

Engine Intake & Exhaust Systems

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ME 417: Internal Combustion Engines

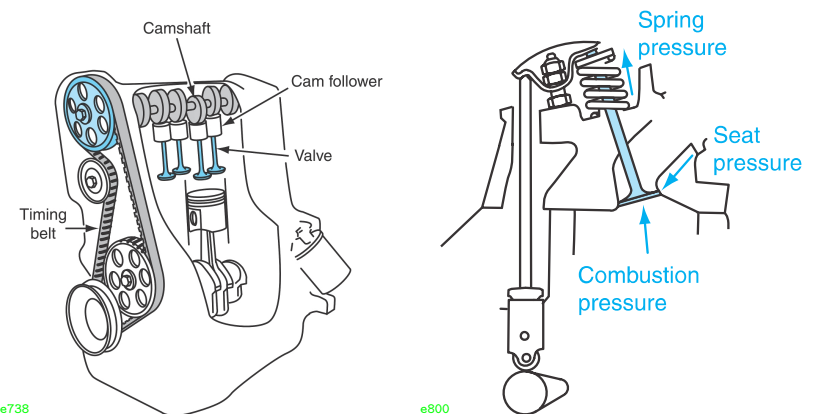
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- The purpose of the intake and exhaust processes is to remove the burned gases at the end of the power stroke and admit fresh charge for the next cycle.
- Indicated power of an ICE at a given speed is proportional to the mass flow rate of air.
- Inducting the maximum air mass and retaining the mass within the cylinder is the primary goal of the gas exchange processes in engines.
- **Gas exchange processes** are characterized by **volumetric efficiency** and it depends on the design of engine subsystems such as manifolds, valves, and ports, as well as engine operating conditions.
- Supercharging and turbo-charging are used to increase air flow into engine cylinder, and hence output power.



- In SI engines, intake system typically consists of an air filter, a carburettor and throttle **or** fuel injector and throttle **or** throttle with individual fuel injectors in each intake port and intake manifold.
- During the induction process, pressure losses occur as the mixture passes through or by each of these components. Pressure drop depends on engine speed, the flow resistance of the elements in the system, the cross-sectional area through which the fresh charge moves, and the charge density.
- In a CI engine intake system, the carburettor or EFI system and the throttle plate are absent.
- The exhaust system typically consists of an exhaust manifold, exhaust pipe, often a catalytic converter for emission control, and a muffler or silencer.

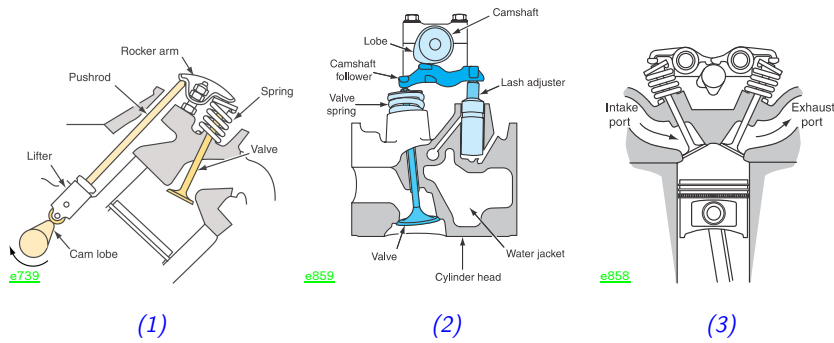


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One complete 4-stroke cycle requires two complete rotation of the crank-shaft (720°) and therefore one complete rotation of the camshaft (360°). Opening and closing of the valves are controlled by the camshaft.

