Turbo Chargers, Super Chargers, and Performance Enhancing Devices

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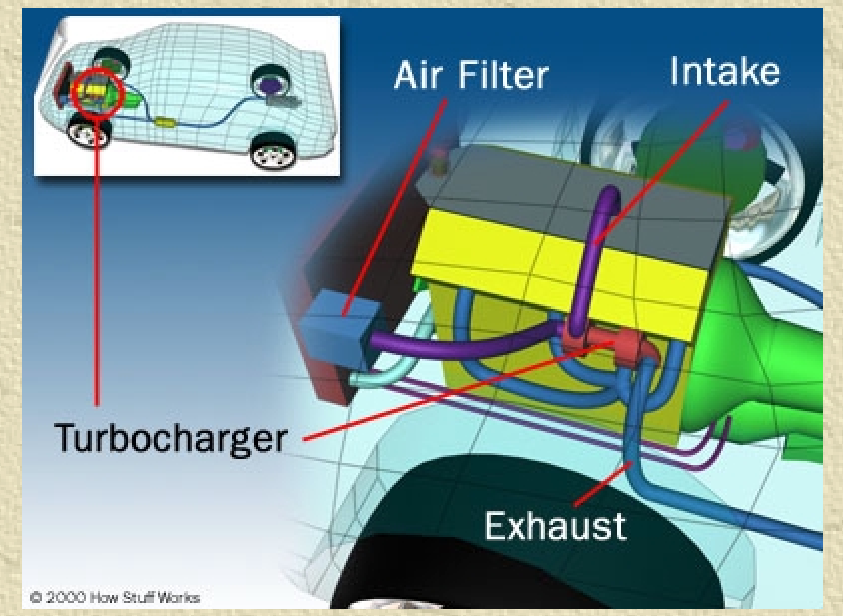
Introduction

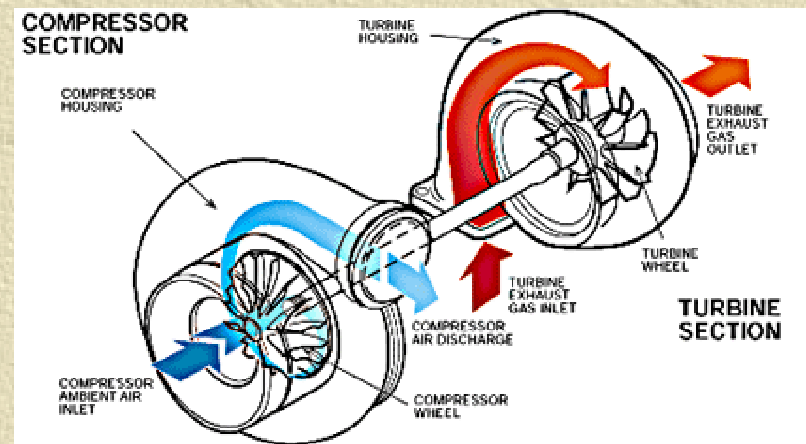
- Basics
- How they work
- Design Considerations
- Features

