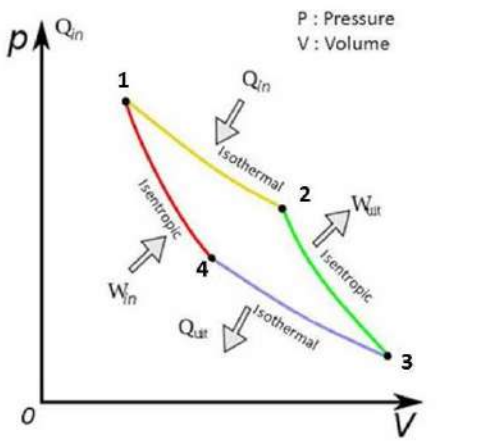
- Heat engines convert energy into work, *i.e.* opposite of refrigerator/heat-pump.

$$\text{Efficiency } \eta = \frac{\text{Work Done}}{\text{Heat Absorbed}} = \frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h} = \frac{T_h - T_c}{T_h} \text{(Carnot)}.$$

$$\text{Coefficient of Performance } (COP) = \frac{\text{Heat Absorbed}}{\text{Work Done}} = \frac{Q_h}{W} = \frac{Q_h}{Q_h - Q_c} = \frac{T_h}{T_h - T_c} \text{(Carnot)}.$$

- Carnot's efficiency is *independent* of fuel/working substance and depends on hot and cold reservoir temperature only!





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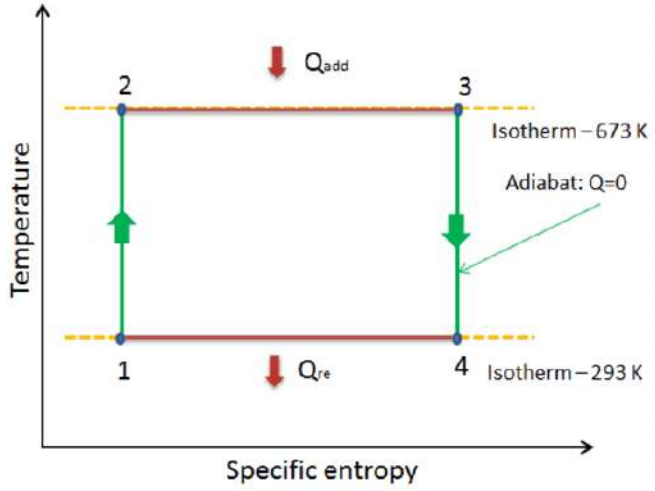

$$dS = \frac{dQ}{T}$$

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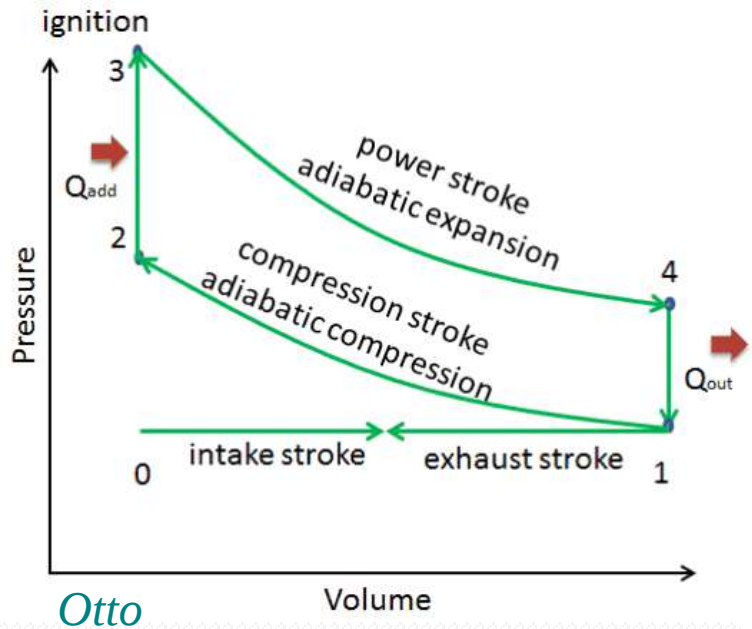
Otto, Diesel & Rankine cycle

- Ideal Carnot efficiency can be closely reached in Thermal power plants based on the **Rankine cycle** (**steam eng.**), **Otto cycle** (petrol eng.) & **Diesel cycle** (diesel eng.).
- Reversible strokes ➔ Intake, Compression, Ignition/Combustion, Power, Valve exhaust & Exhaust stroke.

