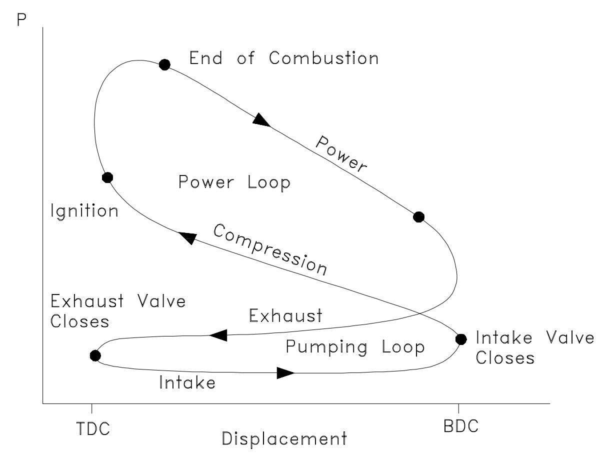
Week 7: Lecture 1

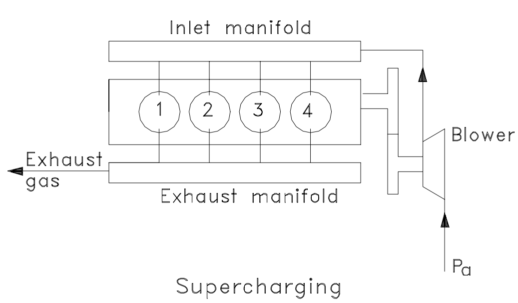
IC Engines

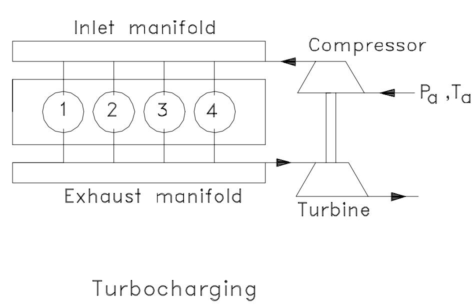
1. **spark ignition**:
   - a mixture of fuel and air is ignited by a spark plug
   - applications requiring power to about 225 kW (300 HP)
   - relatively light and low in cost



2. **compression ignition engine**:
   - air is compressed to a high enough pressure and temperature that combustion occurs when the fuel is injected
   - applications where fuel economy and relatively large amounts of power are required

Power Enhancements:





1. **Supercharging**:
   - compressor is run directly from the engine shaft
2. **Turbocharging**:
   - compressor is run by the exhaust gases
   - more efficient than a supercharger

Week 7: Lecture 2

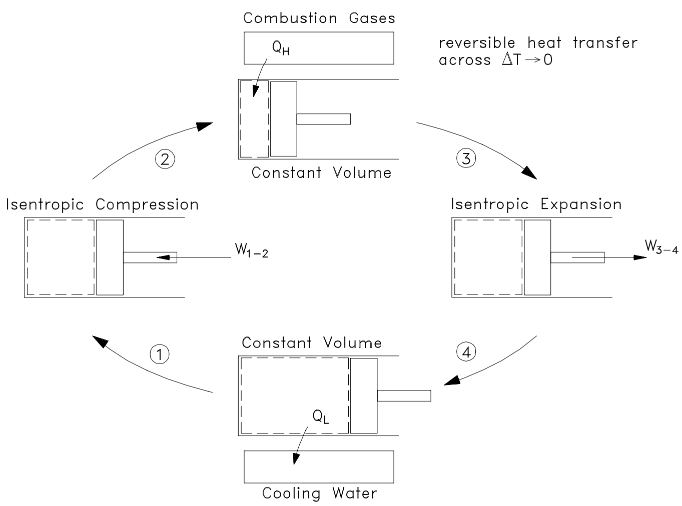
Air Standard Cycle

Assumptions

- air is an ideal gas with constant c_p and c_v
- no intake or exhaust processes
- the cycle is completed by heat transfer to the surroundings
- the internal combustion process is replaced by a heat transfer process from a TER
- all processes are reversible
- heat addition occurs instantaneously while the piston is at TDC