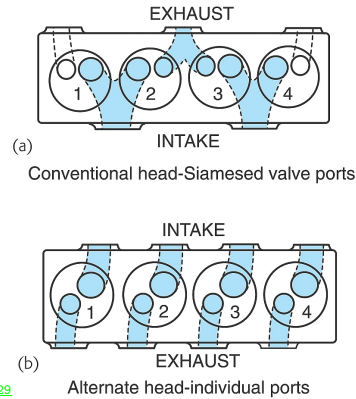




- 1 Push-rod assembly (OHV)
 - 2 Single rocker-arm assembly actuated by overhead cam (OHV/OHC)
 - 3 Twin rocker-arm assembly actuated by overhead cam (OHV/OHC)
- OHV: Overhead Valve
 - OHC: Overhead Cam

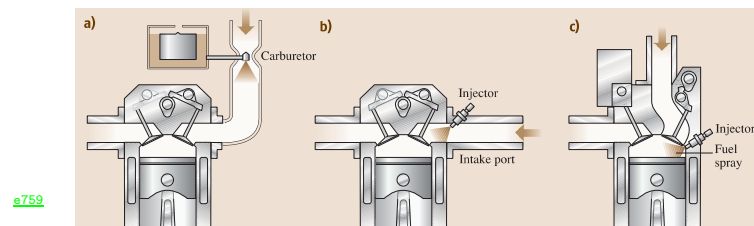
Intake & Exhaust Manifolds

Engine breathing system includes intake & exhaust manifolds that are carefully designed to provide a uniform flow to & from all cylinders.



(a) Conventional head-Siamesed valve ports
(b) Alternate head-individual ports

Intake Manifold



(a) Throttle-body injection, (b) Port injection, (c) GDI

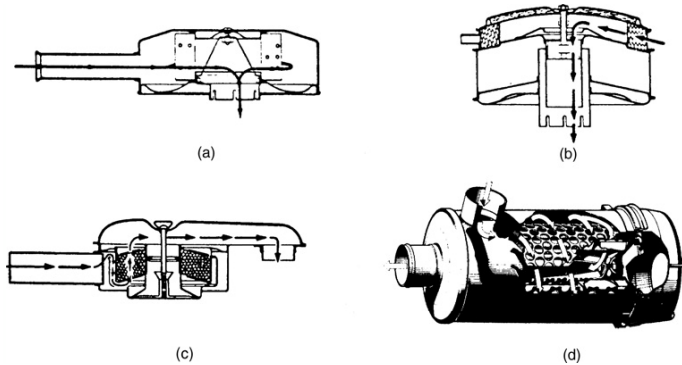
- Intake manifold of throttle-body injection/carburetion engines are designed to provide optimum flow of air-fuel mixture and to reduce the chances of the vaporized fuel re-condensation. Intake manifold runners on these engines have a few bends as possible.
- In port/direct injection SI engines (also CI engines), the manifold is designed for air flow only, so, these can have larger runners and sharp bends as these do not have to keep fuel suspended in air.

Air Cleaning & Silencing

- Efficient removal of dust particles from air flowing into the engine is of vital importance. Air cleaner acts also as a silencer for the intake system; i.e. it must suppress the engine induction noise to an acceptable level.
- With small throttle openings, induction noise is generally of a high-frequency character.
- At medium to large throttle openings and specially with four cylinder engines, the major source of induction noise occurs at low-frequency or boom periods, which arise from the implosion of the air and fuel charge into the cylinder.
- Air cleaners also act as a flame arrester, in the event of engine backfiring through the induction system.

Air Cleaning

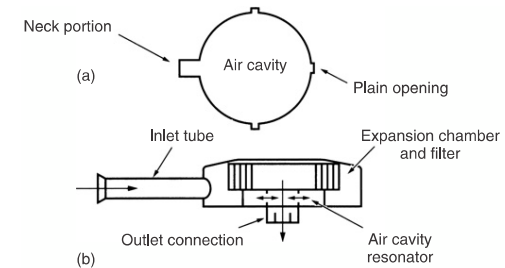
Modern air cleaners incorporate at least one the following physical methods of filtration: sieve, impingement and separation.