Basics of Turbochargers



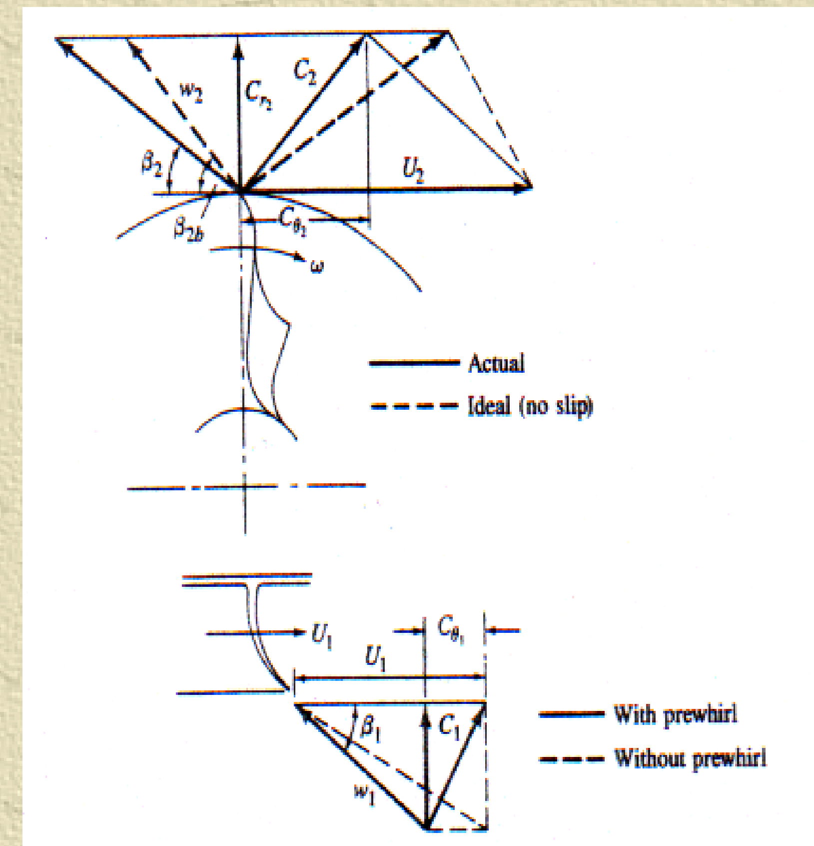
- To increase performance increase the inlet density.
  - Done by manifold tuning or forced induction.
- Pack more air into cylinders.
- Typical boost of 6 to 8 psi provided.
- Significantly raise horsepower without significant weight gain.

How Turbochargers Work



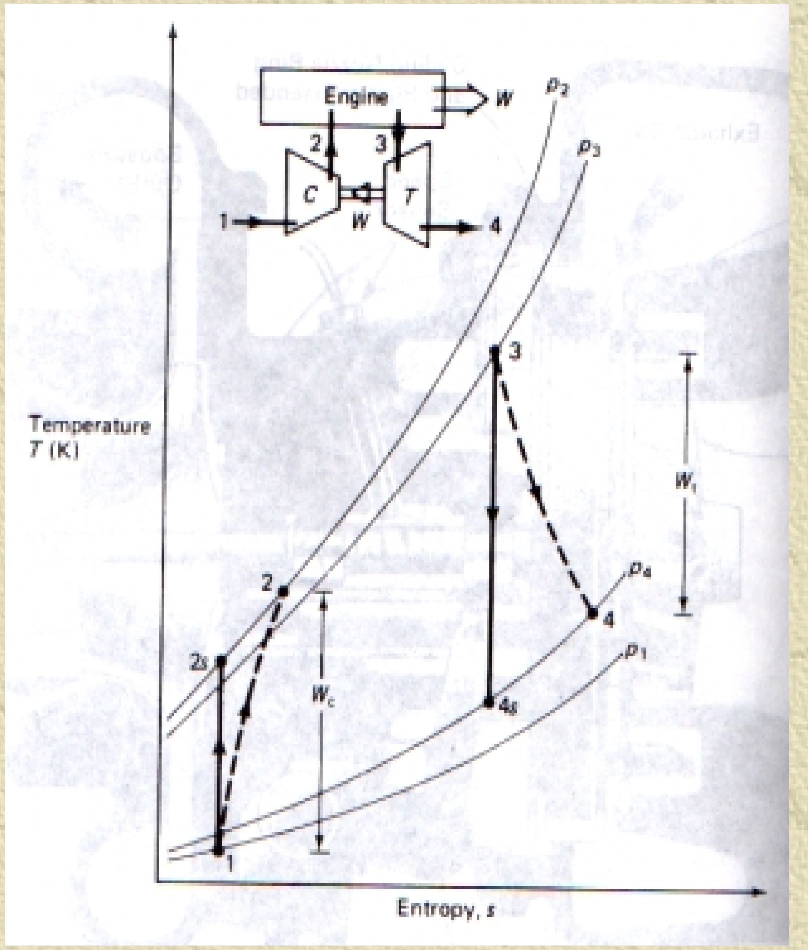
- Turbocharger is a dynamic device.
- Exhaust flow from engine spins a turbine.
- Turbine spins an air compressor.
- Compressor pressurizes the air.
- Air is pumped into cylinders.

