Air Charging of Engines

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ME 417: Internal Combustion Engines

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Air Charging Methods

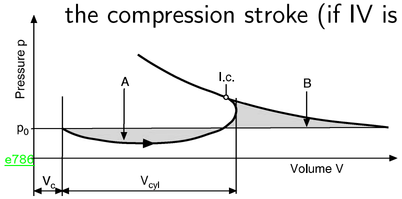
Maximum engine power is limited by the amount of fuel that can be burned efficiently, and it is limited by the amount of air that is introduced into engine cylinders.

- **Natural Aspiration**: induction process relies solely on the pressure difference that exists between retreating piston and air intake arrangements. Natural charging is enhanced by utilizing:
  1. Ram effect of incoming charge
  2. Pressure wave tuning
- **Forced Induction**: charge is forced to enter into the cylinder at a pressure substantially above that of the atmosphere, although the mean gas velocities through the intake part remain unchanged for the same engine speeds.
  1. Mechanical supercharging
  2. Turbocharging
  3. Pressure wave supercharging

- With SI engines, boosting the pressure in the induction system has the effect of increasing the overall compression ratio. To avoid knock as the boost pressure increases, the engine compression ratio must be reduced relative to that required for natural aspiration.
- Because only air is compressed in CI engines, problems associated with knock don't not arise in the same fashion. Increasing the density of the air reduces the delay period, thus actually producing more favourable rate of pressure rise during combustion.
- For every charge temperature rise of l00°C due to pressure charging a SI engine, the increase in absolute temperature at the end of compression will be approximately 200°C.
- In a CIE, with its higher compression ratio, the temperature at the end of compression will be of the order of 300°C higher.
- In both instances, these effects increase the rate of heat generation, and therefore temperature rise, during combustion.

Inertia Ramcharging

- At high engine speed charge flowing through the intake system moves at a high velocity and its momentum keeps it moving toward the cylinder and can continue to compress the charge into the cylinder at the end of intake stroke even after the piston has started upward on the compression stroke (if IV is open).

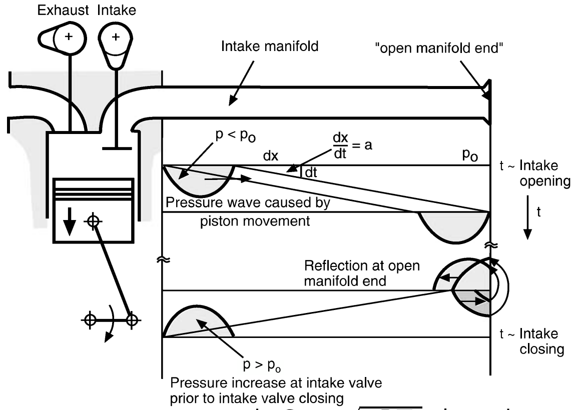


Induction work A of the piston correspond to compression work B.

- By properly tuning intake valve closing, the amount of charge trapped inside the cylinder can be increased. This phenomenon, called the **ram effect**, increases with air velocity and therefore with engine speed.

Pressure Wave Tuning

- The high-pressure wave, created when the exhaust valve opens and rapidly blows down the cylinder contents, travels to the end of exhaust pipe and is reflected as a low-pressure wave or rarefaction wave. If this wave is timed to enter the cylinder near the end of the exhaust stroke it can assist in evacuating the residual gases and draw in fresh charge as the intake valve opens.
- Similarly, rarefaction waves in the intake system are reflected from the open end of the intake as pressure waves that will force more charge into the cylinder.
- The process, known as **Tuning**, is highly dependent on the relationship between valve timing, pipe lengths and the speed of the sound in intake and exhaust gases. As a results, the benefits of tuning tend to be concentrated at specific engine speeds and the effects at other speeds may actually be negative.



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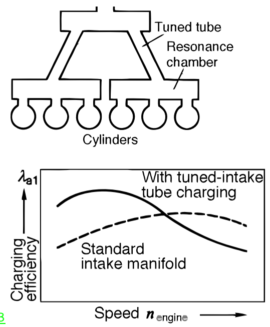
Suction wave moves at sonic speed, $C_o = \sqrt{\gamma R T_o}$ along the pipe length, L. After time $t = L/C_o$, the wave reaches the open manifold end and is reflected as pressure wave which returns to intake valve at same speed. If the intake valve is still open, then this can boost η_v. Travel time $\Delta t = 2L/C_o$ must be shorter than valve opening duration.



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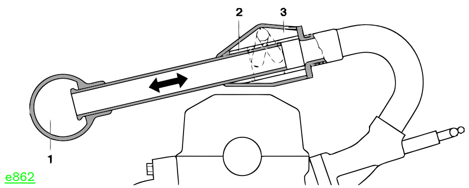
(1) Resonance chamber (2) Adjuster (3) Resonance chamber



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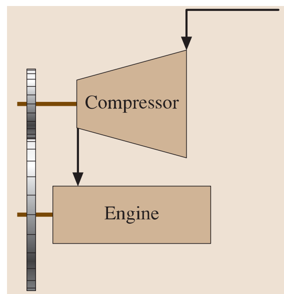
Variable-length intake runners

- In tuned-intake tube charging, resonance chambers are connected to the atmosphere or a common chamber by tuned tubes, and act as Helmholtz resonators.
- At low rpm the variable-length intake runners operate in conjunction with an initial resonance chamber. The length of the intake runners is adjusted continually as engine speed increases.