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Types of air cleaner: (a) fibre element (b) oil-wetted mesh (c) oil bath and mesh (d) cyclone and fibre element

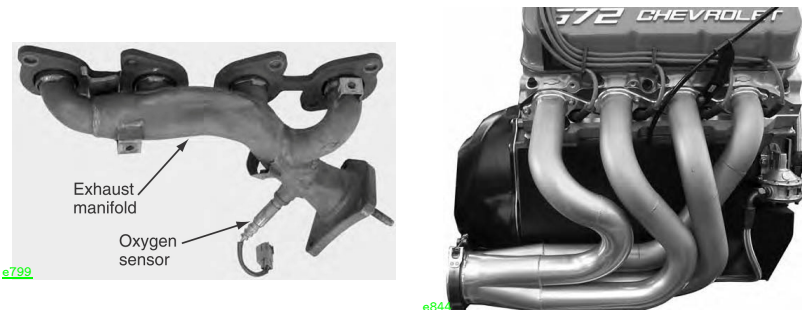
Air Silencing



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The basic structure of an air cleaner/silencer is analogous to that of a **Helmholtz resonator**, because the air flowing through the main expansion chamber and filter also communicates with an annular air cavity in which there is a purely oscillating movement of air. If suitable length of inlet tube is then matched to the large volume of the main chamber, the air cleaner acting as a Helmholtz resonator can be tuned to respond to an unwanted peak of induction noise.

Exhaust Manifold



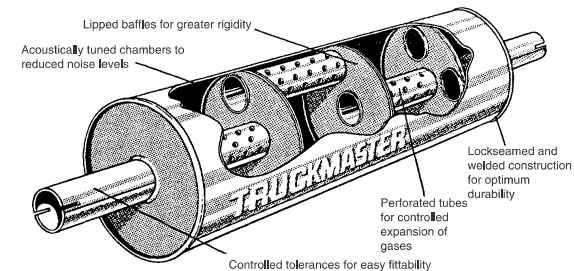
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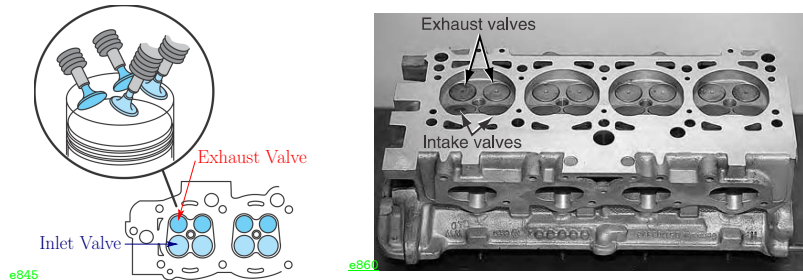
Exhaust manifolds are often made of cast iron because its ability to tolerate fast and severe temperature changes. Exhaust gas temperature is related to the engine load; when the engine works hard the exhaust manifold can run almost red hot.

Exhaust Silencer

Exhaust noise arises from the sudden release of compressed gas traveling at a speed in the region of 60-90 m/s, as each exhaust valve is opened. Exhaust silencer suppresses this noise by breaking up the intermittent system of high velocity exhaust gases into numerous small streams so that they leave the tail pipe in a more nearly constant flow at low velocity.



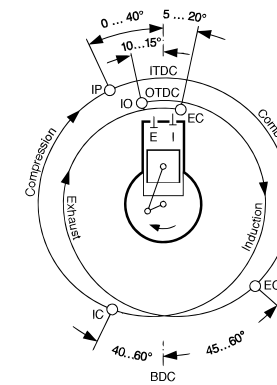
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- Intake valves are usually larger than exhaust valves: when the intake valve is open, air-fuel mixture is pushed into the cylinder by atmospheric pressure, in case of naturally aspirated engines. Throttling in intake valves reduces part-load efficiency.
- When the exhaust valve opens, there is still a high pressure in the engine cylinder. Hence, a smaller exhaust valve provides enough space for the high-pressure exhaust gases to get out of the cylinder.
- Some engines have 3 valves per cylinder: 2 IV and 1 EV.

Valve Timing Diagram

Valve timing - and thus gas exchange - are regulated by a camshaft which opens the valves by depressing them against the valve springs to discharge the exhaust gas and to draw in the fresh gas.