Centrifugal Rotor



- The torque exerted on the air by the rotor equals the rate of change of the angular momentum
- The pressure different between the top and bottom of the wing is proportional to the square of the speed.

Operation of Compressor or Turbine



- The T-S diagram shows the operation of the compressor and turbine.
- $W=h_{in}-h_{out}$
- $W_t=h_3-h_4$
- $W_c=h_2-h_1$

Isentropic Efficiency

- From the work the isentropic efficiency can be found.
- $\eta_c=(T_{2s}-T_1)/(T_2-T_1)$
- $\eta_t=(T_3-T_4)/(T_3-T_{4s})$

Compressors

- In an isentropic process the inlet and outlet temperatures and pressures can be related by $T_{2s}/T_1 = (P_2/P_1)^{(\gamma-1)/\gamma}$
- The power required to drive a compressor is $\text{Power}_c = \text{mass flow rate}_{air} * c_{Pair} * (T_2 - T_1)$

Turbines

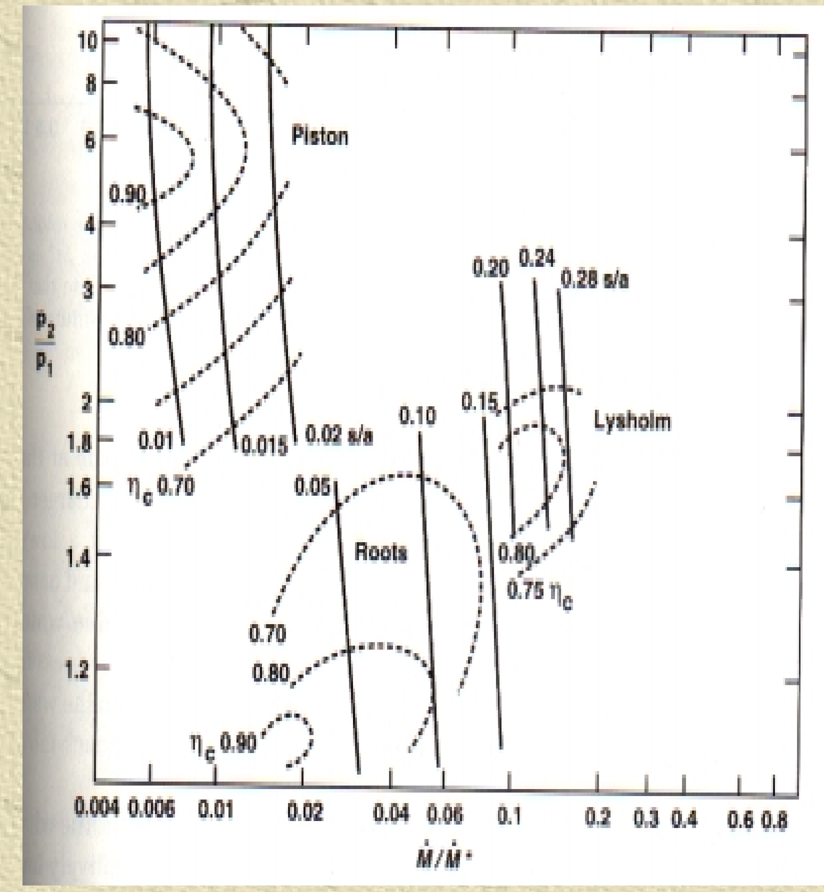
- If the turbine is isentropic then the following relationship holds