Mechanical Supercharging



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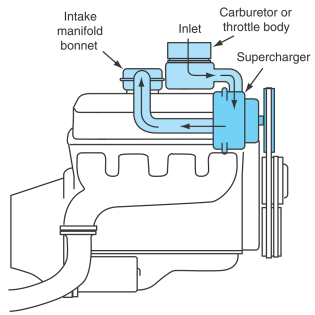

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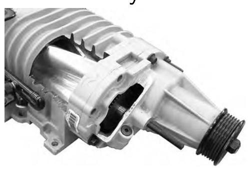
- In mechanical supercharging, the supercharger is powered directly by the engine, which usually drives it at a fixed transmission ratio. Mechanical or electromagnetic clutches are used for its activation.
  - Simple unit on 'cold side' of the engine & exhaust is not involved.
  - Responds immediately to load changes.
  - Directly engine driven, so causes increased fuel consumption.

Superchargers

Superchargers are air pumps, commonly called **blowers**. These can easily produce 50% more power than a normally aspirated engine of the same size. The crack-shaft usually drives the supercharger with a belt, but it is sometimes driven by a chain or gears.



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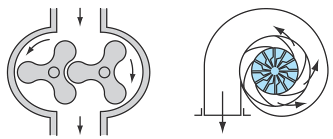

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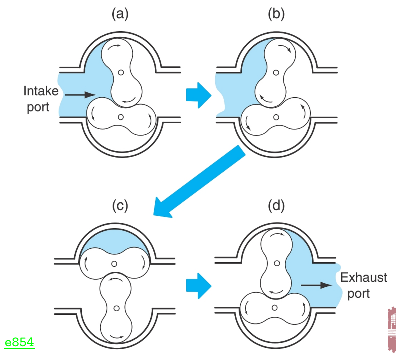

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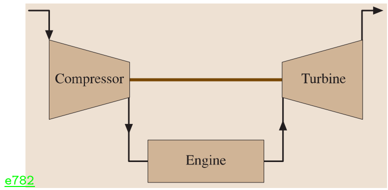
Exhaust-gas Turbocharging



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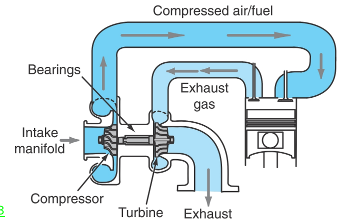

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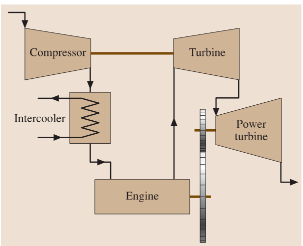
- In turbocharging, exhaust-driven turbine is employed to convert the energy in the exhaust gases into mechanical energy, making it possible for the turbocharger to compress the induction gas.
  - Considerable increase in specific output from a given configuration; enhanced torque within the effective engine-speed range; significant reduction in fuel consumption; improvement in exhaust-emissions.
  - Installation of turbocharger requires materials resistant to high temperatures; space requirements for turbocharger and intercooler; low base torque at low engine speed.

Typical Turbocharger Configuration



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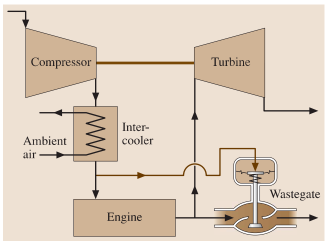
A Turbo-Compounded Engine



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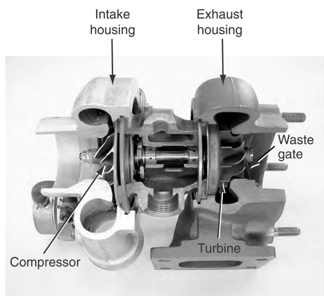
With Intercooler & Waste gate

- In Turbo-compounding system, a second turbine (power turbine) in the exhaust is directly geared to the engine drive shaft which results in higher engine power and efficiency.
- Charge cooling prior to entry to the cylinder, can be used to increase further the air or mixture density. A waste-gate allows a portion of the engine's exhaust gas to bypass the turbine.



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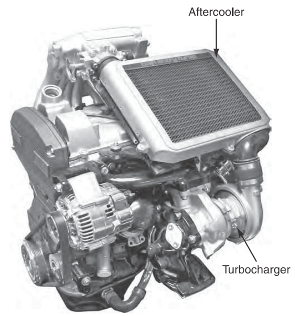

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- In turbocharging, the losses due to back-pressure generated in the exhaust system are more than offset by the effect of the higher induction pressures in reducing specific fuel consumption and increasing power.
- **Turbocharger lag**: Owing the inertia of the rotating assembly, it can take as long as several seconds to respond to higher load demand.