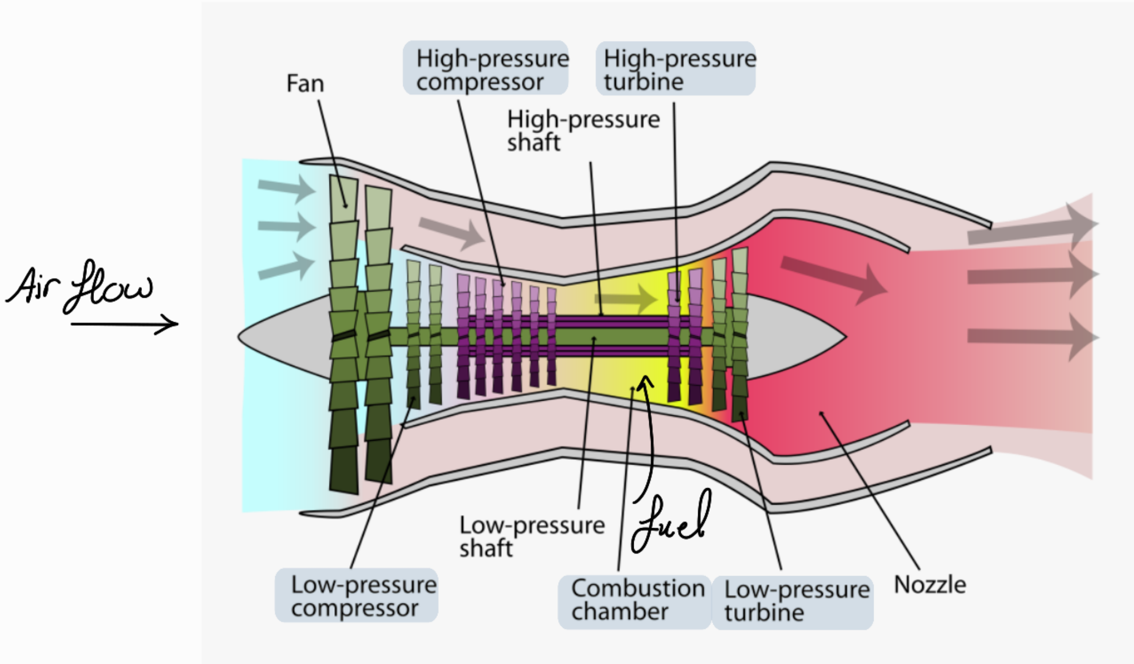
Compressors

Applications:

1) pneumatic control
2) Refrigeration Cycles
3) Air planes

Gas Turbine in Air Planes



• Air expansion is easier than Air compression, so less stages are needed for the turbine

Compressors type

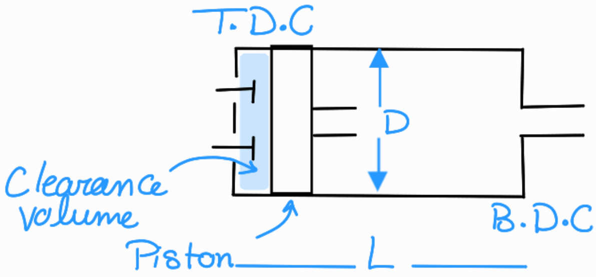
1) Reciprocating compressors : Cylinder + Piston / Used for high P and low flow rate Q / Applications: Refrigeration + HVAC

2) Rotary compressors: Used for high flow rate Q and low P

Reciprocating Compressors

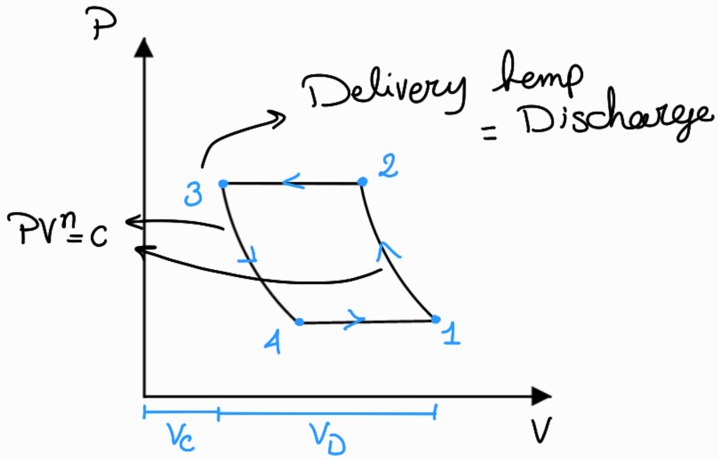
Displacement volume V_D
(Swept volume)