  $T_{4s}/T_3 = (P_4/P_3)^{(\gamma-1)/\gamma}$

- The turbine power can be calculated by

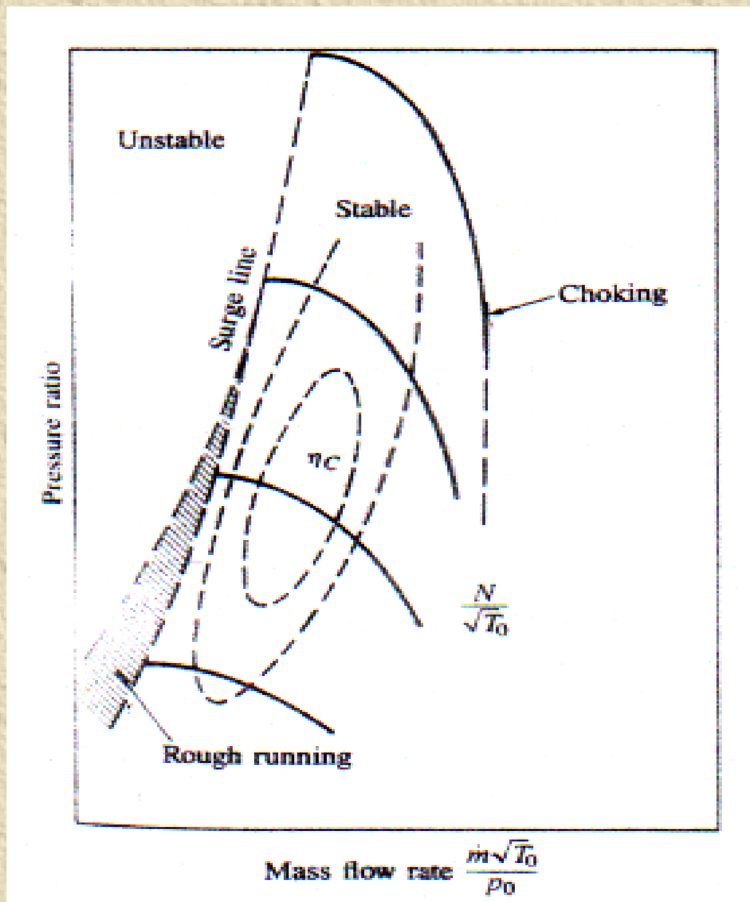
  $\text{Power}_t = \text{mass flow rate}_{ex} * c_{Pex} * (T_3 - T_4)$

Characteristics of positive displacement compressors.



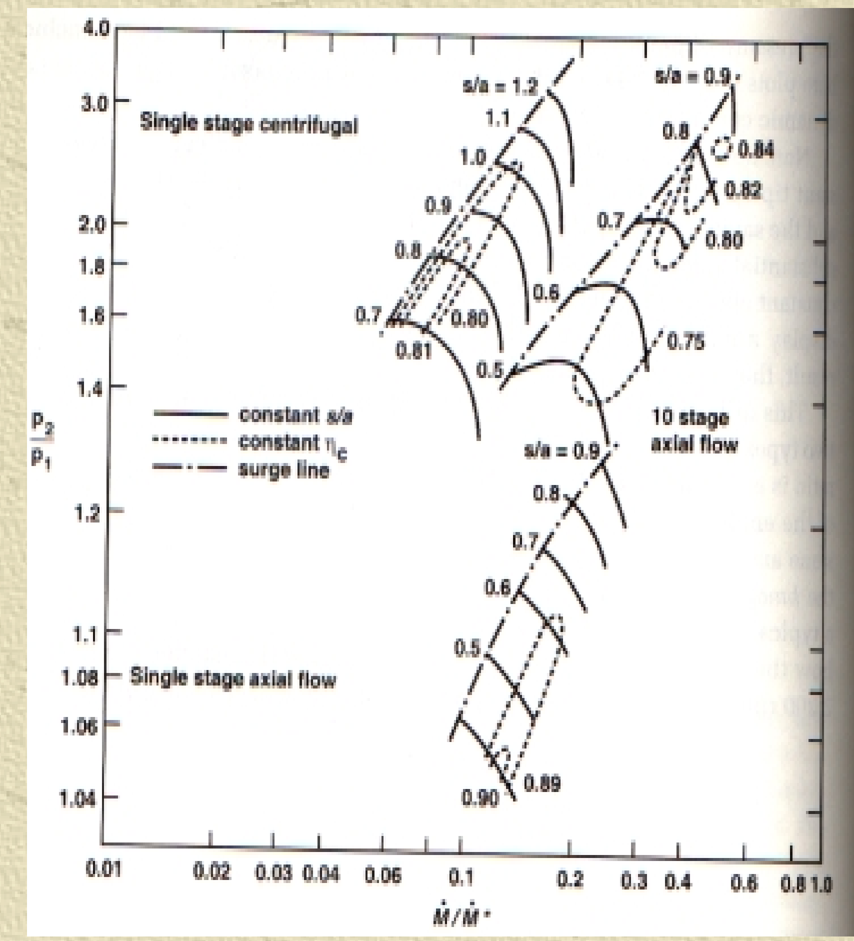
- Critical mass flow rate Vs. Pressure ratio.
- For roots and lysholm blowers.