- E Exhaust
- EO Exhaust opens
- EC Exhaust closes
- I Intake
- IO Intake opens
- IC Intake closes
- TDC Top dead center
- OTDC Overlap TDC,
- ITDC Ignition TDC,
- BDC Bottom dead center
- IP Ignition point

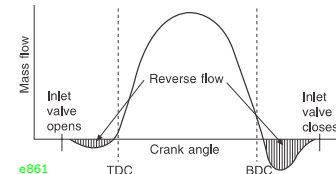
Intake Valve Opening & Closing

- Due to inertia effects and time required in attaining full opening, the inlet valve is made to open earlier so that by the time the piston reaches TDC, the valve is fully open.
- Engine performance is relatively insensitive to the IVO timing.
- Inlet valve remains open long after the piston reaches the BDC and changes direction into the compression stroke. This takes advantage of the velocity of the incoming gases, helping to continue filling the cylinder with additional air-fuel mixture even though the piston is moving back up the cylinder.
- IVC is one of the principle factors that determines the high-speed volumetric efficiency; it also affects low speed volumetric efficiency due to back-flow into the intake.

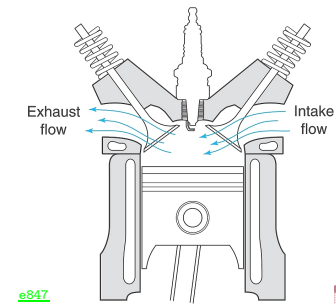
Exhaust Valve Opening, Closing & Overlapping

- Exhaust valve must open well before the end of the power stroke. **Blow-down** is a term describing the part of the power stroke between when the EVO and the piston arrives at BDC. The pressure of the expanded gases must be bled off during the blow-down period before the piston changes direction and moves up on the exhaust stroke.
- Most of the power of the burning gases is delivered to the piston by about halfway through the power stroke so opening the exhaust valve at this point does not significantly reduce an engine's power output.
- EVO timing affects the cycle efficiency since it determines the effective expansion ratio.
- EVC ends exhaust process and determines the duration of **valve overlap** period.

- At idle and light load, in SI engines, valve overlap regulates the quantity of exhaust gases that flow back into the combustion chamber through the influence of intake manifold vacuum.
- At high engine speeds and loads, inertia of moving exhaust gas leaving the cylinder results in lower pressure behind it. This vacuum condition sucks more exhaust from the cylinder and helps draw more fuel-air mixture during valve overlap, increasing power.



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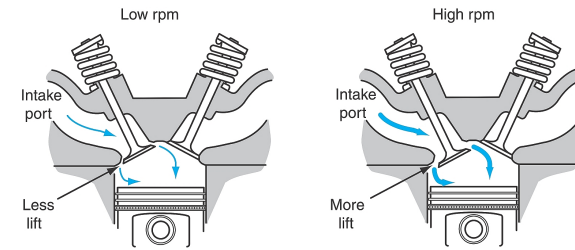


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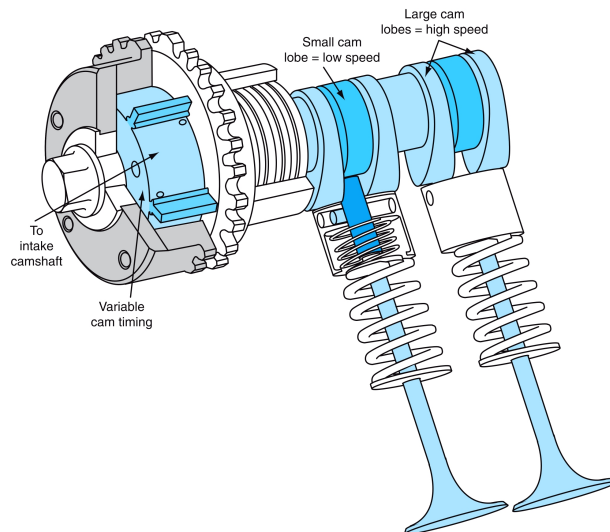
Variable Valve Timing & Lift

- The camshaft profile in conventional engines has always been compromised between low and high rpm demands.
- Variable valve timing (VVT) is common in 2 basic types;
 - Varies the cam-to-crank phasing and also the lift and duration
 - Varies valve timing only
 - A combination of the two is also common.
- VTEC: Variable valve timing and lift electronic control



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VVT causes changes to duration between low and high rpm operation



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Variable cam phasing and variable lift and duration