Otto Cycle

- consists of four internally reversible processes
- heat is transferred to the working fluid at constant volume



1 → 2 isentropic compression or air

2 → 3 constant volume heat addition at TDC (represents the ignition process)

3 → 4 isentropic expansion (power stroke)

4 → 1 constant volume heat rejection at BDC

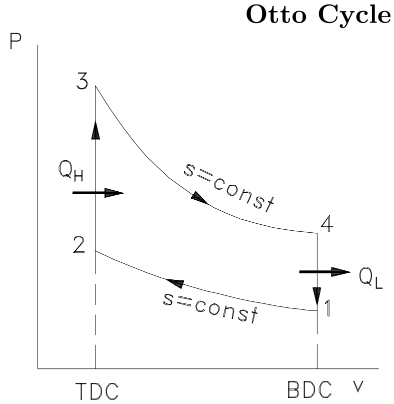
$$\eta_{Otto} = 1 - r^{1-k} \qquad \textbf{where :} \qquad r = \frac{V_1}{V_2} = \frac{V_4}{V_3} \quad \textbf{(compression ratio)}$$

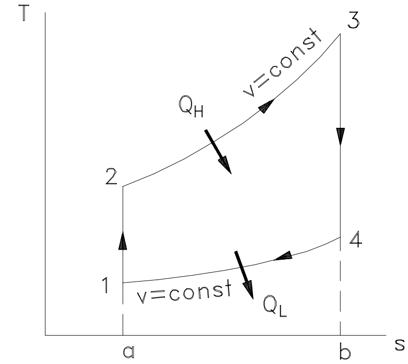
Otto cycle limitations on compression ratio

- increased tendency for the fuel to detonate as the compression ratio increases
- the pressure wave gives rise to engine knock
- can be reduced by adding tetraethyl lead to the fuel
- not good for the environment

Week 7: Lecture 2

Otto Cycle Process Diagrams





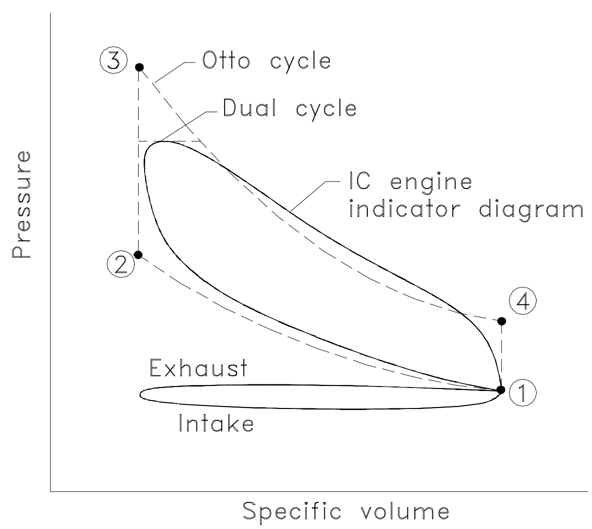
The Diesel Cycle

- heat is transferred to the working fluid at constant pressure

$$\eta_{Diesel} = 1 - \frac{1}{r^{k-1}}\left(\frac{1}{k}\right)\left(\frac{r_v^k - 1}{r_v - 1}\right) \qquad \text{where :} \qquad r_v = \frac{V_3}{V_2} = \text{(volume ratio)}$$

Comparison of the Otto and the Diesel Cycle

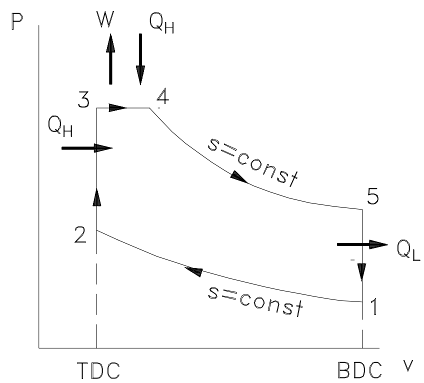
- $\eta_{Otto} > \eta_{Diesel}$ for the same compression ratio
- but a diesel engine can tolerate a higher ratio since only air is compressed in a diesel cycle and spark knock is not an issue
- direct comparisons are difficult