Performance Map



- Graph of different engine speeds and efficiencies.
- Bounded by choking on the right and surge on the left.

Characteristics of Dynamic Compressor



- Critical mass flow rate Vs. Pressure ratio.

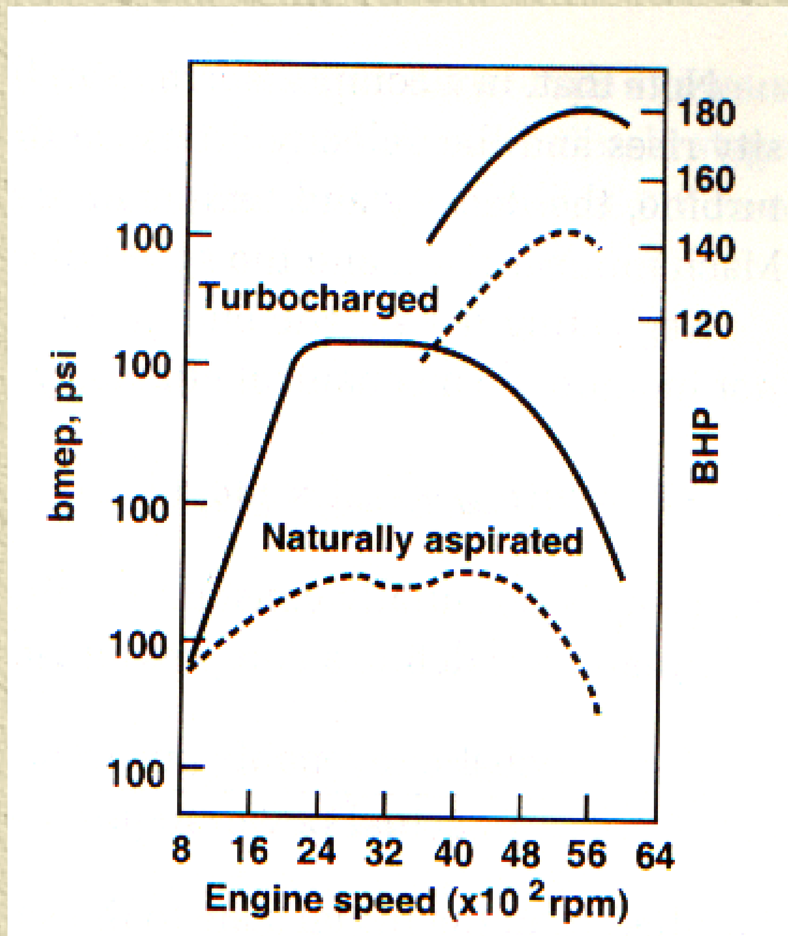
Surge

- When designing a turbine you want to stay away from surge and choking.
- To the left of the surge line is an area of unstable operation.
- The position of the surge line is influenced by the installation of the turbo