$$V_D = \frac{\pi}{4} D^2 L$$



Clearance ratio C

$$C = \frac{V_c}{V_D}$$



Network per cycle

$$W_{net} = \frac{n}{n-1} P_1 (V_1 - V_4)\left(r^{\frac{n}{n-1}} - 1\right)$$

↳ Single acting

Pressure ratio

$$r^{\frac{n-1}{n}} = \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n$$

Net Power

$$\dot{W}_{net}\,(\text{Power}) = W_{net} \times \frac{RPM}{60}$$

Free Air Delievary

$$(F.A.D) = (V_1 - V_4)\ \frac{RPM}{60}$$

1-2: Polytropic compression
2-3: Discharge at constant P
3-4: Polytropic expansion
4-1: Induction at constant P

$$W_{\substack{double\\acting}} = 2 W_{single}$$

$$\left(\dot{V}_{discharging} = V_2 - V_3\right)_{Single}$$

$$\dot{V}_{double} = 2(V_2 - V_3)$$

$$Q = W + C_v(T_2 - T_1)$$

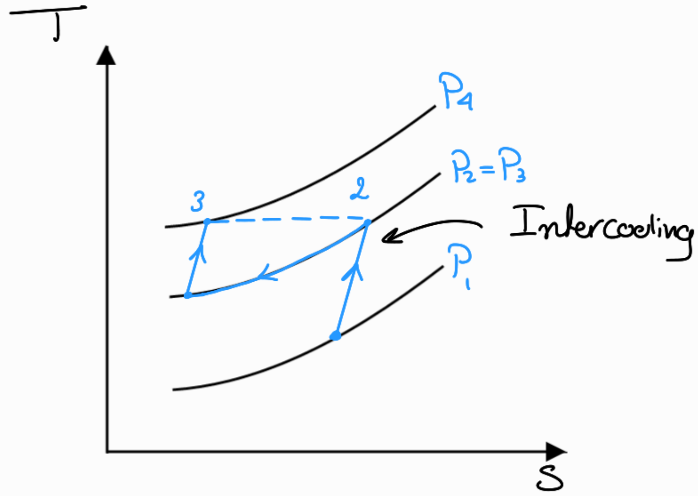
Volumetric efficiency

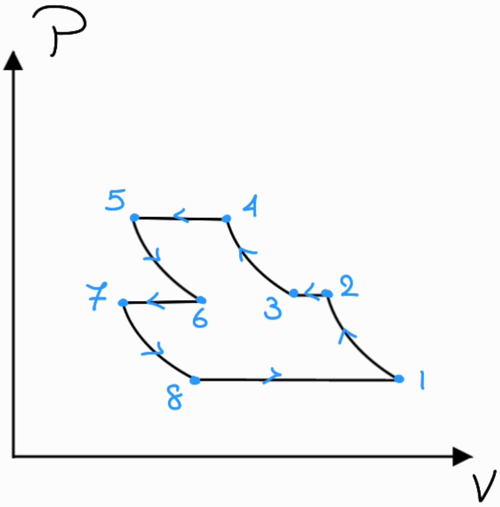
$$\eta_v = \frac{\text{Induced volume}}{\text{Displacement volume}}$$ ← Actual volume

$$= \frac{V_1 - V_4}{V_1 - V_3} = 1 + C - C\left(\frac{V_1}{V_2}\right)$$ → check if clearance ratio

If isentropic process
$n = 1.4$

Multi stage Compressors





Work of the 1st stage

$$W_1 = \frac{n}{n-1} P_1 (V_1 - V_8) \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

Work of the 2nd stage

$$W_2 = \frac{n}{n-1} P_2 (V_3 - V_6) \left[\left(\frac{P_4}{P_3} \right)^{\frac{n-1}{n}} - 1 \right]$$

Total work

$$W_{Tot} = W_1 + W_2$$

Isothermal efficiency

$$\eta_{Iso} = \frac{\dot{W}_{Isoth}}{\dot{W}_{Indicated}}$$

Mechanical efficiency

$$\eta_{Mech} = \frac{\dot{W}_{Ind}}{\dot{W}_{shaft}}$$

Overall efficiency

$$\eta_{overall} = \eta_{Isoth} \cdot \eta_{mech} = \frac{\dot{W}_{Iso}}{\dot{W}_{shaft}}$$

Electrical efficiency

$$\eta_{electrical} = \frac{\dot{W}_{shaft}\ (\text{input})}{\text{Electrical Power}}$$

Shaft work

$$\dot{W}_{shaft} = F.L \times \frac{2\pi N}{60}$$

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Isothermal work

$$W_{Iso} = P_1 V_1 \ln \frac{V_1}{V_2} = P_1 V_1 \ln \frac{P_2}{P_1}$$

Indicated work

$$W_{Ind} = \frac{n}{n-1} P_1 (V_1 - V_4) \left(r_p^{\frac{n-1}{n}} - 1 \right)$$