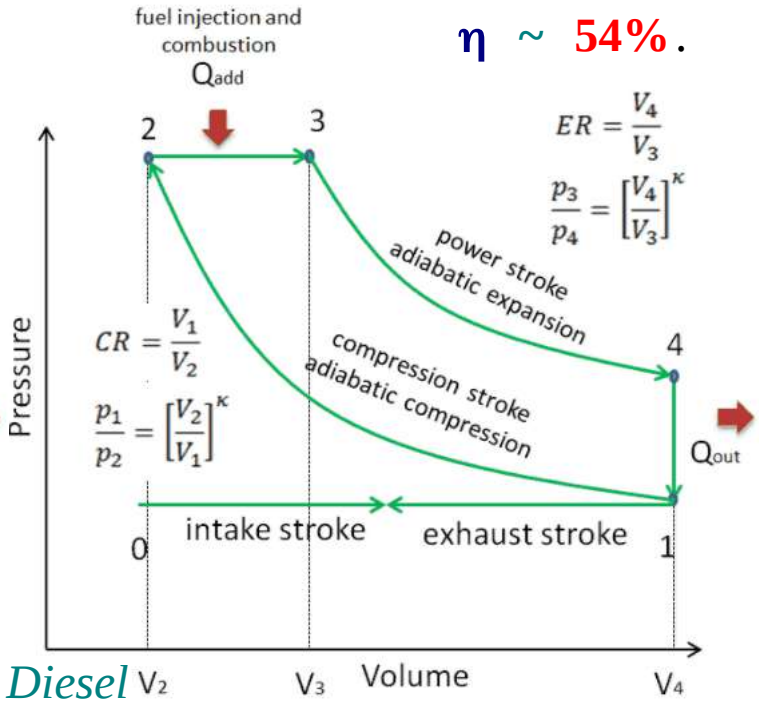
1 → 2 : low to high pressure (liquid)
2 → 3 : constant P heating (liquid → vapour)
3 → 4 : vapour expansion (P & T decrease)
4 → 1 : condensation @ constant P (liquid)

$\eta \sim 67\%$.



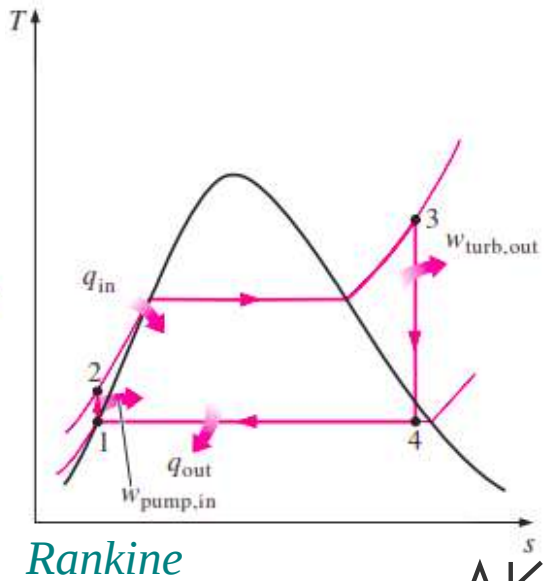
Otto

$\eta \sim 54\%$.



Diesel

$\eta \sim 50\%$.