Flow in the Turbine

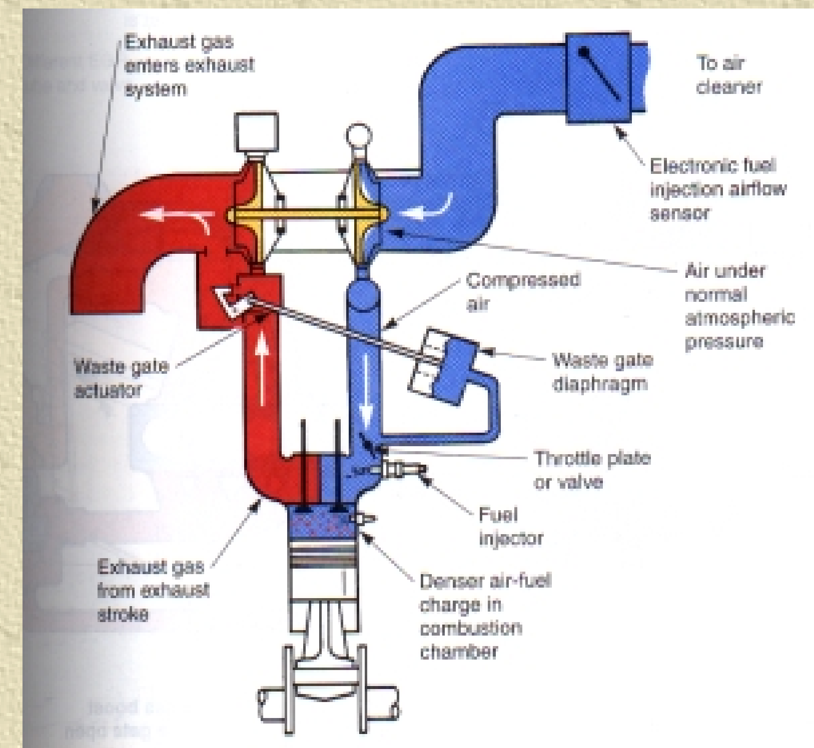
- Turbines will have a greater efficiency if the flow is smooth
- Engine exhaust is not smooth it has pulses
- Pulses can be handled different ways.
- Waves will be reflected in different ways.
  - Pulses will depend on pipe junctions

Bmep of Turbo Charger



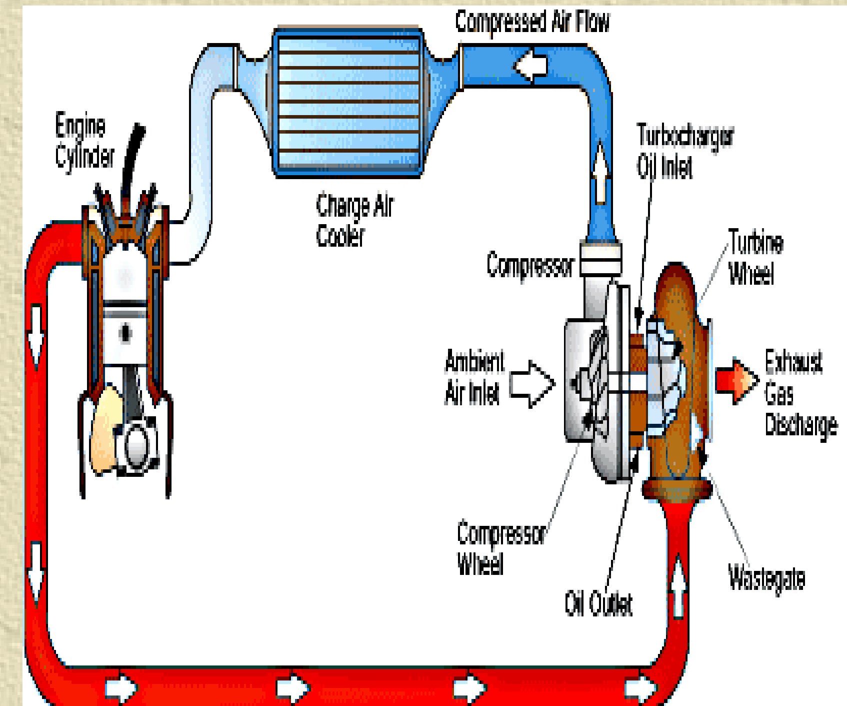
- Power of Naturally aspirated and turbocharged engine.
- Turbo line flattens out due to waste gate.

Waste Gate



- Used to control the level of boost in the engine.

Intercoolers



- An intercooler is a form of a heat exchanger.
- It is used to cool the air compressed from the turbo before it enters the intake manifold.
- It is usually mounted in front of the radiator, at the pressure outlet of the turbo charger.

Why Use an Intercooler

- Cooling the compressed air.

- If the air is not cooled it may also cause knocking.