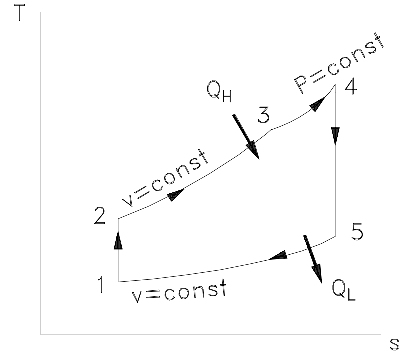


Week 7: Lecture 3

Dual Cycle

- this is a better representation of the combustion process in both the gasoline and the diesel engines
- in a compression ignition engine, combustion occurs at TDC and the piston moves down to maintain a constant pressure





1 - 2	isentropic compression
2 - 3	constant volume fuel injection and initial combustion
	→ modelled as a reversible, constant volume heat addition
3 - 4	isobaric expansion as the fuel burns
	→ modelled as a reversible, isobaric heat addition
4 - 5	isentropic expansion
5 - 1	exhausting of spent gases
	→ modelled as a constant volume heat rejection process

- $\boldsymbol{\eta_{dual} = 1 - \dfrac{r_p r_v^k - 1}{\left[(r_p - 1) + k r_p (r_v - 1)\right] r^{k-1}}}$

  where

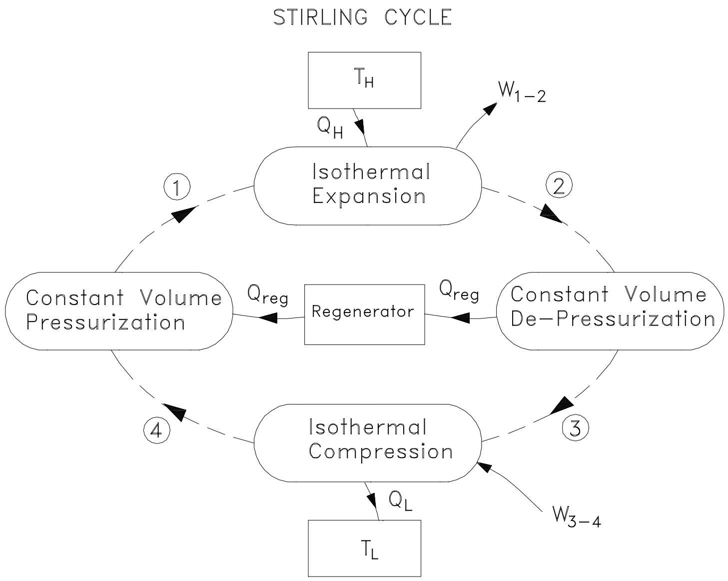
$$\boldsymbol{r = \frac{V_1}{V_2}} \quad \textbf{(compression ratio)}$$