Rankine

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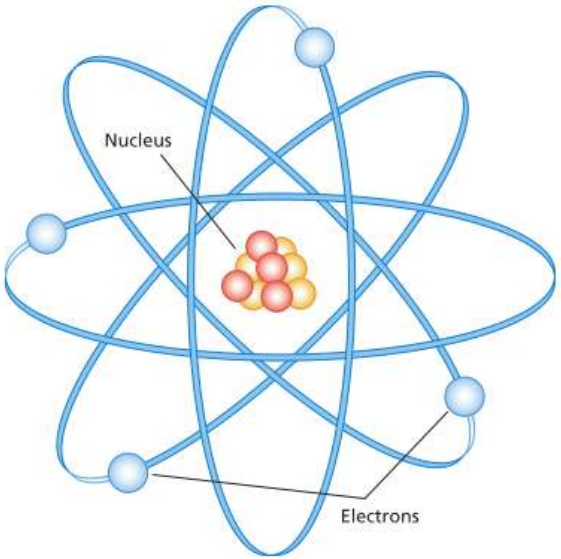
Efficiency Improvement

- **Superheating**, **Reheating** and **Regenerative Heating** are employed to improve the efficiency of a thermal power plant, where close to ideal Carnot efficiency can be reached. In contrast, nuclear power plant uses nuclear energy in a nuclear fission chain initiated by fissile mass (nuclear fuel).

Atoms & Chemical Bond

- **Superheating**, **Reheating** and **Regenerative Heating** are employed to improve the efficiency of a thermal power plant, where close to ideal Carnot efficiency can be reached. In contrast, nuclear power plant uses nuclear energy in a nuclear fission chain initiated by fissile mass (nuclear fuel).
- Atoms are fundamental units (Electrons gyrating Nucleus, Planets gyrating Sun,...).

Bohr Model



Mass $m_p \sim m_n = 1800\, m_e$

Charge $m_p = +1, m_n = 0, m_e = -1$

$m_p = 1.673\, x\, 10^{-27}\, kg$

$m_n = 1.675\, x\, 10^{-27}\, kg = 1 \text{ atomic mass unit } (amu)$

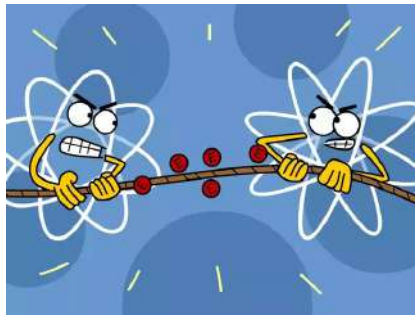
$m_e = 9.1\, x\, 10^{-31}\, kg$

Atoms & Chemical Bond

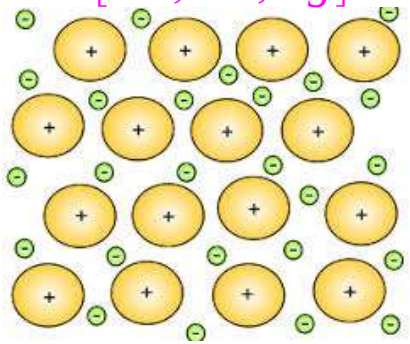
- Chemical bonds form by bringing atoms from infinity to closest separation, so that total energy is negative (cohesive energy) = attractive force of negatively charged cloud of one atom with positive nuclear charge of other atom + repulsive force of overlapping negatively charged electron clouds & positively charged nucleus of two atoms.
- Types of bond : (a) Ionic Bond, (b) Covalent Bond, (c) Metallic Bond, (d) Hydrogen bond, (e) van der Waal's Bond.

$[NaCl, KCl]$

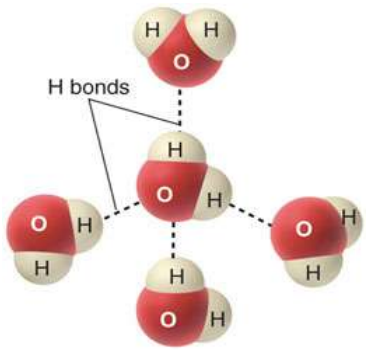
$[F_2, CO_2, HCl]$



$[Cu, Au, Ag]$



$[H_2O]$



[most fluids]