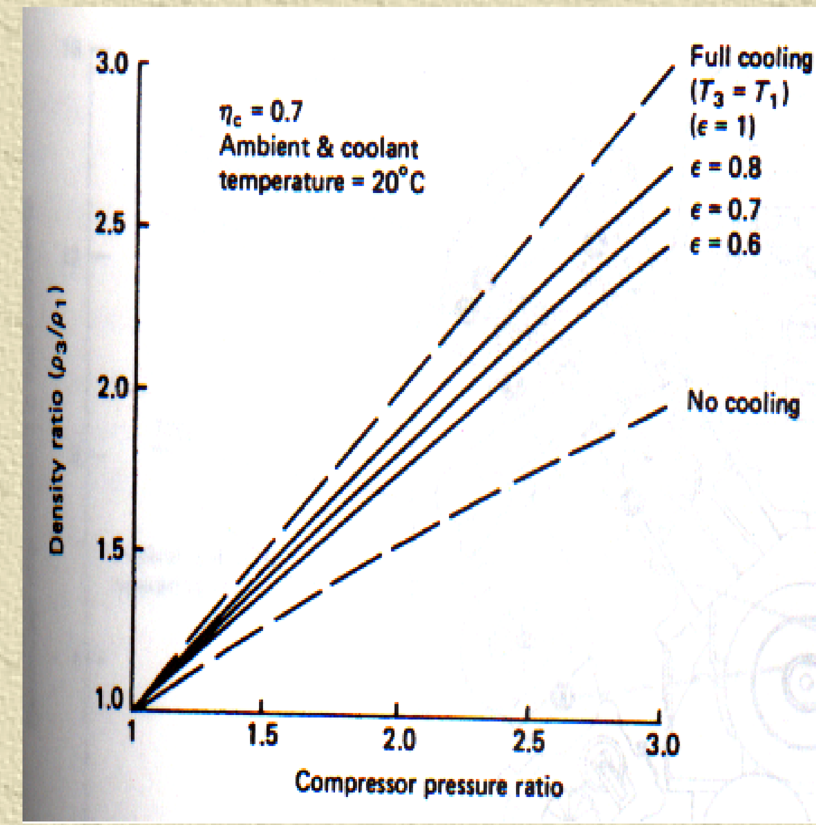
How an Intercooler Works

- Hot air from the turbo enters the intercooler and travels through the tubs allowing heat transfer to take place and cool down the turbo air.
- Overall heat transfer
  - $Q=U*A*(T1-T2)*(F/\ln(T_1/T_2))$
- Heat loss or gained by fluid on one side of intercooler
  - $Q=mCp\Delta T$

Effectiveness of Intercooler

- E=(actual heat transfer)/(max possible heat transfer)
- $E=(T_2-T_3)/(T_2-T_1)$

Intercooler

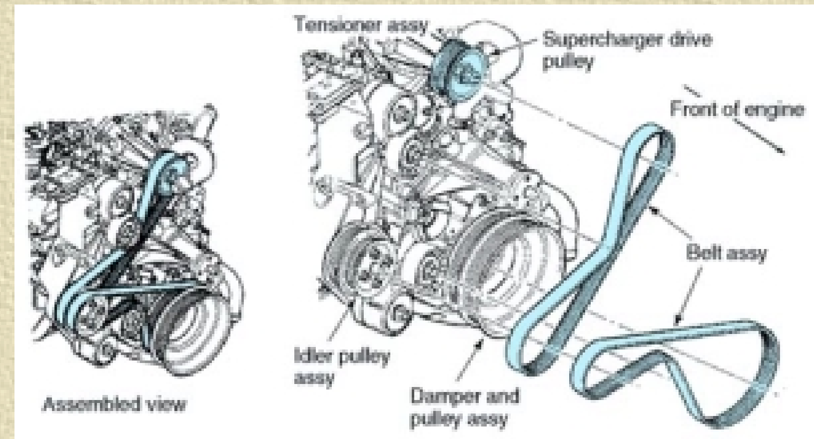


- Effect on charge cooling on the density ratio is seen on the graph for a typical isentropic compressor efficiency of 70% and an ambient temperature of 20 deg C.
- Heat transfer is proportional to pressure drop.