$$\boldsymbol{r_v = \frac{V_4}{V_3}} \quad \textbf{(volume ratio)}$$

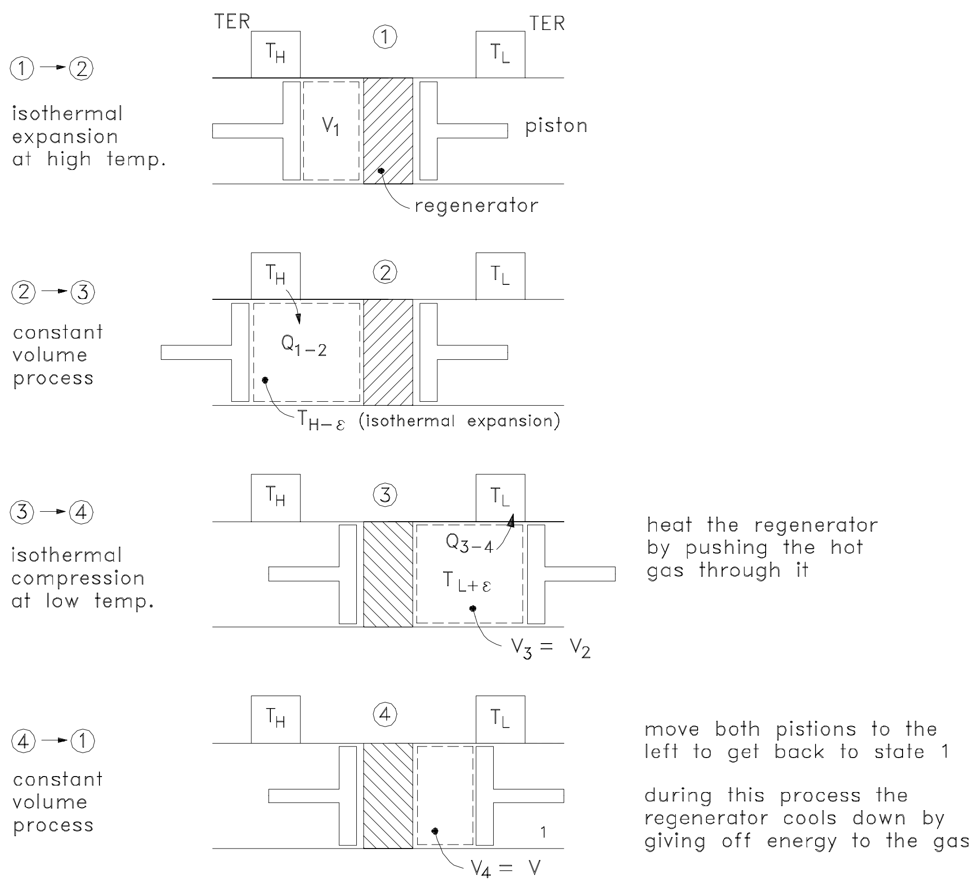
$$\boldsymbol{r_p = \frac{P_3}{P_2}} \quad \textbf{(pressure ratio)}$$

Week 7: Lecture 3

Stirling Cycle

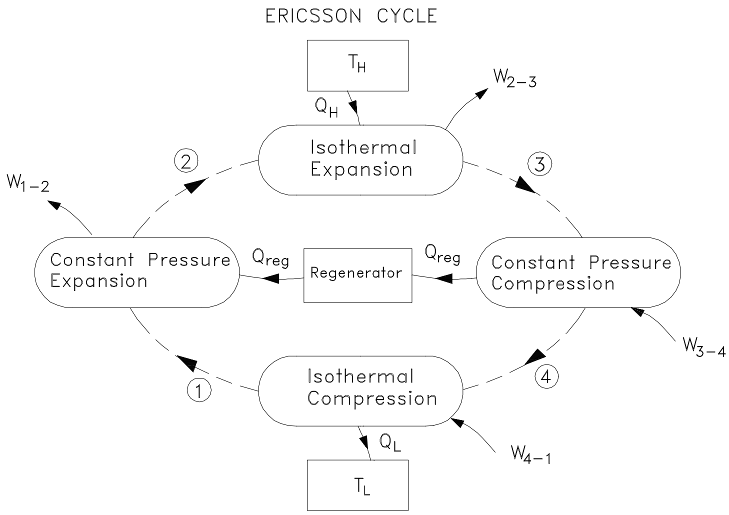


- reversible regenerator used as an energy storage device
- possible to recover all heat given up by the working fluid in the constant volume cooling process
- all the heat received by the cycle is at T_H and all heat rejected at T_L
- $\eta_{Stirling} = 1 - T_L/T_H$ (Carnot efficiency)



Week 7: Lecture 3

Ericsson Cycle



- hardware is not complicated
- but it is very difficult to operate turbines and compressors isothermally
- can approach isothermal conditions by repeated intercooling (compressor) and repeated reheating (turbines)
- $\boldsymbol{\eta_{Stirling} = 1 - T_L/T_H}$ (Carnot efficiency)