Effects of Intercooling on Performance

- Inter cooling increases the airflow rate and weakens the air/fuel ratio for a fixed fueling rate.
- Decreases temperatures through all cycles including exhaust cycle.
- Turbine output is reduced.
- Gains are greatest at low flow rates where inter cooler is most effective.

Superchargers

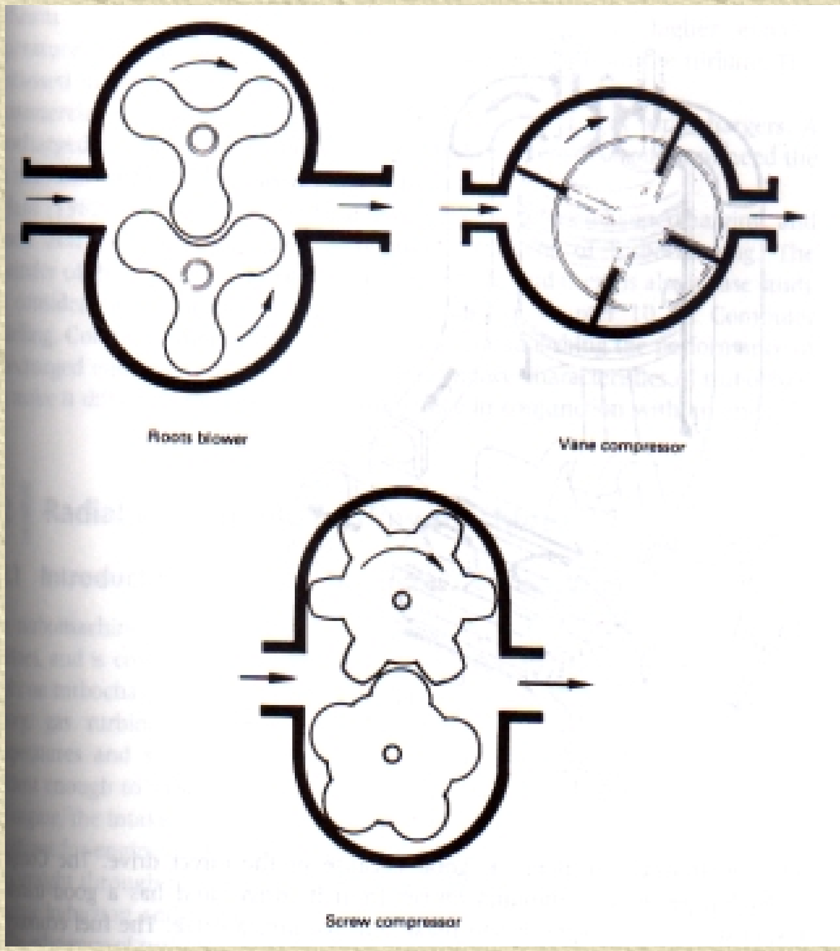


- Driven by pulley attached to crankshaft.
- Does not suffer lag.
- Positive displacement device.
  - No direct connection between inlet and outlet.

Superchargers

- Mass flow rate is proportional to the shaft speed.
- Mass flow rate is proportional to engine speed.
- Superchargers density ratio is fixed by ratio of displacement and rotational speed of the engine and blower.
- Therefore bmep will be the same for all engine speeds.

Types of superchargers



- Roots blower
- Vane compressor
- Screw compressor

Roots Blower

- Rotors not in contact.
- Air is not compressed until it leaves the housing.
- Efficiency is lower then other blower types.
- Positive displacement units, which means every rev of the blower pumps out a fixed volume of air, regardless of the blower's rpm. Result is that boost comes on early. Most application produce full boost at 2000-2500rpm.

Vane Compressor

- Most popular type for fuel injected engines. Provides airflow proportional to blower rpm, thus full boost comes as high rpm.

Screw Compressor

- Positive displacement, similar to roots. differences: uses twin screws instead of lobed rotors to compress air.

Summary

- Forced induction systems significantly increase the output and efficiency of I.C. engines.
- Only small increase in engine weight.
- Ensure compressor is operating away from surge and choke line.